

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



## Agriculture



Implemented by





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# Contents

<b>1</b>	<b>Introduction</b>	
	✿ About the training manual	9
	✿ Agriculture sector background	9
	✿ Training objectives and methodology	10
	✿ Targeted stakeholders	11
	✿ Module content	12
<b>2</b>	<b>Framing Sectoral Problems</b>	
	✿ Problems determined predominantly by natural resources	15
	✿ Problems arising from socioeconomic issues	15
	✿ Problems associated with governance, legislation and administration	16
	✿ Future water demand	18
	✿ Problems of the agriculture sub-sectors	18
<b>3</b>	<b>Impact of Climate Change and Vulnerability Assessment of the Sector Based on RICCAR Outputs</b>	
	✿ Impact of climate change on the sector	23
	✿ Vulnerability assessment	25
	✿ RICCAR contribution to vulnerability assessment and adaptation planning in the Arab region	26
	✿ Linkage of RICCAR outputs to agriculture models	28
<b>4</b>	<b>Identification of Adaptation Measures and Options for the Sector</b>	
	✿ Linking climate change adaptation to integrated water resources management	35
	✿ Adaptation measures in agriculture	38
	✿ Modelling and remote sensing	41
	✿ Water supply and demand options	45
	✿ Adaptation measures: water resources	47
	✿ Adaptation measures: water storage and quality aspects	51
	✿ Adaptation measures: water harvesting	56
	✿ Adaptation measures: rainfed farming and general issues of crop production	60
	✿ Adaptation measures: irrigated farming	67
	✿ Adaptation measures: forestry and agroforestry	71
	✿ Adaptation measures: livestock management	72
	✿ Adaptation measures: pasture management and fodder production	77
	✿ Adaptation measures: fisheries and aquaculture	81
	✿ Screening of adaptation measures	84
<b>5</b>	<b>Adaptation Measures Implementation Matrix</b>	
	✿ Stakeholders and their role in water management	90
	✿ Increasing adaptive capacity	92
<b>6</b>	<b>Areas for Action: Suggestions for Follow-up</b>	
	✿ National policy level	95
	✿ Regional policy level	97

<b>References and Further Readings</b>	100
<b>Annex</b>	106
<b>Figure 1.</b> Water demand and supply in the Arab region, based on climate change scenario	17
<b>Figure 2.</b> Dying date palms in Kebili oasis due to very high groundwater table, caused by over-irrigation with slightly saline fossil water	19
<b>Figure 3.</b> First, second and third order impacts of climate change on agricultural production in the Arab region	24
<b>Figure 4.</b> The components constituting vulnerability based on IPCC AR4 approach	25
<b>Figure 5.</b> Vulnerability chart of the agricultural sector in the Arab region: exposure, sensitivity and adaptive capacity determine vulnerability	25
<b>Figure 6.</b> Change in mean annual precepitation for the time periods 2046-2065 and 2081- 2100 compared to the reference period 1986-2005 for RCP4.5 and RCP8.5	26
<b>Figure 7.</b> Change in mean annual temperature for the time periods 2046-2065 and 2081-2100 compared to the reference period 1986-2005 for RCP4.5 and RCP8.5	27
<b>Figure 8.</b> Application of the IWRM concept for CCA to agriculture	36
<b>Figure 9.</b> Watershed model showing the components used in hydrological modelling	42
<b>Figure 10.</b> Cross-section of river valley	42
<b>Figure 11.</b> The four growth phases of annual plants	44
<b>Figure 12.</b> Three-dimensional water resource planning in WEAP	44
<b>Figure 13.</b> Pivot irrigated areas	46
<b>Figure 14.</b> The most important elements of water demand management in the agricultural sector to combat the impacts of climate change	47
<b>Figure 15.</b> Tools for water supply management	48
<b>Figure 16.</b> Using treated wastewater and sludge in some ACSAD pilot projects	50
<b>Figure 17.</b> Water storage as an adaptation strategy to reduce climate variability	50
<b>Figure 18.</b> The continuum of water storage options	51
<b>Figure 19.</b> Quality of various water sources and water quality needs of people, domestic animals and crops in Arab countries	55
<b>Figure 20.</b> Methods and techniques of rainwater management	56
<b>Figure 21.</b> Importance of resistance to various pests and diseases for adapted varieties	61
<b>Figure 22.</b> Almonds, pistachios and olives	63
<b>Figure 23.</b> Tractor-mounted direct seeder sowing wheat into rice residues in Egypt	64
<b>Figure 24.</b> Agricultural/biological methods of soil and water conservation	65
<b>Figure 25.</b> Mechanical/engineering methods of soil and water conservation	66
<b>Figure 26.</b> Irrigation methods	68
<b>Figure 27.</b> Incrustations in a water pipe	69
<b>Figure 28.</b> Measuring soil moisture with tensiometers	69
<b>Figure 29.</b> Examples of forest functions	72

<b>Figure 30.</b> Sheep at water hole in Sudans	75
<b>Figure 31.</b> Milk analysis at a laboratory	77
<b>Figure 32.</b> Grazing Area in West Bank	78
<b>Figure 33.</b> Atriplex and Salsola are the most widely used plant genera for artificial pasture rehabilitation	80
<b>Figure 34.</b> Commercial production of Opuntia in Palestine	81
<b>Figure 35.</b> Various techniques to improve the nutritional value of agricultural residues	81
<b>Figure 36.</b> Aquaculture contributes to food security and income generation	82
<b>Figure 37.</b> Stakeholders involved in agricultural IWRM in the Arab region	90
<b>Figure 38.</b> A schematic diagram of regional adaptation strategy to climate change	98
<b>Table 1.</b> Biophysical and socioeconomic impacts of climate change on food production	27
<b>Table 2.</b> Climate change impacts on farming systems of the Arab region	29
<b>Table 3.</b> Projected relative average change of main crops in three target areas	30
<b>Table 4.</b> Overview of adaptation measures in rainfed and irrigated agriculture	39
<b>Table 5.</b> Overview of the various types of water resources available for agriculture	48
<b>Table 6.</b> Storage types and relevant biophysical risks associated with climate change	53
<b>Table 7.</b> Storage types, their characteristics and possible CCA measures	53
<b>Table 8.</b> Overview of water harvesting methods and relevant CCA measures	57
<b>Table 9.</b> Area of seasonal crops under rainfed cropping in Arab countries	61
<b>Table 10.</b> Various types of agroforestry systems and relevant CCA measures in Arab countries	74
<b>Table 11.</b> Relationship between ambient temperature and consumed water by dairy cows	76
<b>Table 12.</b> Fish production in Arab countries, 2011-2013	83
<b>Table 13.</b> Screening criteria	85
<b>Table 14.</b> Options for CCA in agriculture in the Arab region	91

## Acronyms

<b>ACSAD</b>	Arab Center for the Studies of Arid Zones and Dry Lands
<b>ACWUA</b>	Arab Countries Water Utilities Association
<b>AI</b>	artificial insemination
<b>AOAD</b>	Arab Organization of Agriculture Development
<b>ARIJ</b>	Applied Research Institute – Jerusalem Society
<b>CC</b>	climate change
<b>CCA</b>	climate change adaptation
<b>CEHA</b>	Centre for Environmental Health Activities (WHO)
<b>DSS</b>	decision support systems
<b>ESCWA</b>	Economic and Social Commission for Western Asia
<b>FAO</b>	Food and Agriculture Organization
<b>GCC</b>	Gulf Cooperation Council
<b>GDP</b>	gross domestic product
<b>GIS</b>	geographic information system
<b>GIZ</b>	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
<b>GW</b>	groundwater
<b>GWP</b>	Global Water Partnership
<b>ICARDA</b>	International Center for Agricultural Research in the Dry Areas
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>IWRM</b>	integrated water resources management
<b>LAS</b>	League of Arab States
<b>MENA</b>	Middle East and North Africa
<b>NAMA</b>	nationally appropriate mitigation actions
<b>NAP</b>	national adaptation plan
<b>NAPA</b>	national adaptation programme of action
<b>NGO</b>	non-governmental organization
<b>RICCAR</b>	Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region
<b>RWH</b>	rainwater harvesting
<b>RWR</b>	renewable water resources
<b>SI</b>	supplemental irrigation
<b>SWC</b>	soil and water conservation
<b>UN</b>	United Nations
<b>UNDA</b>	United Nations Development Account
<b>UNDP</b>	United Nations Development Programme
<b>UN Environment</b>	United Nations Environment Programme
<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>WEAP</b>	water evaluation and planning system
<b>WH</b>	water harvesting
<b>WHO</b>	World Health Organization
<b>WM</b>	water management

# CH. 1

**Introduction**



Source: Prinz.



# Introduction

## About the training manual

This training manual has been developed within the activities of the United Nations Development Account (UNDA) project on developing the capacities of Arab countries for climate change adaptation (CCA) by applying Integrated Water Resources Management (IWRM) tools. The project aims to provide a set of regionally appropriate IWRM tools for supporting CCA in five key sectors namely agriculture, economic development, environment, health, and human settlements by deriving a training manual that includes the five modules on the 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 Center for the Studies of Arid Zones and Dry Lands (ACSAD) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
- 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 led by ESCWA and implemented by the League of Arab States (LAS) and United Nations organizations.

## Agriculture sector background

The Arab region is one of the world's most water-scarce regions with a growing population and a high share of climate-sensitive agriculture. Tremendous economic, demographic and social changes have been taking place during recent decades and will continue for the decades to come, such as migration from rural to urban areas, movement from traditional farming activities to manufacturing and service sector and changes in lifestyle. While a high degree of diversity exists across the Arab region, the region as a whole is particularly vulnerable to climate change. It will pose an additional stress on the ecological and socioeconomic systems of the region, which are already under pressure. Land degradation, desertification, loss of biodiversity and finally a reduction in food and water security of the region will aggravate in the future, such as the movement of ecological belts from south to north accompanied by land use change.

Climate change (CC) is a fact and it will affect the Arab region more severely than many other regions in the world. When dealing with climate change, there is a need to distinguish



between assessment, adaptation and mitigation. Climate change assessments should be performed as integrated climate change assessment, which is defined as aiming “not only to identify the impacts of CC on freshwater resources, but also the [...] implications these pose for socioeconomic vulnerability and sustainable development” (ESCWA, 2011, p.5). CCA is the process by which individuals, communities and countries seek to cope with the consequences of climate change (IPCC, 2014; Cap-Net, 2009). However, adaptation alone is not a sufficient answer to the problem as adaptation options have limits, especially if certain levels of warming are exceeded. CCA must therefore be accompanied by mitigation efforts. These generally involve (a) reducing anthropogenic greenhouse gas emissions, for example by switching from fossil to renewable energies (such as solar energy), or (b) increasing the capacity of carbon sinks, such as through reforestation.

Integrated water resources management (IWRM) is defined as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP, 2009). As such, IWRM is a comprehensive, participatory planning and implementation tool for managing and developing water resources in a way that balances social and economic needs, and that ensures the protection of ecosystems for future generations. The different uses of water — for agriculture, healthy ecosystems, people and livelihoods — demand coordinated action. An IWRM approach is consequently cross-sectoral, aiming to be an open, flexible process, and bringing all stakeholders to the table to set policy and make sound, balanced decisions in response to specific water challenges. IWRM is the key process that should be used in the Arab water sector for water-related developments and measures, and hence for achieving the goals of CCA.

Agricultural development and food security problems, in their political, economic and social dimensions, are among the most outstanding issues that are receiving wide attention in the Arab region. The problem of water availability for agricultural purposes is even more difficult in many Arab countries where the demand for water for non-agricultural use is growing, which reduces the share of water available for irrigation purposes (AOAD, 2007). Rainfed farming, animal husbandry, forestry and fisheries receive much less attention than irrigated farming. The complex interaction of CCA, water resources management, agricultural production and sustainable development is increasingly understood by governments in an increasing number of Arab countries, which are beginning to prepare responses to this new challenge.

Capacity development is an urgent need at the institutional and political level as well as at the local level, because it strengthens the resilience of communities and civil society. Highest priority has to be given to decision makers in order to improve their capacity in taking scientifically based decisions regarding CCA and mitigation today to avoid even larger problems in the future. Pillar 3 of RICCAR (capacity-building and institutional strengthening) covers institutional strengthening and capacity-building in knowledge management, modelling, impact analysis and vulnerability assessment, with focus given to working through existing networks on climate change to enhance capacity in these areas.

## Training objectives and methodology

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



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 impacts of climate change in the water sector on agriculture in the Arab region.

The training material presents basic facts on the inter-relationship between water and agriculture sectors, as well as IWRM tools and other modern tools needed to adapt to future conditions, and how to prioritize adaptation measures and implementation considerations. Case studies and exercises from the Arab region are incorporated to learn from experiences of real world projects and programmes.

Specific objectives of this agriculture module are:

- Increase understanding of government officials and regional stakeholders of the impact of climate change on water resources;
- Frame the linkages between climate change, water sector and crop production (rainfed and irrigated), to pasture management and livestock production, to forest management and inland fisheries;
- Review the vulnerability assessment protocols and indicators in the water sector;
- 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. CCA)
- Present tools for adaptation in the water sector in order to protect agriculture;
- Review the governance framework and implementation mechanisms towards identifying the needed adaptation interventions for the sector.

The exercises included in the annex to this module are:

**Exercise 1.** Dealing with sea level rise and seawater intrusion in a densely populated river delta.

**Exercise 2.** How to manage horticultural production in a desert area with marginal water sources.

**Exercise 3.** Optimizing agricultural water use in a semi-arid country.

**Exercise 4.** Prioritising different adaptation measures based on screening criteria.

## Targeted stakeholders

With water resources intersecting numerous 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 agriculture and the use of integrated water resources management (IWRM) as a tool for CCA in these two sectors. The following target groups should find this module of particular interest:

- Decision makers and technical staff in the water and agriculture sectors who are concerned with the agriculture dimensions of climate change and with developing and implementing respective policies, programmes or projects;

- Decision makers and technical staff in other government sectors concerned with water and agriculture 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 (NAPs) and national adaptation programmes of action (NAPAs), nationally appropriate mitigation actions (NAMAs) and national communications;
- Representatives involved in the global United Nations Framework Convention on Climate Change (UNFCCC) process, such as negotiators and UNFCCC focal points;
- General agriculture and water sectors staff and other professionals providing water and agriculture services;
- Women and other vulnerable groups of society;
- Civil society and, to a lesser extent, local community representatives;
- Non-governmental organization (NGO) experts active in the areas of climate change, water and/or agriculture;
- Academics, scientists and researchers working on CCA in the water and agriculture sectors.

## Module content

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

- **Chapter 2.** This chapter frames the impacts of climate change on water and agriculture, the linkages between these sectors, and the future water demands.
- **Chapter 3.** A structured view of the impacts of climate change on the agricultural sector, the RICCAR framework for assessing vulnerability indicators and its contribution to adaptation planning are the focus of chapter 3, setting the stage for the focus on adaptation in the next chapter.
- **Chapter 4.** This chapter starts with a discussion about linking CCA to IWRM, followed by a distinction of different types of adaptation measures and review of modelling and remote sensing, and water supply and demand options. The bulk of the chapter is dealing with adaptation measures targeting different activities in the agriculture sector, as well as screening criteria that can be used to evaluate and prioritize adaptation measures.
- **Chapter 5.** Stakeholders involved in the implementation of adaptation measures, the different scales of implementation, and means to increase adaptive capacities are the focus of chapter 5.
- **Chapter 6.** The last chapter will lay out how to follow up on the development of adaptation programmes at the national and regional policy level.
- **References and further readings.** A listing of the references that supported the preparation of this module, as well as selected readings that may be of interest.
- **Annex. A** set of exercises providing an opportunity for practitioners to extend their understanding of the various concepts underlying IWRM.

# CH. 2

**Framing Sectoral Problems**



# Framing Sectoral Problems

Agriculture, forestry and fisheries in the Arab region have been facing a considerable amount of adverse pressures due to natural and socioeconomic constraints, and these are already being exacerbated by the impacts of climate change. The pressures faced by this sector differ in magnitude across countries (such as between North Africa and the Arabian peninsula) and within countries (such as between river valleys and remote dry lands).

## Problems determined predominantly by natural resources

### Limited water resources

Water scarcity is regarded as the main factor limiting agricultural development in the Arab region as a whole. Regardless of climate change, the already critical situation of water scarcity in the Arab region will continue to worsen – particularly for the agriculture sector – due to population growth, economic activities and a highly consumptive lifestyle of urban elites (at least in some countries) as well as other drivers. Pollution is further aggravating water scarcity by reducing water usability, while shortcomings in the management of water and a focus on developing new resources rather than enhancing the management of existing ones are making the physical water crisis even worse (Cap-Net, 2005a).

### Shrinking land resources

Land is a second limiting factor facing sustainable agricultural development in the Arab region. Only 35 per cent of land in the Arab region is regarded as suitable for agricultural production purposes and this share is dwindling due to the expansion of urban areas and settlements and due to desertification and other forms of land degradation (such as soil erosion as a result of floods). The desertified land in the Arab region was estimated to be about 9.76 million km<sup>2</sup> or 68.4 per cent of the total area (Mansour et al., 2011).

### Climatic fluctuations

Droughts, floods, sandstorms and other climate phenomena have impacted all 'green' sectors (i.e. agriculture, horticulture, forestry and agroforestry) in the Arab region, especially during record years.

## Problems arising from socioeconomic issues

### Population

The population of Arab countries nearly tripled between 1970 and 2010, rising from 128 million to 359 million. According to a United Nations projection, the Arab region will have around 600 million inhabitants by 2050, representing a two-third increase – around 240 million – from 2010 (Mirkin,

2010). The total fertility declined from 6.8 children per woman in 1970-1975 to 3.6 children per woman in 2005-2010 and is expected to fall to 2.1 children per woman by 2045-2050. While some countries are at or near the replacement level, high fertility persists in other countries (UN-DESA, 2015).

### Urbanization

The Arab region is one of the most urbanized regions in the world. Between 1970 and 2010, the region experienced 400 per cent urban growth, while during the next 40 years growth is expected to halve to 200 per cent. Whereas in 2010 about 56 per cent of the total population lived in cities, in 2050 the percentage will have risen to 68 per cent; Cairo will remain the largest city of the Arab region, growing to 16 million inhabitants in 2050. The urbanization process is driven by economic development, migration to oil-rich countries, drought and conflict, with the importance varying by sub-region (UN-DESA, 2014). Water demand of urban dwellers is generally higher than that of rural ones, causing the overall water demand to increase as urbanization rises.

## Problems associated with governance, legislation and administration

### Governance

According to the United Nations Development Programme (UNDP), “key elements of good governance include equity, transparency, accountability, environmental and economic sustainability, stakeholder participation and empowerment, and responsiveness to socioeconomic development needs” (UNDP, 2013). However, the reality deviates from this postulate: “Many factors impede progress in water governance, including unclear and overlapping responsibilities, inefficient institutions, insufficient funding, centralized decision-making, limited public awareness and ineffective regulations and enforcement” (UNDP, 2013, p.1).

Some pressing problems related to agriculture, forestry and fisheries are:

- Often, the government’s commitment to support rural areas is too low, accompanied by an absence of local community empowerment;
- Inadequate cooperation between ministries and other governmental bodies that deal with agriculture, forestry, water resources and environment;
- Fragmented responsibilities in the agricultural, forestry and water sector amongst several ministries and subordinated bodies;
- Insufficient funds to support applied research that is suitable to address problems of farmers, herders and fishermen, especially women who do not have access to credit;
- Minimal government action focusing on sustaining healthy environments, maintaining natural habitats, biodiversity and eco-tourism by conserving agricultural lands, forests and natural sites through land capability and land suitability mapping (FAO, 2012);
- Lack of governmental multi-sectoral strategies that take gender mainstreaming into consideration;
- Missing or fragmented national water resources management and land use master plans, possibly due to the typical inexistence of an assertive, powerful central body that plans, coordinates and oversees related activities;
- There is a need for centralized and decentralized water resources management styles, such as water user associations.



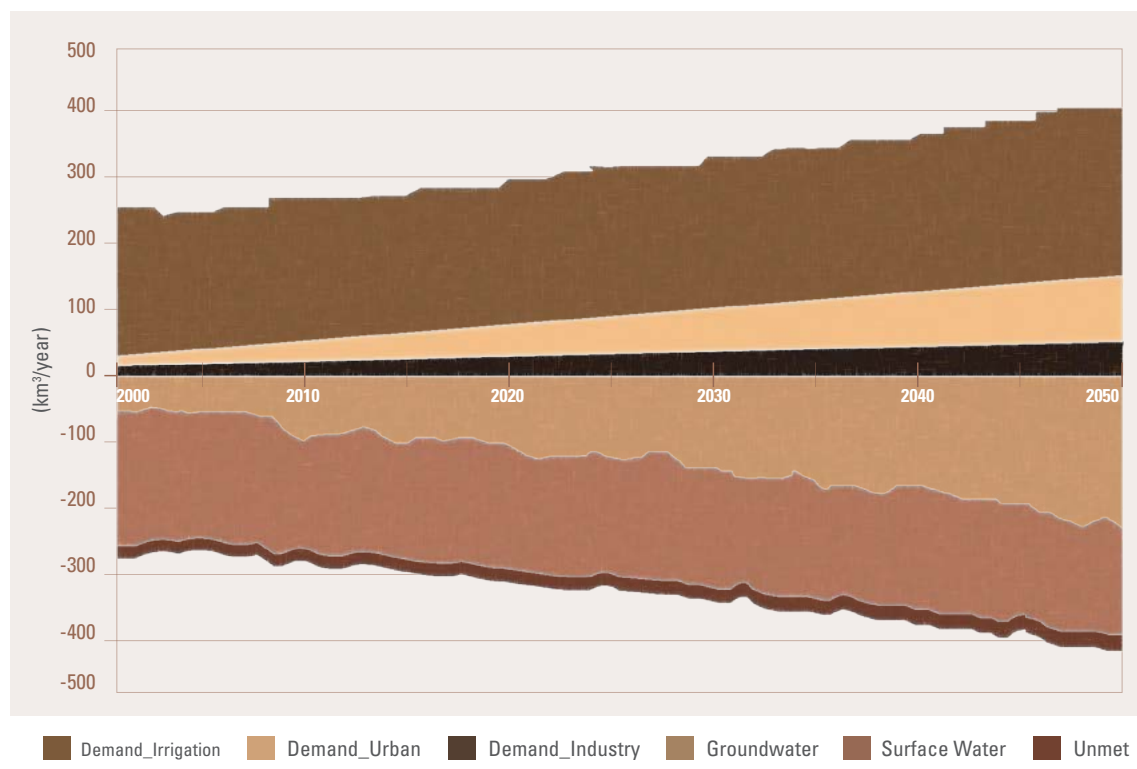
### Legislation

- Missing legal and policy frameworks, supporting and materializing government decisions and the absence of associated cultures to raise awareness on the legal framework significance;
- Absent legislation and regulations such as regarding land leases, land fragmentation, transmission of inheritance, annexation of land, and the need to emphasize the importance of agricultural land holding and the right of women to inherit and own land;
- A slow pace of handling of water and land legal issues and ownership disputes;
- Missing laws and regulations regarding the rural cadastre, one of the main constraints to land tenure, land management and agricultural investment;
- Disregard of zoning regulations through the building and construction on agricultural lands leading to a waste of fertile lands.

### Management

- Low levels of schooling and training of farmers and herders (males, as well as females);
- Absence of rational management of land and water in the majority of cases in rural areas;
- Low levels of technical infrastructure and equipment and a limited availability of qualified staff;
- Insufficient funds for agricultural modernization and implementation of rainwater harvesting;
- Missing support for improved, well-functioning agricultural extension services;
- Inadequate land use planning and its implementation to regulate urban expansion and to protect groundwater resources;
- Lack of economic incentives for farmers, companies and urban dwellers to improve water efficiency and apply water conservation methods.

**Figure 1.** Water demand and supply in the Arab region, based on climate change scenario (average)



Source: World Bank, 2011.



## Future water demand

Future demand of managed water will largely be determined by population increases, urbanization, lifestyles and the extent of climate change. By 2050, it is expected that the demand for fresh water in the Arab region will increase by (at least) 50 per cent, coupled with a halving of the per capita water availability (World Bank, 2007; ESCWA, 2006). Currently, nearly 75 per cent of the water resources in the Arab region is allocated to agriculture, 22 per cent to domestic use, and 3 per cent to industries (FAO, 2012). Figure 1 shows the presumed water demand and supply in Arab region until 2050, based on a climate change scenario (average).

While the water demand is continuously rising, the groundwater and surface water supply is slightly diminishing, leaving a steadily growing gap of unmet demand, which is the real challenge ahead. This graph does not include usable rainwater resources (on the supply side) and water use by nature, rainfed cropping and livestock (on the demand side).

There are many different types of water demand. Some of these compete directly with one another in that the water consumed by one sector is no longer available for other uses. In other cases, a given unit of water may be used and reused several times as it travels through a river basin, for example, providing benefits in succession to aquaculture, hydropower generators and irrigation. A complete analysis of the effects of climate change on human water uses should consider cross-sector interactions, including the transfers of water from one sector to another. If economic sectors compete for the scarce water resources, in most cases the sector offering the highest return per unit water is the winner. Agriculture is normally the loser in this competition for water, as its return per unit water is the lowest in comparison with industry and municipalities.

## Problems of the agriculture sub-sectors

### Rainfed agriculture

- Rainfed agriculture is vulnerable to the vagaries of the rainfall regime, while frequent dry spells are an important cause for low yield levels;
- High production risks lead farmers to low investment in agricultural inputs, such as mineral fertilizer or improved seed material, typically resulting in soil nutrient mining (often associated with soil degradation) and low yields. Missing field manuring reduces the water holding capacity of the soil and the water uptake potential of plants, with adverse impacts on agricultural productivity;
- In most Arab countries – with the notable exception of Yemen – farmers hardly invest in terracing and other soil conservation measures, which often results in soil erosion and hence in productivity losses;
- Rainfed agriculture is limited to only a few crops, and often these crops are traditional varieties;
- Suitable, improved varieties are available for many locations, but their use is hindered by lack of information (due to ineffective or absent agricultural extension services), risk aversion and lack of funds;
- Supplemental irrigation could be helpful, but investments are difficult to afford for most farmers, particularly as the steadily declining groundwater table in many areas drives up pumping costs;
- Water harvesting techniques in agriculture hold a great potential, but advice on their use is often lacking;
- Land fragmentation due to inheritance laws is another grave problem for gaining a livelihood from agriculture, resulting in out-migration from rural areas;



- The low yield levels in rainfed agriculture prevent any increase strong enough to achieve food self-sufficiency as most Arab countries cannot meet their domestic demands with local food production and thus increasingly compensate through food imports.

### Irrigated agriculture

- Groundwater tables are sinking, impeding water lifting and increasing production costs;
- Growing cities demand rising water volumes to satisfy urban water needs at the expense of the water resources available for irrigated farming;
- Due to lack of renewable water and fossil water, wastewater and agriculture drainage water are used in increasing volumes. The generally lower quality of these water sources can cause problems for agricultural production;
- Salinization of land reduces yield level and may be toxic to plants. In Arab countries, salinization of agricultural land has very different causes, which have to be appropriately tackled;
- Use of brackish water or (saline) drainage water for irrigation without leaching;
- Irrigation (even with good quality water) without sufficient drainage;
- Over-irrigation (such as in oases by pumping slightly saline fossil water) inducing groundwater table rising near to the surface (figure 2);
- Available funds often dictate the applied irrigation method, and not ideally the needs of the crop or the conditions of scarcity of water: the full potential of alternative and meanwhile appropriate irrigation methods is rarely tapped;
- Water use efficiency is often low due to inadequate management and the 'more crop per drop' principle is too often neglected;
- In many cases conveyance and distribution losses are high;

**Figure 2.** Dying date palms in the Kebili oasis (Tunisia) due to very high groundwater table, caused by over-irrigation with slightly saline fossil water



Source: Prinz.

- Even in arid Arab countries, so-called 'cash crops' with a very high water demand are cultivated because of the high price they achieve on the market (such as banana production in Jordan and rice production in the Nile delta). This conduct goes against IWRM principles;
- Governments give insufficient consideration to drainage compared with irrigation;
- Governments do not satisfactorily promote rational water resources management nor do they give enough encouragement to the private sector to do so.

#### **Animal husbandry**

- Due to population growth in rural areas, the numbers of sheep and goats have been rising steadily, often far beyond the grazing capacity;
- Large-scale overgrazing is the consequence, causing vegetation decline and finally land degradation;
- In many areas, supply of good quality water is insufficient for the larger number of animals, while also facing diversions of water for other purposes;
- Diversification is at a low level, but needs to be intensified (poultry raising, milk production, etc.);
- Veterinary services are often inadequately staffed and equipped, contributing to the spread of infectious diseases among animals;
- Low attention is given to developing grazing areas through using non-traditional water sources;
- Insufficient promotion of camel breeding, despite the ability of camels to cope with dry lands and their potential to fill the protein gap;
- Inadequate government attention to building capacities of females and males in animal breeding.

#### **Forestry**

- Agricultural activities are affecting deforestation. Due to a growing demand for food products, huge amounts of trees are felled to grow crops and create space for cattle to graze;
- Wood is used as fuel, both directly and indirectly (such as firewood or charcoal). Therefore, trees are chopped to increase supplies;
- Overpopulation directly affects forest covers, as with the expansion of cities more land is needed to establish housing and settlements;
- A significant number of trees are lost each year due to forest fires in various portions of Arab countries. This happens due to extremely warm summers and milder winters. Fires, whether caused by man or nature, result in huge losses of forest cover.

#### **Inland fisheries**

- Fisheries and aquaculture play a marginal role in national and sectoral development in spite of having a great potential in this respect (such as for fish and shrimp species suitable for brackish water);
- Applied research in aquaculture is generally limited in Arab countries;
- Production of fingerlings is still in an infancy stage in most Arab countries;
- The same applies to the cold storage infrastructure and processing industry in most Arab countries;
- Absence of using the value chain approach within the fishing communities, which could create job opportunities, especially for women.

# CH. 3

**Impact of Climate Change  
and Vulnerability Assessment  
of the Sector Based on  
RICCAR Outputs**



# Impact of Climate Change and Vulnerability Assessment of the Sector Based on RICCAR Outputs

Actions needed to assess the impact of climate change and vulnerability on the sector:

1. Strengthening the capacity of meteorological and hydrological services to collect, analyse, interpret and disseminate weather and climate information to support implementation of national adaptation programmes;
2. Strengthening national research and training institutions in order to ensure the sustainability of the capacity-building programmes;
3. Developing and enhancing technical capacities and skills to carry out and effectively integrate vulnerability and adaptation assessment into sustainable development programmes and develop national adaptation programmes of action;
4. Enhancing public awareness (level of understanding and human capacity development) on climate change impacts, mitigation and adaptation;
5. Supplying the financial means to implement the programme of CCA (and mitigation).

Based on the recommendations of the United Nations Framework Convention on Climate Change.

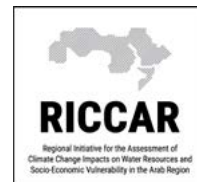
## Impact of climate change on the sector

Climate change will exacerbate the already existing problems of the 'green' sector. The challenges of water resources development in the Arab region will be aggravated by the occurring climatic changes, with serious implications for socioeconomic development. Climate change threatens agricultural production through higher and more variable temperatures, changes in precipitation patterns and increased occurrences of extreme weather events such as droughts and floods. Reduced precipitation, in combination with higher temperatures, leads to an increase in demand for water, strongly surpassing existing levels of renewable supply. Extreme precipitation events could lead to flooding, water logging, soil erosion and direct damage to plants. Prolonged droughts may have detrimental effects on crops, domestic animals and ecology. Sea level rise will not only lead to inundations of fertile lands and city quarters, but will also impact groundwater quality by seawater intrusion (IPCC, 2014). The already existing problems of food security and dependence on imports in the region will therefore be strongly exacerbated (Solh and Saxena, 2011).

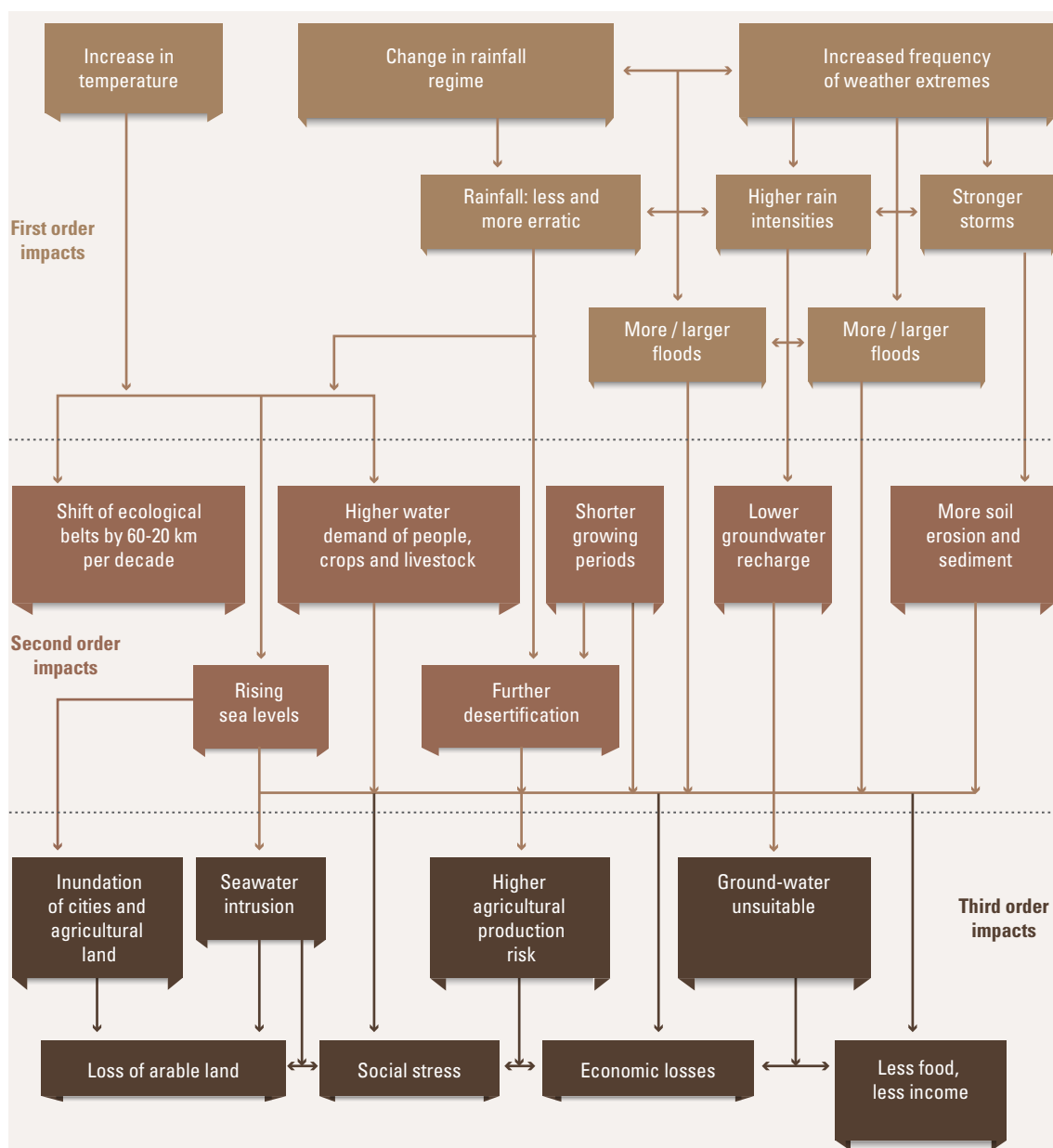
When discussing the impacts of climate change on agriculture, three orders have to be distinguished (figure 3). First order (or primary) impacts are the direct effects of climate change due to the increase of greenhouse gases in the atmosphere, such as increased temperatures, higher rain intensities, stronger storms, higher evapotranspiration (ET) values, longer droughts and larger floods. Second order impacts include the changes in our ecosystems induced by the first order impacts of climate change; special regard is given to impacts related to agriculture and forestry (figure 3). Third order impacts are the changes

in the anthroposphere (with special reference to the agricultural sector) caused by second order impacts, such as loss of arable land, higher production risk, and economic losses.

The Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) distinguishes between two levels only: Primary impacts are the direct effects of climate change on water resources. At the regional level, those impacts are either meteorological impacts or hydrological impacts. Secondary impacts are the indirect result of both climate change and human activities (socioeconomic factors) (ESCWA, 2011, pp. 62-64).



**Figure 3.** First, second and third order impacts of climate change on agricultural production in the Arab region



Source: ESCWA, 2011.



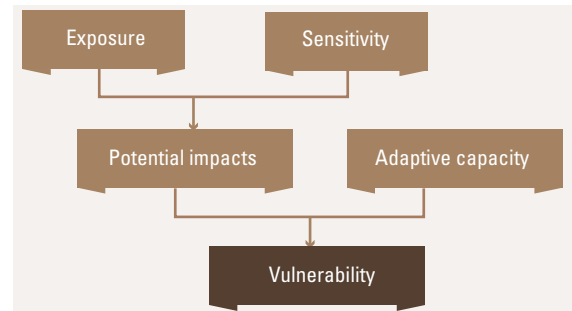


## Vulnerability assessment

Vulnerability is understood to be the function of a system climate change exposure, sensitivity and adaptive capacity to cope with climate change effects (IPCC, 2007, figure 4).

RICCAR provides a vulnerability approach, as illustrated in figure 5. The exposure section shows the impact of the most relevant climate parameters (affected by climate change) on water-related parameters important for agriculture.

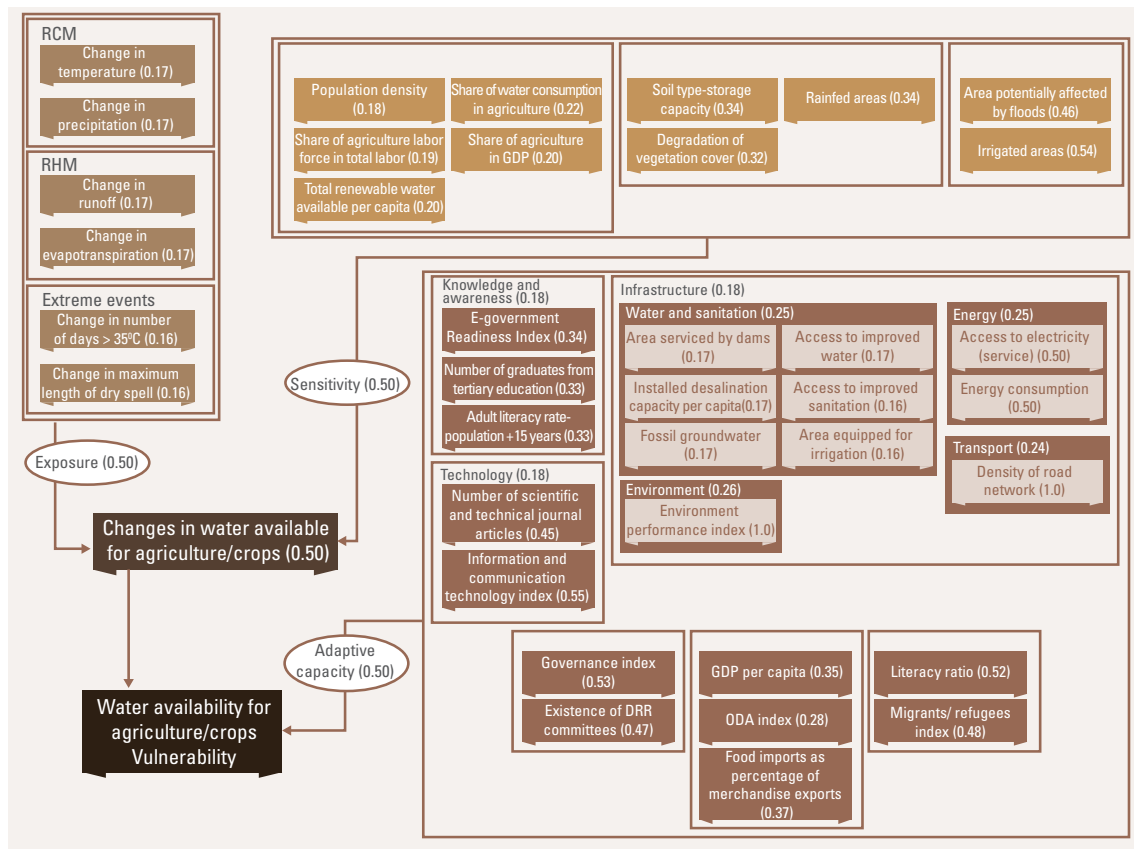
**Figure 4.** The components constituting vulnerability based on IPCC AR4 approach



Source: IPCC, 2007.

The sensitivity section contains parameters that determine the robustness or weakness of farming systems towards exposure to climate change impacts, while the degrees of exposure and sensitivity determine the potential impacts of climate change on specific farming systems. Finally, the adaptive capacity has to be measured through institutional, socioeconomic, financial and other parameters.

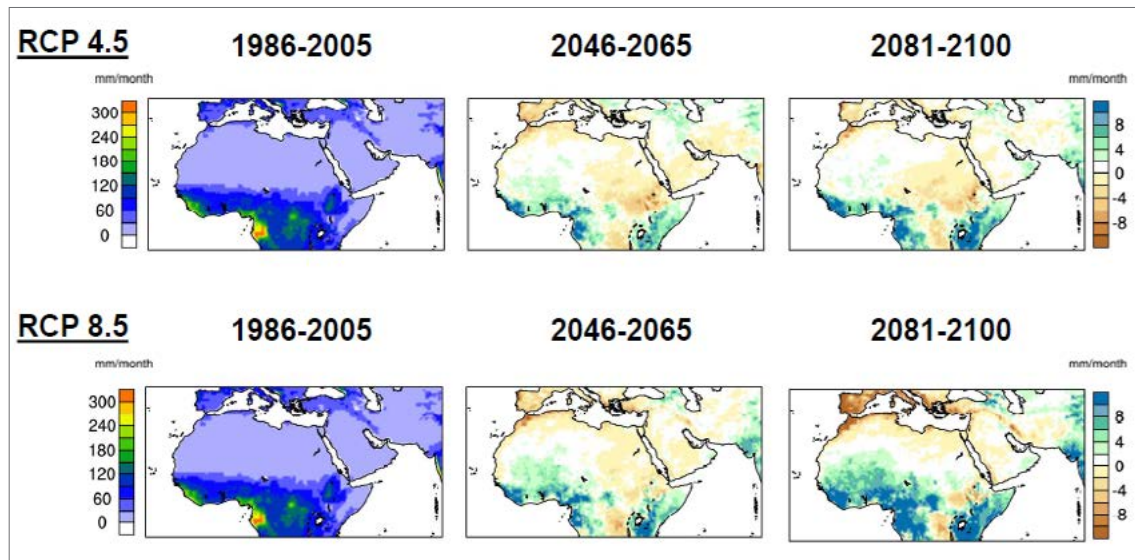
**Figure 5.** Vulnerability chart of the agricultural sector in the Arab region: exposure, sensitivity and adaptive capacity determine vulnerability



Source: RICCAR, 2017.



**Figure 6.** Change in mean annual precepitation for the time periods 2046-2065 and 2081- 2100 compared to the reference period 1986-2005 for RCP4.5 and RCP8.5 (RICCAR)



Source: RICCAR, 2017.

## RICCAR contribution to vulnerability assessment and adaptation planning in the Arab region

RICCAR is an initiative for conducting an integrated assessment of vulnerability to climate change in the Arab region, developed by ESCWA and RICCAR partners, and is supported by the German Agency for International Cooperation (GIZ) through its regional programme “Adaptation to climate change in the water sector in the MENA region” (ACCWaM) (RICCAR, 2011).

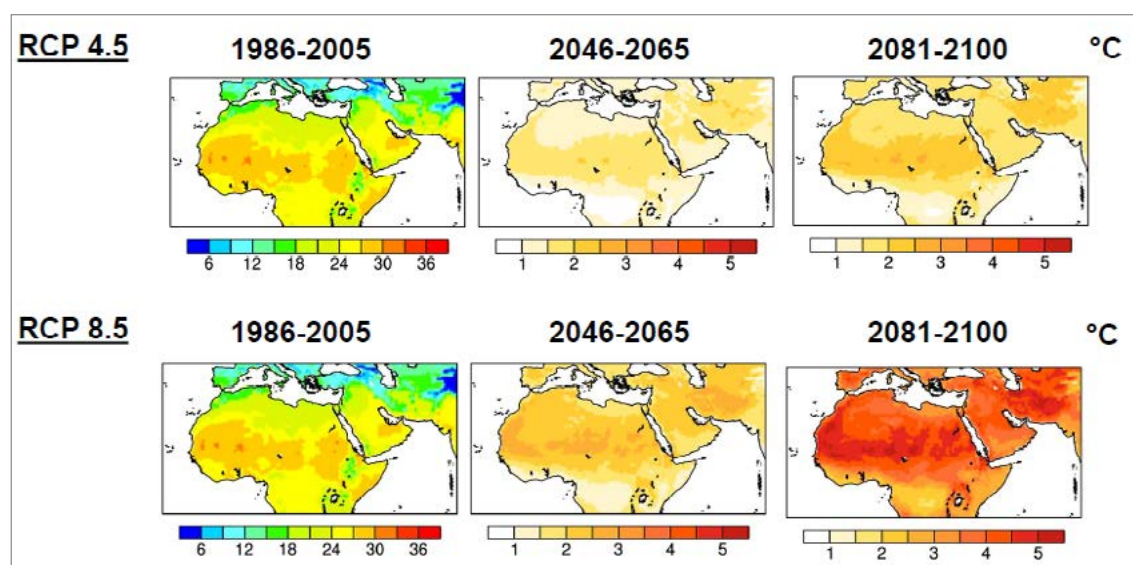
Datasets available on a regional scale were selected and three types of indicators were used:

1. Exposure indicators, such as change in temperature, change in precipitation, or change in run-off;
2. Sensitivity indicators, such as population density, share of population employed in agriculture (females/males) or total renewable water available per capita;
3. Adaptive capacity indicators, such as literacy rate, number of university graduates, share of GDP expenditure on research and development, area equipped for irrigation, adaptive capacity for professional mobility, geographical mobility, culture change environment, availability of water user associations, effectiveness of these associations, effects of the participation of these associations on the design making locally, or number of women participating in these associations and the effectiveness of women participation as design makers in these associations.

The collected data sets were classified and normalized, after which a geometric aggregation approach was selected to aggregate individual indicators to a composite indicator. The aggregated data for exposure and for sensitivity are multiplied to calculate the potential impacts, while a correlation of this factor with the adaptive capacity yields the level of vulnerability. As outcome of the impact assessment, maps for the Arab region were prepared with a spatial resolution of 50 km x 50 km (RICCAR, 2011).



**Figure 7.** Change in mean annual temperature for the time periods 2046-2065 and 2081-2100 compared to the reference period 1986-2005 for RCP4.5 and RCP8.5 (RICCAR)



Source: RICCAR, 2017.

A RICCAR Regional Knowledge Hub for Water and Climate is currently under development and its main objective is providing an interactive, online platform that provides access to information and knowledge on climate change-related analysis, water resources and socioeconomic vulnerability assessment tools for informing CCA planning, policies and projects in the Arab region.

Secondary objectives are: (1) To provide access to information that can facilitate cooperation, coordination, dialogue and exchange among Arab countries; (2) To support regional networking

**Table 1.** Biophysical and socioeconomic impacts of climate change on food production

Second order (biophysical)	Third order (socioeconomic)
<ul style="list-style-type: none"> <li>• Physiological effects on crops, pasture, forests and livestock (quantity and quality)</li> <li>• Change in land, soil and water resources (quantity and quality)</li> <li>• Increased weed and pest challenges</li> <li>• Shifts in spatial and temporal distribution of impacts</li> <li>• Sea level rise, changes to seawater salinity and acidity</li> <li>• Sea temperature rise causing fish to inhabit different ranges</li> </ul>	<ul style="list-style-type: none"> <li>• Decline in yields and production</li> <li>• Reduced marginal GDP from agriculture</li> <li>• Fluctuations in world market prices</li> <li>• Changes in geographical distribution of trade patterns</li> <li>• Increased number of people at risk of hunger and food insecurity</li> <li>• Migration and civil unrest</li> <li>• High demographic fluctuations</li> <li>• Fragile socioeconomic conditions of women, children and elderly people</li> <li>• Spread of unconventional diseases affecting humans, animals and plants</li> <li>• Lower livestock production due to constant conflict between humans and animals on land use</li> </ul>

Source: Adapted from FAO, 2007.

and exchange; (3) To support awareness raising for national and local stakeholders; (4) To provide capacity-building support; and (5) To develop an early warning platform by establishing a simple disaster early warning component (ESCWA, 2014).

The expected climate change impact on precipitation in the various parts of the Arab region is shown in figure 6, and for temperature in figure 7, illustrating the exposure as defined in RICCAR (or the first order impacts). The biophysical (or second order) and socioeconomic (or third order) impacts of climate change on food production can be found in table 1.

Table 2 supplies an overview of exposure and sensitivity of selected farming systems in Arab countries, indicating their vulnerability level. This is followed by a vulnerability assessment of the three main agricultural activities, namely crop production, livestock production and fisheries.

### **Crop production**

Expected climatic changes will lead to region-specific impacts on land and water resources, greatly affecting crop production and the agricultural sector in the coming decades. Vulnerability of rainfed cropping is highest as its adaptive capacity is very low. Vulnerability of irrigated agriculture with a secure water supply (such as sufficient water storage capacities) is the lowest and rainfed cropping with means for supplemented irrigation is the somewhere in between; hence, it becomes necessary to build capacities of farmers (males and females) to adapt to the new tough conditions.

### **Livestock production**

Livestock producers in the Arab region were always forced to adapt to environmental and climate changes. An overall decrease in precipitation and more extreme weather situations will, however, add additional stress on livestock production and increase its vulnerability. The availability of sufficient fodder will remain a key question for livestock producers, but if financial means are available to buy fodder from other sources, vulnerability will decrease. There is a need to conduct research to determine which animal species best resist the pressuring conditions found in the region, and non-traditional types of fodder. As women in rural communities are typically responsible for livestock and poultry breeding, they are more in need for capacity development in that regard.

### **Inland fisheries**

Inland fisheries are affected by climate change, with some of the impacts expected to include stress due to increased temperature and oxygen demand, deteriorated water quality, and reduced flows, all of which increase vulnerability. Therefore, there is a need to apply a value chain approach to eliminate poverty and create job opportunities for women and youth.

## **Linkage of RICCAR outputs to agriculture models**

A project entitled “Climate Change and Adaptation Solutions for the Green Sectors of Selected Zones in the NENA Region” was implemented in 2015-2016 to provide the evidence to support regional dialogue and strategic thinking about joint adaptation responses required to cope with the challenges of climate change, water scarcity and food security. This required the project to study and analyse the impact of climate change on green sectors in identified hotspots within the region. The study is a partnership between GIZ, ACCWaM, FAO, ACSAD and ESCWA and builds on the GIZ programme on adaptation to climate change in the water sector in the Arab region and the thorough analysis and science-based anticipation of RICCAR.

**Table 2.** Climate change impacts on farming systems of the Arab region

Farming system	Exposure: expected climate-related changes	Sensitivity: likely impacts on farming systems
<b>Irrigated</b>	<ul style="list-style-type: none"> <li>• Increased temperatures</li> <li>• Reduced supply of surface irrigation water</li> <li>• Dwindling groundwater recharge</li> <li>• Loss of production in low-lying coastal areas</li> </ul>	<ul style="list-style-type: none"> <li>• More water stress</li> <li>• The disappearance of some plant species as addressed by the United Nations Convention on Biological Diversity</li> <li>• More communities and regional conflicts on water</li> <li>• More fragile agriculture and coastal communities</li> <li>• Increased demand for irrigation and water transfer</li> <li>• Reduced yields due to high temperatures</li> <li>• More difficulty in agricultural planning</li> <li>• Salinization from reduced leaching</li> <li>• Reduction in cropping intensity</li> </ul>
<b>Highland mixed</b>	<ul style="list-style-type: none"> <li>• Increased aridity</li> <li>• Greater risk of drought</li> <li>• Possible lengthening of the growing season</li> <li>• Reduced supply of irrigation water</li> </ul>	<ul style="list-style-type: none"> <li>• Reduction in yields</li> <li>• Reduction in cropping intensity</li> <li>• Increased demand for irrigation water</li> </ul>
<b>Rainfed mixed</b>	<ul style="list-style-type: none"> <li>• Increased aridity</li> <li>• Greater risk of drought</li> <li>• Reduced supply of irrigation water</li> <li>• Loss of production in low-lying coastal</li> </ul>	<ul style="list-style-type: none"> <li>• Reduction in yields</li> <li>• Reduction in cropping intensity</li> <li>• Increased demand for irrigation</li> <li>• More difficulty in agricultural planning area</li> </ul>
<b>Dryland mixed</b>	<ul style="list-style-type: none"> <li>• Increased aridity</li> <li>• Greater risk of drought rangeland</li> <li>• Reduced supply of irrigation water</li> </ul>	<ul style="list-style-type: none"> <li>• System very vulnerable to declining rainfall; some lands may revert to rangeland</li> <li>• Increased demand for irrigation</li> </ul>
<b>Pastoral</b>	<ul style="list-style-type: none"> <li>• Increased aridity</li> <li>• Greater risk of drought</li> <li>• Reduced water for livestock and fodder</li> </ul>	<ul style="list-style-type: none"> <li>• Very vulnerable system, where desertification may reduce carrying capacity significantly</li> <li>• Increase in nonfarm activities, exit from farming, migration</li> </ul>

Source: Adapted from Verner, 2012.

The RICCAR vulnerability assessment (VA) maps for crops show that most of the cropped area in the Arab region lies within the highest three vulnerability classes (i.e. medium to high vulnerability). The areas with highest vulnerability are the Nile Valley, the Euphrates-Tigris basin, the south-west of the Arab Peninsula, and the western parts of North Africa on the Atlas Mountains. The analysis shows that evapotranspiration will increase and run-offs will decline, resulting in increased intensity of water scarcity, as confirmed by the crop hotspots characterized by global water scarcity classes. The biophysical characterization of the crop hotspots by global farming systems revealed that the most productive systems of the region, namely the irrigated and the dry savanna agriculture, are those more prone to climate change vulnerability as 85-90 per cent of their combined areas are located under the high vulnerability classes.

### Climate change impact on cropping production systems

Although some global climate models (GCMs) predicted yield increases for some climate scenarios, these increases will mostly occur in areas less important for the relevant crops, while the areas where the crops are concentrated will be negatively affected under all climate scenarios (both moderate and worst-case scenarios). For example, irrigated sorghum is predicted to realize some yield increases within low to moderate vulnerability classes; however, sorghum, which is mostly grown in the highest vulnerable areas, will experience yield declines under all climate change scenarios. As for wheat, its yield is projected to decline under all scenarios; the largest yield decline is expected in areas with high wheat concentrations. For maize, the crop is the least vulnerable cereal and its yield reduction is expected to be modest, despite being mostly located within highly vulnerable areas. Trends for potatoes are similar to

**Table 3.** Projected relative average change (per cent) of main crops in three target areas

Location	Crop	Climate scenario			
		RCP4.5		RCP8.5	
		At the mid-century (2046-2065)	At the end of the century (2081-2100)	At the mid-century (2046-2065)	At the end of the century (2081-2100)
Irrigated crop					
At Orontes watershed (Lebanon)	eggplant	-9.4	-13.3	-9.8	-27.3
	maize	-7.4	-12.3	-9.9	-17.1
	potato	-3.9	-5.2	-5.2	-10.7
At North Delta (Egypt)	maize	0.3	-1.0	-1.5	-8.9
	wheat	-4.1	-5.7	-4.0	-5.5
	cotton	-3.0	-4.3	-3.2	-6.3
Average		-4.6	-7.0	-5.6	-12.6
Rainfed crop					
At Karak governorate (Jordan)	wheat	-1.5	-15.5	-5.2	-55.3
	barley	-7.0	-17.3	-2.4	-59.3
Average		4.3	16.4	3.8	57.3





those of maize and olives (which are the only tree crops examined and found to be the most vulnerable to climate change) with substantial yield reduction under all scenarios and all GCMs.

The FAO AquaCrop model was calibrated and used to assess the impact of climate change on the dominant crops in the selected zones within the region. The selected zones are the areas that are planted with wheat, maize, and cotton in the North Delta of Egypt representing the irrigated agriculture; rainfed wheat and barley in Karak governorate, Jordan, representing very dry aridic zone; and irrigated eggplant, maize, and potato in the Orontes watershed in Lebanon, representing mixed agriculture zone. The results show that climate change will have several impacts on crops. The growing period is projected to decrease by 10 to 30 days per year due to an increase in temperature. Moreover, in spite of this projected temperature rise, the crop water requirement (ETC) is projected to decrease between 5 and 20 per cent. This reduction in ETC is mainly due to the decrease in the length of the growth period.

The simulation also shows that without inclusion of elevated CO<sub>2</sub> effects, the climate change is projected to result in the decrease of crop yields. The reduction in yield is 4.6 per cent and 7 per cent at the mid-century and end of century respectively for the moderate scenario RCP4.5; and 5.6 per cent and 12.6 per cent at the mid-century and the end of the century respectively for the extreme scenario RCP8.5 (table 3). The simulation also shows that rainfed crops are more sensitive to climate change than irrigated ones. On average, the yield reductions of rainfed crops are 4.3 per cent and 16.4 per cent at the mid-century and end of century respectively for the moderate scenario RCP4.5, and 3.8 per cent and 57.3 per cent at the mid-century and end of century respectively for the extreme scenario RCP8.5.

Increasing atmospheric CO<sub>2</sub> concentration is likely to have some positive effect on yields. Plants produce more vegetative matter as atmospheric concentrations of CO<sub>2</sub> increase. The effect depends on the nature of the photosynthetic process used by the plant species. So-called C3 plants (such as eggplant, potato, wheat and cotton) use CO<sub>2</sub> less efficiently than C4 plants (such as maize), so C3 plants are more sensitive to higher concentrations of CO<sub>2</sub>. However, it still remains an open question whether these laboratory results of impacts of CO<sub>2</sub> can also be demonstrated in actual field conditions.

A report on field experiments on CO<sub>2</sub> fertilization (Long et al. 2006) finds that the effects in the field are approximately 50 per cent less strong than in experiments in enclosed containers. Therefore, the actual benefits of CO<sub>2</sub> fertilization for farmers' fields remain uncertain.



CH.

4

**Identification of Adaptation  
Measures and Options  
for the Sector**





# Identification of Adaptation Measures and Options for the Sector

## Climate change, integrated water resources management and mitigation:

1. Climate change projections signal the need for immediate action in the water sector, which includes a combination of good water management and climate adaptation.
2. Water management requires maintaining the balance among economic efficiency, social equity, and environmental sustainability to enhance overall climate change resilience.
3. Integrate water resources management across water and non-water sectors (agriculture, tourism, and urban development) creates a total resource view with water as a cross-sectoral input to development.
4. Adaptation must be coupled with mitigation. The agriculture sector offers promising opportunities for mitigating certain root causes of climate change such as emissions, through carbon sequestration in soil (organic matter) and trees or other perennial plants.

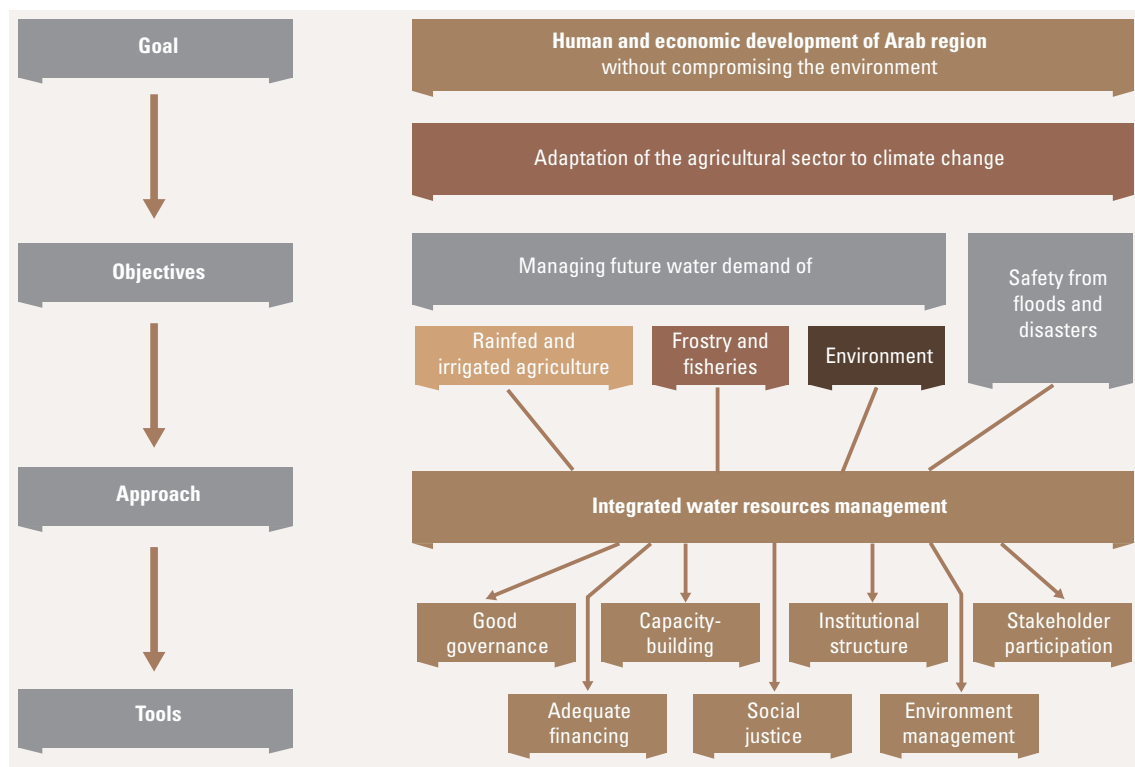
## Linking climate change adaptation to integrated water resources management

It is now recognized that climate change will have severe impacts beyond the direct impact on agricultural water management (shorter growing seasons, storms, floods, droughts), especially on food security. “Progress requires integrated approaches to the water crisis that address the links between water and health, education, poverty alleviation, environmental protection, job creation, and food and energy security” (UNDP, 2013).

Integrated water resources management (IWRM) provides a holistic approach (figure 8), seeking to (a) balance water demand with available water resources; (b) improve allocation of water amongst competing uses; (c) apply water conservation measures in all sectors; (d) protect water quality; and (e) improve cost management.

As shown in figure 8, IWRM includes a wide range of elements (‘tools’) related to CCA:

- Good governance
- Human resources development/capacity-building
- Improving institutional structures
- Stakeholder participation
- Adequate (public) financing
- Social justice
- Natural resources management

**Figure 8.** Application of the IWRM concept for CCA to agriculture

Source: Adapted from Prinz, 2014a.

These elements are further supported by other aspects that touch more on the implementation process:

- Adapted planning (resources have to be wisely assessed, allocated and managed)
- Conflict resolution
- Monitoring

The management tools for IWRM shall enable and help decision-makers to make rational and informed choices between alternative actions (UNDP, 2013).

When looking for application of these core tools of IWRM in CCA policy in the agriculture sector of Arab countries, a number of recommendations are proposed as further discussed in this section.

### Good governance

Key elements of good water governance include (a) equity; (b) transparency in all decisions; (c) accountability for decisions taken; (d) environmental and economic sustainability; (e) stakeholder participation and empowerment; and (f) responsiveness to socioeconomic development needs (UNDP, 2013).

Good governance/adapted policy includes:

- A water policy favouring water demand instead of water supply management and the further development of marginal water sources;
- A water policy including water (supply) pricing (payment according to quantity used instead of flat rates);



- An agricultural policy in support of improved water use (such as in water conveyance and irrigation), climate-proof crop selection, climate change adapted animal husbandry, etc.;
- A long-term agricultural policy creating optimal framework conditions not only for the production sector, but for the socioeconomic sector as well, including land ownership/tenure (such as by cadastre development), an adjusted commodity and trade policy (including the 'virtual water' aspect), etc.;
- A policy able to improve protection from floods, droughts and other calamities;
- CCA water policies and strategies based on consultations with stakeholders (water user associations, local communities, etc.);
- More stress on enforcement of laws and regulations related to land use and water pollution (by industry, agriculture, cities);
- Strengthened agricultural extension and applied research and demonstrations to counteract impacts of climate change;
- Improved communication systems and exchange of data within and between governmental bodies, as well as between public bodies and stakeholders;
- High priorities to 'climate change hot spots' and reduction of the vulnerabilities of poor and disadvantaged people.

#### **Human resources development, including capacity-building**

- Reducing illiteracy and lifting up general education level, particularly for women;
- Offering training courses for farmers and herders on how to cope with climate change impacts (avoid overgrazing);
- Keeping stakeholders informed and allowing participation in decision-making;
- Raising awareness through campaigns in social media, print media, schools etc. on water conservation at all sectors, including drinking water consumption and industrial water use; and supporting water audits in ministries etc., in order to reduce the stress on agricultural water needs;
- Awareness campaigns to reduce food losses by changing food consuming/eating habits, etc.

#### **Key adaptation measures within the IWRM framework include:**

1. Overall water governance needs improvement at all levels, including the full participation of stakeholders.
2. Climate change will require upgrading disaster risk management for floods and drought, taking gender perspectives into consideration while planning, implementing, monitoring and evaluating on all levels.
3. Nonconventional supply options, storage, and conveyance capacity can enhance resilience in the face of droughts and floods.
4. More elaborate water demand management is required to achieve sustainability and reduce the need for expensive water-supply infrastructure.
5. Investments should be made in developing an information base on adaptation to climate change in agriculture, forestry and fisheries.
6. To protect water resources from pollution, governments should enact and enforce water laws and regulations.
7. Promote river transportation as a sustainable transportation method.
8. Encourage researchers to adopt the interdisciplinary approach for comprehensive water resources management taking into consideration gender dimensions.

**Institutional structures**

- A move from top-down, hierarchical structure to more decentralized administrative settings is advised;
- Institutions should promote cooperation among authority levels, both vertically and horizontally;
- Water stakeholders need well-developed institutional mechanisms to get their voice heard;
- Well-staffed institutions are needed in each country to deal with climate change impacts and modes of adaptation;
- The involvement of water user associations is central to improved water management and governance;
- The set-up of institutions has to reflect a clear line of responsibilities to deal efficiently with water and CCA issues .

**Adequate (public) finance**

- Establish hydraulic structures (for reservoirs, etc.);
- Support incentives for water conservation (soil and water conservation, water harvesting, multiple reuse of water, xeriscape);
- Supply cheap loans for improvement of irrigation systems, higher water use efficiency and supplemental irrigation;
- Establish an early warning system for flood waves, drought, etc.

**Natural resources management**

- Collection of relevant data related to CC impacts on natural resources to allow CCA policy;
- Protection of surface water and groundwater resources (such as by land use planning/enforcement);
- Initiation of programmes to protect biodiversity particularly under climate change impacts and establishment of new nature reserves;
- Protection of wetlands from pollution and water over-extraction through laws, regulations and communication;
- Soil protection to avoid any form of land degradation (soil erosion, salinization. etc.), such as by consulting with farmers, land developers, infrastructure planners;
- Minimization of groundwater over-abstraction from renewable and fossil sources through law enforcement, etc.;
- Improvement of cooperation between various governmental bodies (local administration, police, legal, etc.) in order to work hand-in-hand to enforce laws/decrees.

## Adaptation measures in agriculture

The goal of adaptation measures is to improve water management in order to balance multiple uses of water resources while realizing social, economic and environmental benefits. The social and environmental value of water is hardly recognized by economic policy-makers and its importance for national economies is largely unaccounted for. There is a strong nexus between water, energy and food production (ESCWA, 2015), and all adaptation measures should comply with this nexus in order to maximise resource use efficiency.

The term autonomous adaptation is used for measures occurring spontaneously, whereas the term planned adaptation is used for measures that are the results of decisions taken. Another way of classifying adaptation options is to distinguish between reactive and anticipatory



adaptation. The first term is used for measures taken after the impacts of climate change have become manifest, while the second one is used before measures taken before impacts are apparent (Cap-Net, 2009).

Adaptation planning is an important IWRM tool. Table 4 is a compilation of measures serving directly or indirectly the purpose of CCA in agriculture, where such measures are categorised based on objectives. When dealing with IWRM, reducing the impact of water abstraction and pollution on natural environments and ecosystems must maintain a high priority. The same applies to the duty to reduce the vulnerability of populations to extreme weather events such as droughts, floods and storms.

**Table 4.** Overview of adaptation measures in rainfed and irrigated agriculture

Adaptation measure	Remarks	Adaptation type*
<b>Increasing available water quantities: see section "Water resources and their potential"</b>		
<b>Improving water storage: see section "Water storage"</b>		
<b>Protecting water resources</b>		
Avoiding surface water contamination	By point source (such as industrial plant) and agricultural contamination (pesticides)	AA
Avoiding groundwater contamination	Prohibiting settlements, fuel stations etc. in drinking water extraction zones; general watershed protection	AA
Avoiding canal water contamination (such as by solid waste dumping)	Awareness campaigns and alternative places for solid waste collection are needed	RA
<b>Reduction of water losses</b>		
Lower losses in conveyance and distribution canals	Lining of canals, good maintenance; replacing canals by pipes; good control according to needs	AA
Leakages in canals and pipes	Permanent control, repair service	AA
In-situ moisture conservation	Improving organic matter content in soil	AA
Soil and water conservation measures	Reducing soil erosion and catching water	
Water harvesting (microcatchments, macrocatchments, floodwater harvesting, etc.)	Collecting rainfall and overland flow and storing it either in the soil volume or in ponds	RA
Evaporation losses from soil surfaces	Using (organic or plastic) mulch, windbreaks, shelterbelts	RA
Cultivation in protected environments	Cultivation in greenhouses and plastic tunnels reduces evapotranspiration	RA

Adaptation measure	Remarks	Adaptation type*
<b>Increasing available water quantities: see section “Water resources and their potential”</b>		
<b>Improving water storage: see section “Water storage”</b>		
Use of efficient irrigation methods	Example: drip/trickle irrigation. Filters and good maintenance needed, high costs	RA
Use of efficient application techniques	Examples: surge irrigation, LEPA technique (LEPA = low energy precision application)	RA
Use of special irrigation modes	Example: deficit irrigation. Preconditions: well trained farmers, water storage	RA
Applying the quantities needed by plants	Using the calculated evapo-transpiration $ET_0$ or measured evaporation pan values to determine irrigation applications; measure regularly soil moisture	RA
Applying supplemental irrigation (SI)	Irrigating rainfed crops during drought periods	RA
<b>Improving agricultural practices</b>		
Change of sowing dates, and depth	Applied agricultural research helpful	RA
Better plant nutrition	Application of organic manure and mineral fertilizer	RA
Use of less water demanding, well adapted crops and varieties and crop diversification	Breeding work, seed distribution; a motivated agricultural extension service	AA
Combination of cropping with animal husbandry and fish farming	Crop residues as fodder, manure for crop nutrition	RA/AA
Conservation agriculture	Mainly for mechanized agriculture	AA
Provide agriculture and rural extension services to both (F/M) taking in consideration that these services should be provided to female by females extension workers		
Better linkages with the markets		
Promote for interdisciplinary future studies with different scenarios		
<b>Additional measures</b>		
Establishment of early warning systems		AA
Drought monitoring		AA
Education in water management, soil and water conservation, water harvesting etc.		AA

\*AA = Anticipatory adaptation; RA = Reactive adaptation.



### Case study. Gender in the agricultural sector in Egypt

The contribution of the agriculture sector in Egypt exceeds 13 per cent of GDP and over 30 per cent of employment opportunities (Handoussa, 2010). In Egypt, female agricultural workers comprise 23 per cent of the total workers in this sector, and 58 per cent of total female rural workers, having little or no social and other benefits (Gender office of the International Union for Conservation of Nature (IUCN), 2011). Women take part in all agricultural stages, especially tasks such as storing, marketing, cultivating and harvesting. Despite this, however, many studies point to the fact that women rarely own land in Egypt. Only 5.7 per cent of landowners in Egypt are women (World Bank, 2003) and much of these lands tend to be relatively small. Moreover, when women actually do own land, a male member of the family often controls such land until marriage, and after marriage her husband or son controls it. In addition, during climate related food shortages, malnourished women are at higher risk for developing iron-deficiency-anemia (CAPMAS, 2005).

**More than 4 million women work in agriculture in Egypt**



**Photo:** Better Life for Full Development Institution.  
**Source:** Raslan, 2011.

**Source:** Handoussa, H. (2010). Situation Analysis: Key Development Challenges Facing Egypt. Gender office of the International Union for Conservation of Nature IUCN (2011). National Strategy for Mainstreaming Gender in Climate Change in Egypt. CAPMAS (2005). Health Statistics. Retrieved from CAPMAS: <http://www.capmas.gov.eg/>. World Bank (2003). Retrieved from Arab Republic of Egypt Gender Assessment: <http://siteresources.worldbank.org/INTMNAREGTOP-GENDER/Resources/CGA.pdf>.

## Modelling and remote sensing

The hydrological cycle has several components: rainfall, run-off, infiltration, which recharges the groundwater, evaporation from soil and water bodies and evapotranspiration (figure 9).

Effective water management is essential especially for arid and semi-arid areas that have particular challenges and have received little attention. This requires appropriate decision support systems, including modelling tools. Modelling methods have been widely used over 40 years for a variety of purposes. Several models are used in IWRM, some deal with climate, some with surface and groundwater, and others with modelling crop growth.

The tasks for which rainfall run-off models are used are diverse, and the scale of applications ranges from small catchment areas, of the order of a few hectares, to that of global models. Hydrological models are usually used to design rainwater-harvesting construction such as dams and mountain lakes.

Available models are numerous, so they could be presented by a range of approaches, in order of increasing complexity as:

- Simple empirical methods (such as curve number and regression equations);
- Large scale energy-water balance equations (such as Budyko curve);
- Conceptual rainfall run-off models (such as SIMHYD, Sacramento, AWBM);
- Landscape daily hydrological models (such as VIC, WaterDyn);
- Fully distributed physically-based hydrological models which explicitly model hill slope and catchment processes (such as SHE, TOPOG).



## Modelling water resources and water requirements

Groundwater is a very important resource in arid and semi-arid areas, because of the high evaporation rate from surface water bodies. Groundwater is of fundamental importance in water resources planning as it serves both as a storage and a release entity. Groundwater is normally extracted from aquifers that are coupled through complex processes to the ecosystem; modelling groundwater aquifers increases the sustainability of the use of this precious resource.

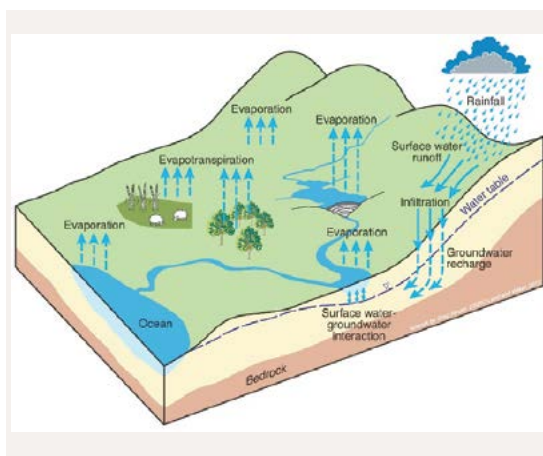
Groundwater models may be used to predict the effects of hydrological changes (such as groundwater abstraction or irrigation developments) on the behaviour of the aquifer (figure 10) and are often named 'groundwater simulation models'. Nowadays, they are also used in various water management plans for urban areas.

The primary coupling between groundwater and hydrological inputs is the unsaturated zone or vadose zone. The soil acts to partition hydrological inputs such as rainfall or snowmelt into surface run-off, soil moisture, evapotranspiration and groundwater recharge. Flows through the unsaturated zone that couple surface water to soil moisture and groundwater can be upward or downward, depending upon the gradient of hydraulic head in the soil.

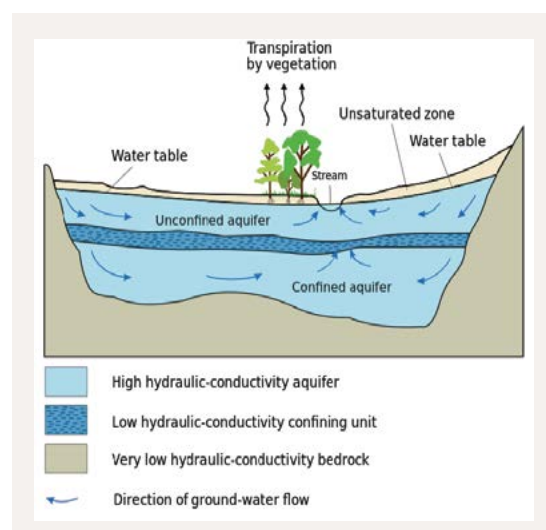
Management of a groundwater system, means making such decisions as regarding:

- The total volume that may be withdrawn annually from the aquifer
- The location of pumping and artificial recharge wells, and their rates
- Groundwater quality
- Groundwater contamination by:
  - Hazardous industrial wastes
  - Leachate from landfills
  - Agricultural activities such as the use of fertilizers and pesticides
  - Improper hazardous waste disposal
  - Septic systems

**Figure 9.** Watershed model showing the components used in hydrological modelling



**Figure 10.** Cross-section of river valley



Source: <http://www.centralbasin.org>.



- Saline intrusion
- Animal wastes

The crop water need is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally. The crop water need always refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favourable soil conditions (including fertility and water). The crop thus reaches its full production potential under the given environment.

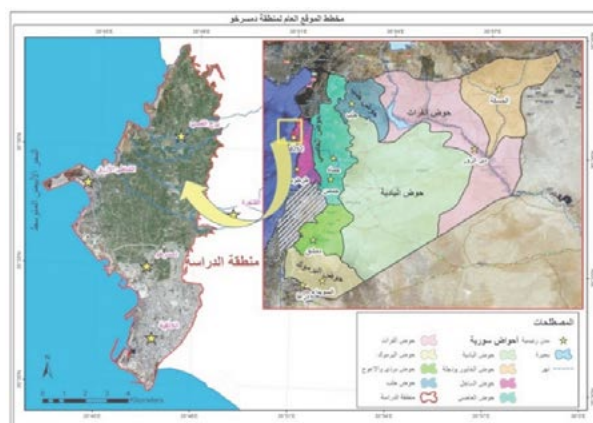
The crop water need mainly depends on:

- Climate: in a sunny and hot climate crops need more water per day than in a cloudy and cool climate;
- Crop type: crops such as maize or sugarcane need more water than crops such as millet or sorghum;
- Growth stage of the crop: fully grown crops need more water than crops that have just been planted (figure 11);
- Management and environment factors: such as soil salinity, poor land fertility, absence of control of diseases and pests and poor soil management.

CROPWAT is a FAO computer programme for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the programme allows the development of irrigation schedules for different management conditions and the calculation of water supply schemes for varying crop patterns. CROPWAT can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rainfed and irrigated conditions.

### Using groundwater modelling to study seawater intrusion in Demserkho (Syrian Arab Republic)

Demserkho is a coastal area in the Syrian Arab Republic where seawater intrusion started to appear recently in the form of salinization of some wells. The project assessed the current situation of the seawater intrusion by preparing a hydrogeological model to estimate the future evolution of the groundwater levels by applying the different scenarios of the Ministry of Water Resources for the exploitation of the groundwater resources in the study area.



The model was prepared by ACSAD and implemented at the Ministry of Water Resources in the Syrian Arab Republic as a decision support system for water strategy planning and for estimating the safe yield and promising areas.

**References:** Water Resources Department at ACSAD, Final report on the project, [www.acsad.org](http://www.acsad.org).

AquaCrop is the FAO crop-model to simulate yield response to water (Steduto et al., 2009; Raes et al., 2009). It is designed to balance simplicity, accuracy and robustness, and is particularly suited to address conditions where water is a key limiting factor in crop production. AquaCrop is a companion tool for a wide range of users and applications including yield prediction under climate change scenarios. AquaCrop is a completely revised version of the successful CropWat model. The main difference between CropWat and AquaCrop is that the latter includes more advanced crop growth routines.

AquaCrop includes the following sub-model components: soil, with its water balance; crop, with its development, growth and yield; atmosphere, with its thermal regime, rainfall, evaporative demand and CO<sub>2</sub> concentration; and management options, with its major agronomic practice such as irrigation and fertilization.

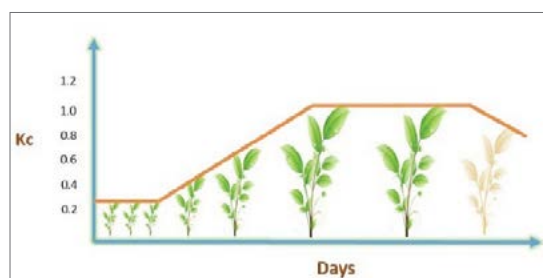
The particular features that distinguishes AquaCrop from other crop models is its focus on water, the use of ground canopy cover instead of leaf area index, and the use of water productivity values normalized for atmospheric evaporative demand and of carbon dioxide concentration. This enables the model with the extrapolation capacity to diverse locations and seasons, including future climate scenarios. Moreover, although the model is simple, it gives particular attention to the fundamental processes involved in crop productivity and in the responses to water, from a physiological and agronomic background perspective.

Decision support systems (DSS) can assist the water resources planner in making the right decisions by evaluating the implications of various planning options on the water resources system. According to the classic definition by Sprague and Carlson (1982), a DSS is “an interactive computer based support system that helps decision makers to utilize data and models to solve unstructured problems.” In general, it consists of three main components: a user-interface for dialogue generation and providing the interface between the user and the system, a model management subsystem and an information management subsystem (database).

As water management in the Arab countries often suffers from the absence of the link between the basic information and its application for water management decisions, a DSS is an appropriate tool to solve this problem.

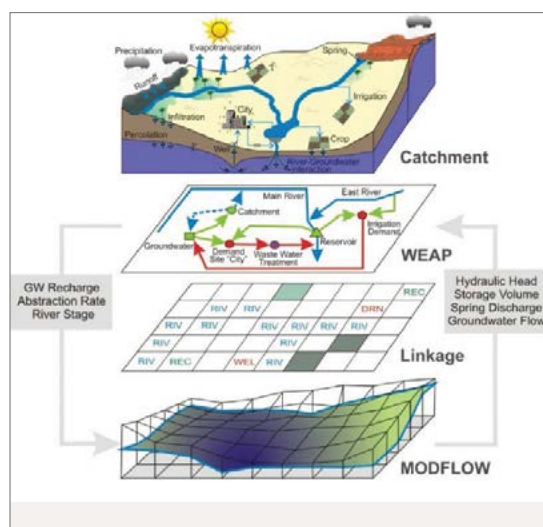
As an example of DSS systems, WEAP (Water Evaluation and Planning System) is a software

**Figure 11.** The four growth phases of annual plants



Source: <http://www.smart-fertilizer.com/articles/water-requirements-of-crops>.

**Figure 12.** Three-dimensional water resources planning in WEAP

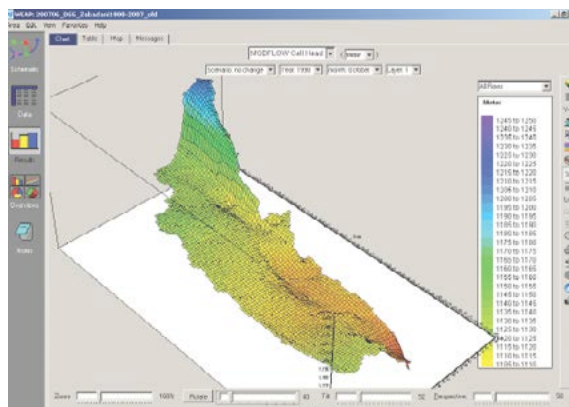


Source: [http://www.bgr.bund.de/EN/Themen/Wasser/Projekte/abgeschlossen/TZ/Acsad\\_dss/dss\\_fb\\_en.html](http://www.bgr.bund.de/EN/Themen/Wasser/Projekte/abgeschlossen/TZ/Acsad_dss/dss_fb_en.html).



### Application of WEAP (decision support system) in Zabadani basin in the Syrian Arab Republic

A water competition exists in Zabadani Basin in the Syrian Arab Republic between the local drinking water suppliers, the Damascus water supply authority as well as agricultural and touristic demands. During the project, all relevant stakeholders of relevant ministries, the municipality and water suppliers were integrated into the DSS development, data acquisition and scenario planning. The WEAP software was used to build a planning and evaluation model, which then was linked to the MODFLOW groundwater flow model as a component of the DSS.



A MODFLOW groundwater model of the study area was linked successfully with WEAP and different scenarios were built in collaboration with the stakeholders. The results showed that the linked WEAP-MODFLOW DSS is able to calculate realistic groundwater, surface and soil water balances as well as hydraulic heads. The scenarios developed within the project deal with realistic assumptions on domestic and agricultural demands as well as influences of climate change and consecutive drought years.

**Source:** BGR, [http://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/TZ/Acsad/dss\\_fb\\_en.html?nn=1546392](http://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/TZ/Acsad/dss_fb_en.html?nn=1546392).

tool for integrated water resources planning. It provides a comprehensive, flexible and user-friendly framework for policy analysis. A growing number of water professionals are finding WEAP to be a useful addition to their toolbox of models, databases, spreadsheets and other software.

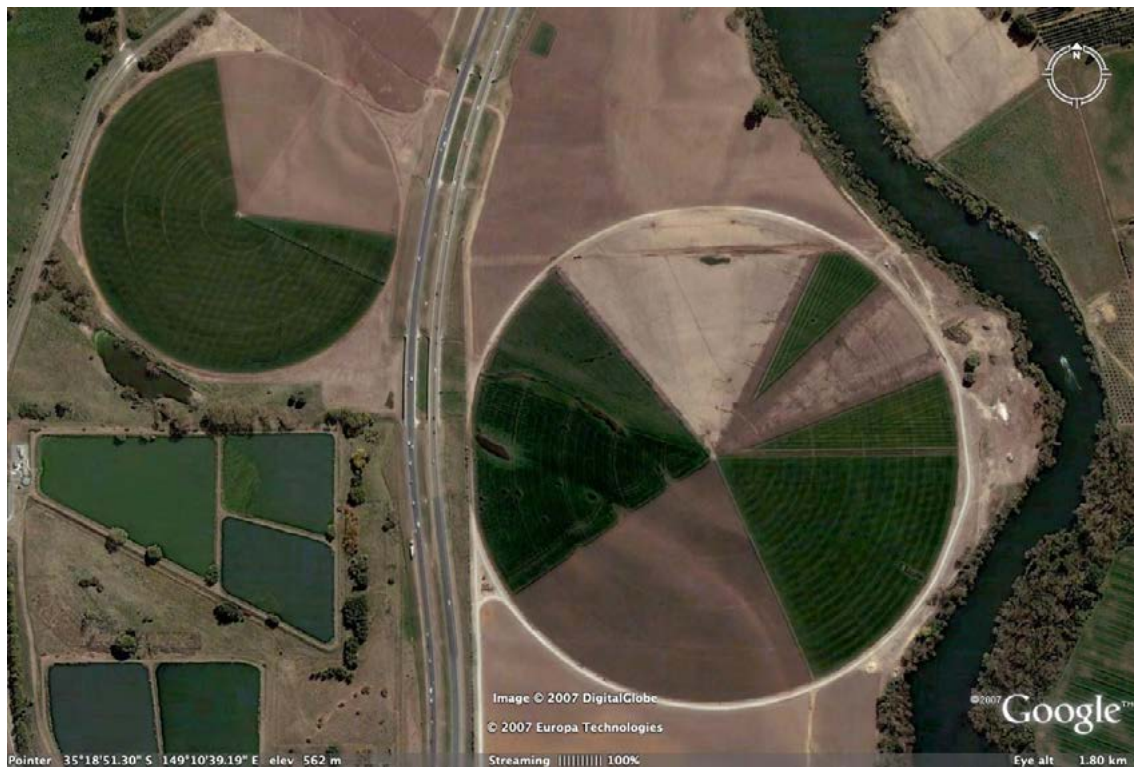
The WEAP approach operates on the basic principle of water balance accounting, and is applicable to municipal and agricultural systems, single sub-basins or complex river systems. Moreover, WEAP can address a wide range of issues, such as sectoral demand analyses, water conservation, water rights and allocation priorities, rainfall run-off and baseflow, groundwater and stream flow simulations, reservoir operations, hydropower generation, water quality, ecosystem requirements, and project benefit-cost analyses (figure 12).

Databases are indispensable for efficient and reliable water planning. The FENIX Platform is an internet-based and scalable system able to meet different user requirements and adaptable to support global, regional and national level projects and initiatives. The main goal is to contribute to creating a global data sharing network for agriculture and food security by establishing a scalable system integrating many different data sources. FENIX is one of the products of FAO that adheres to the Open Data Initiative and is designed to avail data and technologies to anyone as “public good” using free, open-source software and providing data at no cost.

## Water supply and demand options

In chapter 2, the projected future water demand was sketched. For the year 2050, World Bank experts anticipate a water deficit of about 200 km<sup>3</sup>/year in the Arab region. Which options are given to close the gap between future water demand and supply?



**Figure 13.** Pivot irrigated areas

Source: Google Earth (ACSAD).

- Demand management: It is heading for a decrease in water use, such as by (a) education and training; (b) water pricing and other economic measures; and (c) making use of technical options. An overview on these technical options is given in figure 14.
- Supply management: It tries to increase the available quantity of water by making best use of all sources of water in reach, such as (a) surface water of permanent rivers or ephemeral streams (wadis); (b) groundwater sources; (c) rainwater and overland flow; (d) atmospheric water (fog and dew); and (e) unconventional water such as wastewater, drainage water, brackish water and seawater, and virtual water (figure 15).

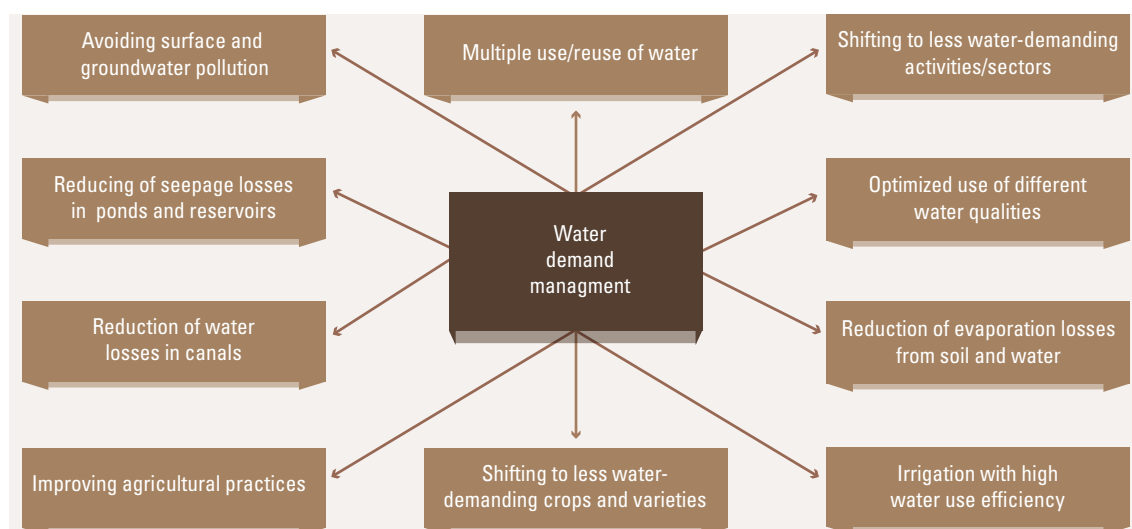
### The potential of remote sensing (including Google Earth) in CCA

Remote sensing can provide data to help identify and monitor crops. When these data are organized in a geographical information system (GIS) along with other types of data, they become an important tool that helps in making decisions about crops and agricultural strategies.

National governments can use remote sensing data and related technologies such as GIS to make important decisions about the policies they will adopt, or how to tackle national issues regarding agriculture. Individual farmers can also receive useful information from remote sensing images, when dealing with their individual crops, about their health status and how to deal with any problems.



**Figure 14.** The most important elements of water demand management in the agricultural sector to combat the impacts of climate change



Source: Prinz, GIZ.

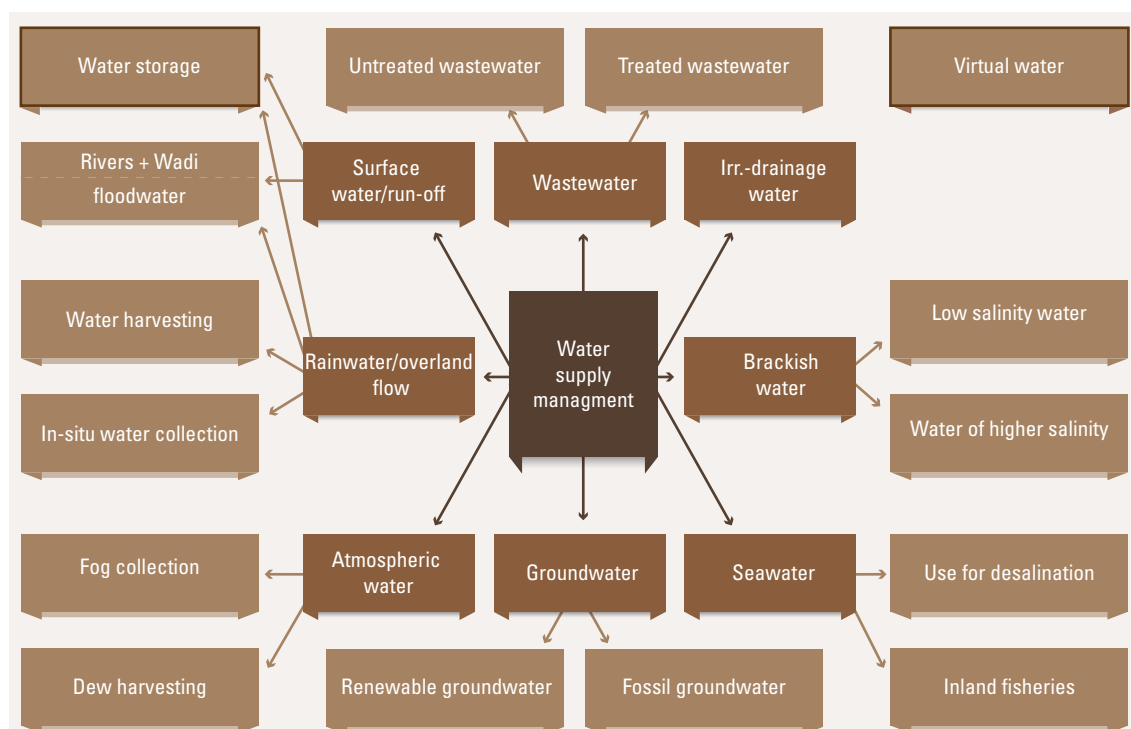
Remote sensing and GIS can be used for a variety of applications in agriculture, such as:

- **Monitoring crop status:** Plants have a particular way to reflect the electromagnetic radiation. When a plant is stressed, it usually expresses certain visible symptoms, but also some that are not visible to the human eye.
- **Crop yield estimation:** Having information on potential crop yield at an early stage, is very beneficial for the farmer, but also for countries that rely heavily on agricultural production, to satisfy the national needs for the crops and also for income through exports.
- **Crop identification:** By observing the various kinds of crops, it is possible to map the boundaries of the fields. Mapping of the boundaries of land parcels provides information for the creation of cadastral maps. Cadastral maps are usually in a vector format and can therefore be used in a GIS system, along with other types of data (ownership, crop types cultivated, etc.). These can be used by the local and national authorities, to estimate how much land is used for agriculture, and how much area is used for the cultivation of each crop.

With its high-resolution images, Google earth is a powerful tool for crop identification and provides digitizing tools allowing users to digitize features and export them for use in GIS and other systems, thereby benefiting from an integrated technology platform (figure 13).

## Adaptation measures: water resources

Adaptation to climate change in the framework of IWRM means making full use of the potential of the various water resources in an integrated way (table 5). The volumes of the various water resources available per capita or per country and other important water features are available from the FAO AQUASTAT website: [www.fao.org/nr/water/aquastat/dbases/index.stm](http://www.fao.org/nr/water/aquastat/dbases/index.stm).

**Figure 15.** Tools for water supply management

Source: Prinz, GIZ.

**Table 5.** Overview of the various types of water resources available for agriculture**Floodwater for GW recharge in Saudi Arabia**

Photo: Al Torbak, 2011.

**Groundwater**

Measures to reduce a further lowering of (renewable and fossil) groundwater (GW) levels are: (a) GW recharge of surplus water during the rainy season; (b) GW recharge of floodwater, collected in large basins; (c) construction of percolation dams; (d) quota, licenses etc. to limit GW extraction; and (e) water demand management.

Readings: Margane, 2003.

**Pumping station at the Nile river**

Photo: Prinz.

**Surface water**

Most permanent rivers in the Arab region cross borders and any increase in extraction fuels disputes between riparian states. Therefore a higher water use efficiency in agriculture (and a lowering of urban water demand) is needed, which can be achieved by (a) better awareness and professional training of farmers; (b) support of farmers to have access to (affordable) loans for investments; and (c) a functioning agricultural extension service, etc.

Readings: Immerzeel et al., 2011.



### Fog collection



Photo: Prinz.

### Wastewater stream



Photo: Prinz.

### Choked irrigation canal

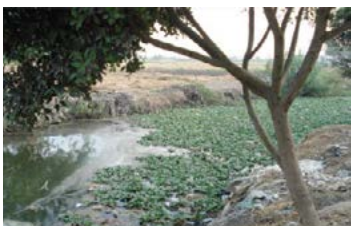


Photo: Dalia Gouda, ACCWaM.

### Fossil hot water of low salinity in Tunisia



Photo: Prinz.

### Shrimps cultivation



Photo: Herman Gunawan.

## Atmospheric water

Fog collection (with fog nets or three-dimensional collectors), dew harvesting and cloud seeding are the options, if the physical preconditions are met. In Saudi Arabia, Yemen, Oman and Morocco good results were achieved with fog collection. In Oman for example, up to 50 liters per m<sup>2</sup> per day were collected during the monsoon season. The costs are relatively low, but maintenance is often a problem.

**Readings:** Al-hassan, 2009; Lekouch et al., 2012.

## Wastewater

Only in rare cases is untreated wastewater safe to be used in agriculture or forestry. Wastewater (of domestic origin only) should have passed at least an oxidation pond for treatment. Higher treatment levels are fitting better with WHO guidelines, but nutrient levels become lower. Wastewater application for drip irrigation often faces the problem of clogging unless high level filtration is applied.

**Readings:** WHO, 2006; Drechsel et al., 2010; Hamdi, 2011; Abdel-Dayem et al., 2012.

## Irrigation drainage water

The use of drainage water might supplement available good quality water resources when in short supply. However, harmful effects on crop production, soil productivity and water quality have to be minimized. Sewage discharge into the drainage canals has to be avoided to allow drainage water reuse. Its quality determines which crops can be irrigated.

**Readings:** Tanji and Kielen, 2003. See case study on the ACCWaM Pilot Study "Enhancing the Overall Efficiency."

## Brackish water

Brackish groundwater differs strongly in its salinity level. If the salinity level is higher than tolerable by the crop to be irrigated, fresh water is mixed with it. Some crops with a certain salt tolerance have got sensitive stages. During these stages they are irrigated with good quality water and with brackish water at other times. Irrigation with brackish water leads to salt accumulation in the soil, which has to be leached regularly.

**Readings:** JVA and GTZ, 2003.

## Seawater

Seawater, as well as brackish water, can be taken for desalination, preferably using solar radiation as energy source. Brine disposal remains an environmental hazard. Costs for reverse osmosis desalination are still too high for most agricultural crops. Seawater as well as brackish water can be used for aquaculture of sea fish species as well as shrimps and prawns. As species differ considerably in their preferred salinity level, selection has to be based on salinity level of the available water resources.

**Readings:** Schäfer and Richards, 2007; Trieb, 2007.



**Figure 16.** Using treated wastewater and sludge in some ACSAD pilot projects

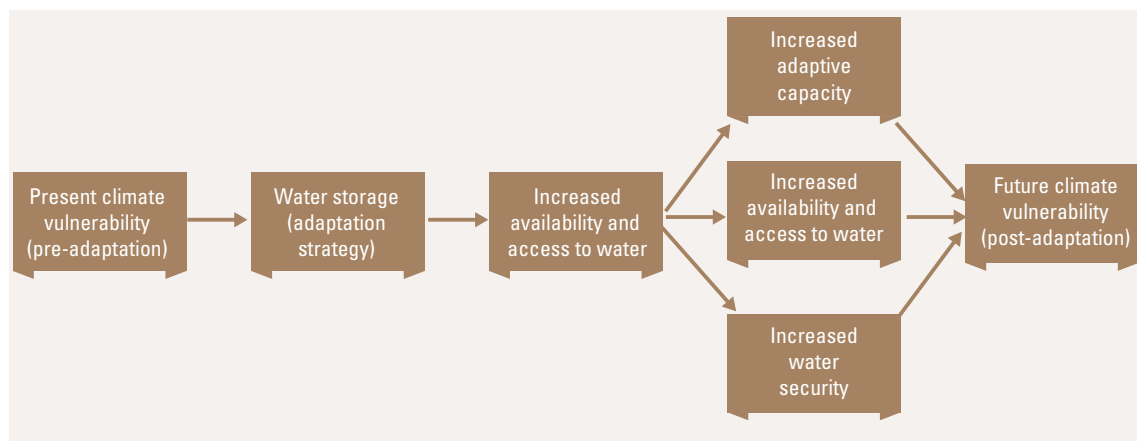
Source: ACSAD.

One impact of climate change will be the incidence of higher rain intensities. To avoid excessive soil moisture, more drainage facilities have to be provided. Excess water, if not infiltrating (and eventually recharging) groundwater has to be collected and stored for later use. Soil and water conservation measures will become even more important in future.

It is likely that run-off will decline under climate change impacts, and that groundwater recharge will do likewise. Decreasing run-off will affect salinity by reduction of dilution flows, while lower rainfall and reduced surface water availability will result in less salt leaching and higher salt accumulation in soils (FAO, 2011c).

Climate change measure (if sufficient water of good quality is available): Leaching the agricultural area to leach the salts and to restore soil quality must be applied every one to two years. Leaching could be performed by flood or sprinkler irrigation but not by drip irrigation, as it needs to cover the whole area and not just part of it.

The annex provides an exercise (exercise 1: Dealing with sea level rise and seawater intrusion in a densely-populated river delta) looking at how to deal with seawater intrusion and polluted irrigation water in the Nile delta, and possible changes in land use and production and the different roles/actions to be undertaken by various stakeholders.

**Figure 17.** Water storage as an adaptation strategy to reduce climate variability

Source: McCartney and Smakhtin, 2010.



## Adaptation measures: water storage and quality aspects

### Water storage aspects

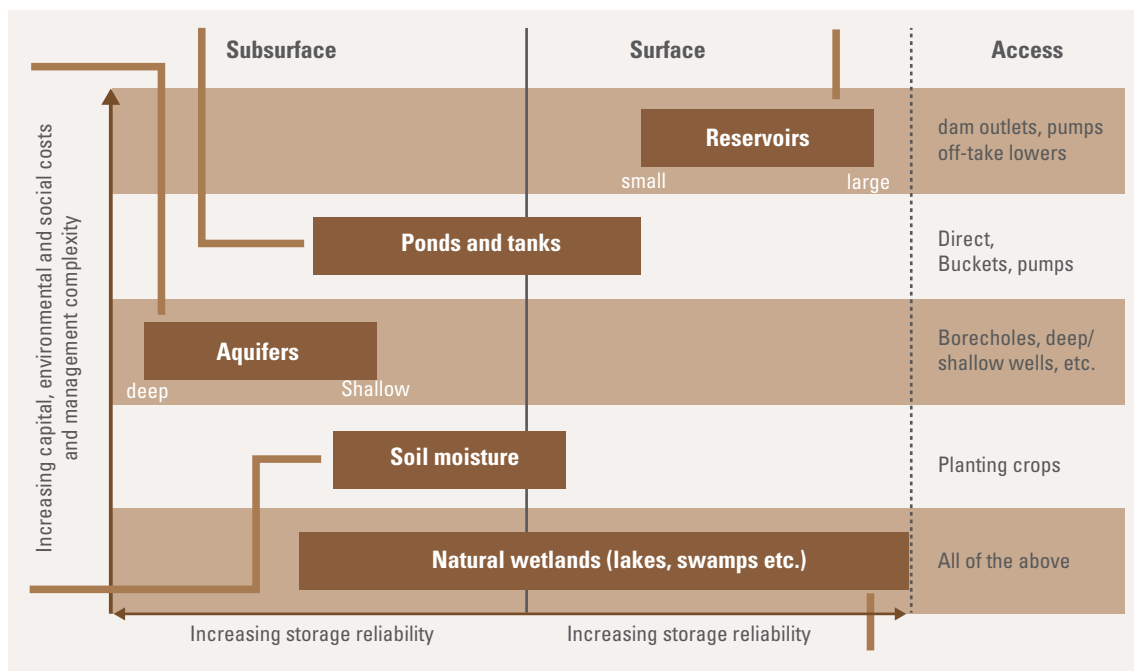
The impacts of climate change demand more water storage in rural areas. Water storage allows a bridging of dry spells during the rainy season and a prolongation of the cropping period into the dry season (Van Steenberg and Tuinhof, 2009). To balance the increasing inter-annual variation of rainfall, larger reservoirs or underground storage (groundwater recharge) are feasible options. Storing water underground avoids evaporation losses, but a sound geological exploration is needed to avoid failures. Salt lenses in the selected geologic stratum may render good quality water injected useless.

Groundwater recharge includes pumping surface water directly into an aquifer and/or enhancing infiltration by spreading water in infiltration basins. Water storage (in all its forms) plays a key role for sustainable development, poverty reduction and adaptation to climate change. By providing a buffer, water storage reduces risk and offsets some of the potential negative impacts of climate change, thereby reducing the vulnerability of people. Water storage can enhance both water security and agricultural productivity (figure 17). However, all water storage options are also potentially vulnerable to the impacts of climate change (McCartney and Smakhtin, 2010).

In adapting to climate change, careful attention must be given to the full continuum of physical water storage from aquifers, through soil moisture, small tanks and ponds to small and large reservoirs (IWMI, 2009; figure 18).

The case study on rooftop water harvesting for greenhouse production in the mountains of Lebanon describes a project carried out by the Green Plan agency, where rainwater is

**Figure 18.** The continuum of water storage options



Source: IWMI, 2009.

### **Case study.** Rooftop water harvesting for greenhouse production in the mountains of Lebanon

In areas with at least 250 mm/year a rainfall, harvesting the run-off from the greenhouse roofs and utilizing the water within the greenhouse is a viable option practiced in many Arab countries.

In the mountains of Lebanon, there is a high potential for production of flowers and vegetables in greenhouses, but water supply is a problem.

**Rainwater from greenhouses is stored in ponds to be used for irrigation in other greenhouses**



Already decades ago, farmers started catching rainwater but the rainy season (in winter) does not correspond with the season of highest demand. Storing water in ponds is difficult due to the karstic underground.

The Green Plan agency, an autonomous authority under the Lebanese Ministry of Agriculture (and partially financed by international donors) started a programme in the Lebanese mountains to enable farmers to catch the unpolluted rainwater from plastic greenhouses and to store it in ponds.

The ponds are lined with PVC sheets and geo-textiles to avoid percolation losses. The pond water is flowing by gravity into other greenhouses slightly below the pond location and is used there by applying drip irrigation. Average greenhouse area per farm is 3500 m<sup>2</sup>; pond size is 1700 m<sup>3</sup>; expected lifetime of the pond: 7-10 years.

Green Plan experts develop together with interested farmers technical and financial development plans for their enterprises. Farmers receive soft loans and subsidies; the progress is documented. The farmers contribute only between 18 and 39 per cent of the total costs and receive soft loans (annual 1 per cent interest rate) for it. A drawback for wider application is the limited availability of government funds.

**Source:** Republic of Lebanon (2012). Hilly Areas Sustainable Agricultural Development (HASAD). Project Design Report. Prepared by IFAD. Beirut, Lebanon, [www.greenplan.gov.lb](http://www.greenplan.gov.lb).

harvested from greenhouse rooftops and stored in large, lined ponds for later use. The same agency is famous for its 'hill lake programme' in Lebanon.

Nevertheless, while water storage may prove to be a viable adaptation measure in certain situations, there are biophysical risks associated with climate change in regard to various storage types that need to be considered by stakeholders (table 6).

The various modes of water storage, their characteristics and possible CCA measures are given in table 7.

Where very high intensity events (extreme events) are likely, it may not be possible to capture adequate proportions of the peak flows with available or affordable infrastructure and new sites for reservoirs will be difficult to find and very expensive to develop.

In order to deal with increasingly intensive storm events, stronger and more sophisticated spillways will be needed (FAO, 2011c).

**Table 6.** Storage types and relevant biophysical risks associated with climate change

Storage type	Possible biophysical risks associated with climate change
<b>Reservoirs, ponds and tanks</b>	<ul style="list-style-type: none"> <li>• Reduced inflow, resulting in longer periods between filling</li> <li>• Higher evaporation, increasing the rate of reservoir depletion</li> <li>• Infrastructure damage as a result of higher flood peaks</li> <li>• Improved habitat for disease vectors (such as mosquitoes)</li> <li>• Increased risk of eutrophication and salinization</li> <li>• Increased siltation</li> </ul>
<b>Soil moisture</b>	<ul style="list-style-type: none"> <li>• Reduced infiltration resulting from modified rainfall intensities</li> <li>• Waterlogging resulting from modified rainfall intensities and duration</li> <li>• Longer dry periods resulting from altered temporal distribution of rainfall</li> <li>• Depleted soil moisture arising from higher evaporative demand</li> <li>• Soil erosion resulting from modified rainfall intensities and duration</li> <li>• Reduced soil quality (including water holding capacity and nutrient status) resulting from modified rainfall and temperature</li> </ul>
<b>Aquifers</b>	<ul style="list-style-type: none"> <li>• Reduced recharge resulting from modified rainfall intensities</li> <li>• Reduced recharge resulting from land-cover modification and increased soil moisture deficits</li> <li>• Saline intrusion in near-coast aquifers</li> <li>• Increased percolation through frequent flooding</li> </ul>

Source: IWMI, 2009.

**Table 7.** Storage types, their characteristics and possible CCA measures

Photo: Prinz.

### Soil moisture

Soil storage capacity depends on soil type, soil structure and soil depth. In recent decades, in situ rainwater management techniques that enhance infiltration and water retention in the soil profile have found more interest. Soil and water conservation (SWC) techniques such as contour bunds, contour ditches and small basins keep the rainfall on the spot ('in-situ'). They are indispensable for CCA in agriculture and agriculture extension services should be well trained on SWC.

Readings: McCartney and Smakhtin, 2010.



Photo: Saher Khouri, ARIJ.

### Cisterns

Cisterns are constructed fully or partially subsurface and their capacity ranges from 10 to 1000 m<sup>3</sup>, or more. Modern cisterns are often built using reinforced cement concrete (see photo). Main problems of cisterns' use are maintenance and the right of water use. Beneficiaries should sign a contract on rights and duties (such as cleaning the sedimentation tank) prior to construction. Standard designs for future higher run-off should be available, adaptable to local needs. In general, a very important element of CCA.

Readings: Akhtar et al., 2009.



Photo: ACSAD.

## Ponds

Ponds fill by surface run-off from land, roads or (greenhouse) rooftops. A common limitation is that they are shallow. The even higher evaporation losses in future can be lowered by constructing deeper ponds with smaller surfaces. Covering the ponds (such as with white, ultraviolet resistant plastic sheets) could be another means to reduce evaporation. If technically feasible, the volumes of the ponds should be enlarged in order to catch higher run-off volume; siltation traps can reduce sedimentation.

**Readings:** Oweis et al., 2012.



Photo: ACSAD.

## Hafairs

Hafairs are either ponds in natural depressions or excavated tanks. They fill by surface run-off from hills and their sedimentation rate is normally high. To adapt them to climate change conditions. (a) the catchment area should be cleared to reduce sedimentation and to enhance water yield; (b) some lining could reduce percolation losses; and (c) a trough aside of the hafair could improve health conditions of the animals. As maintenance is a problem, arrangements with the beneficiaries are needed.

**Readings:** Oweis et al., 2012; Keller et al., 2000.

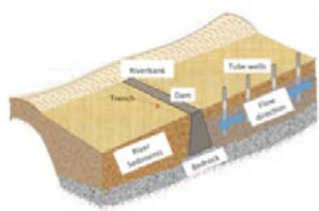


Photo: ACSAD.

## Reservoirs

Reservoirs are structures with water impounded behind small and large dams constructed across streams and rivers. They tend to be shallow with relatively large surface areas so that a significant proportion of the water may be lost through evaporation. The water is used for multiple purposes. Some large reservoirs provide multi-year carryover of water. In future, this function will become even more important than in the past.

**Readings:** FAO, 2001; McCartney and Smakhtin, 2010.



Drawing: Prinz.

## Subsurface dams

The groundwater flow within the wadi bed lasts for weeks after a rainfall event. Subsurface dams are built in wadi beds, but can be extended above the sediment level to facilitate infiltration. Advantages: very low evaporation, hardly any pollution, no breeding of mosquitoes and other disease vectors, low maintenance costs and long life. Preconditions are predominantly coarse sand and availability of expert knowledge. They are also well adaptable to climate change conditions.

**Readings:** Nissen-Petersen, 2006; RAIN, 2008.

## Water quality aspects

The smaller a water body, the larger is the impact of any contamination. Climate change-induced reduction of groundwater recharge as well as a drop in river flows or reservoir filling increases vulnerability to contamination.

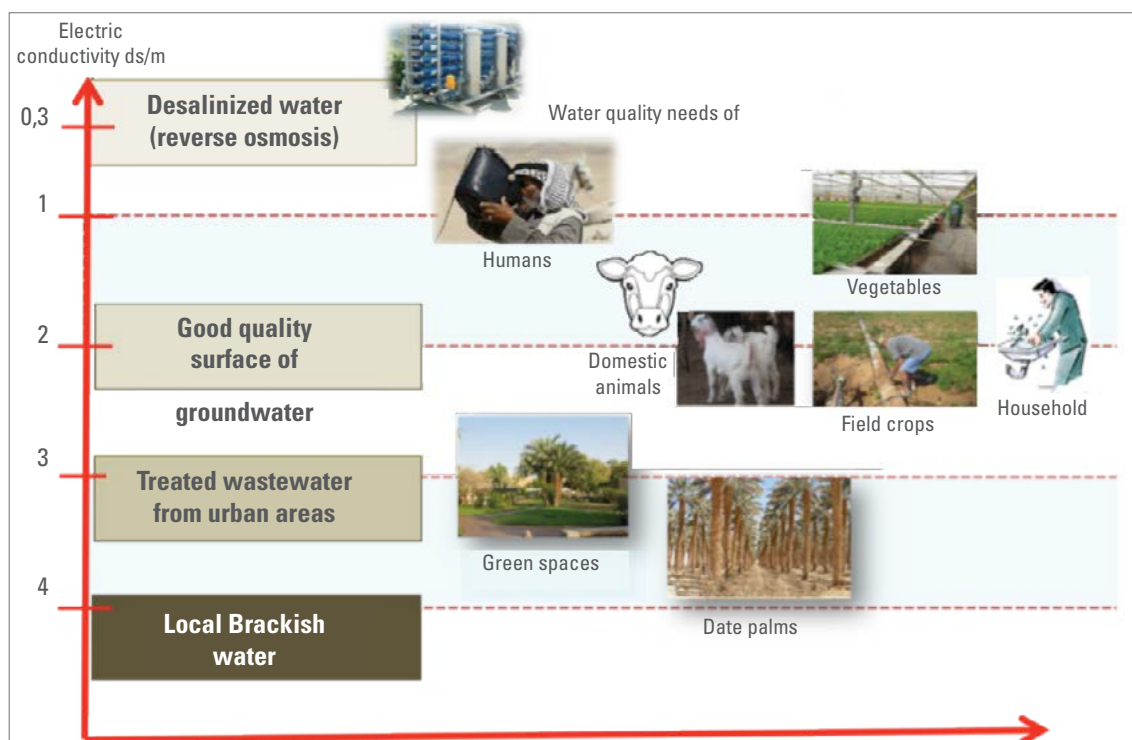




This asks for even stricter observance of all water protection rules and laws as follows:

- Human wastes need to be totally separated from any water source, such as by improving toilets (equipping them with septic tanks, etc.).
- Animal wastes should never run into nearby streams, but should be collected and used for crop manuring.
- New rural settlements should be equipped with a wastewater collection system and treatment plant.
- Filling stations in rural areas should be regularly controlled (in regard to fuel spilling) and their construction not be allowed in water extraction areas.
- Rural industries should not be located in water sensitive areas and should be supervised to ensure that they do not contaminate surface or groundwater. Their wastewater should be treated separately before being released and not mixed with wastewater from settlements (to allow the latter's use for irrigation). Water recycling should be promoted.
- Special care is needed when dealing with heavy metals, released in wastewater or exhaust gases. Their accumulation contaminates soil and water, damaging health of humans and livestock.
- Under water shortage conditions, water of drinking water quality should not be 'wasted' for other purposes, where a lower water quality can do. The various field and fruit tree crops and domestic animals differ strongly in their need/tolerance to water quality (in regard to salt content) and by blending the water sources, the needed/tolerable water quality can be provided (figure19).
- Develop the rural citizen capacities especially rural women on the pollution, causes of pollution, its resources and simple methods for protection and assure the good practices to prevent harmful practices.

**Figure 19.** Quality of various water sources (in regard to salt content) and water quality needs of people, domestic animals and crops in Arab countries (average values)



Source: Prinz, GIZ.

Jordan's food security in the face of limited water resources is the subject of an exercise in the annex (exercise 2: How to manage horticultural production in a desert area with marginal water sources). Different methods of water conservation, options for water resources, variations in horticulture, and management decisions regarding a possible production centre are addressed in the exercise.

## Adaptation measures: water harvesting

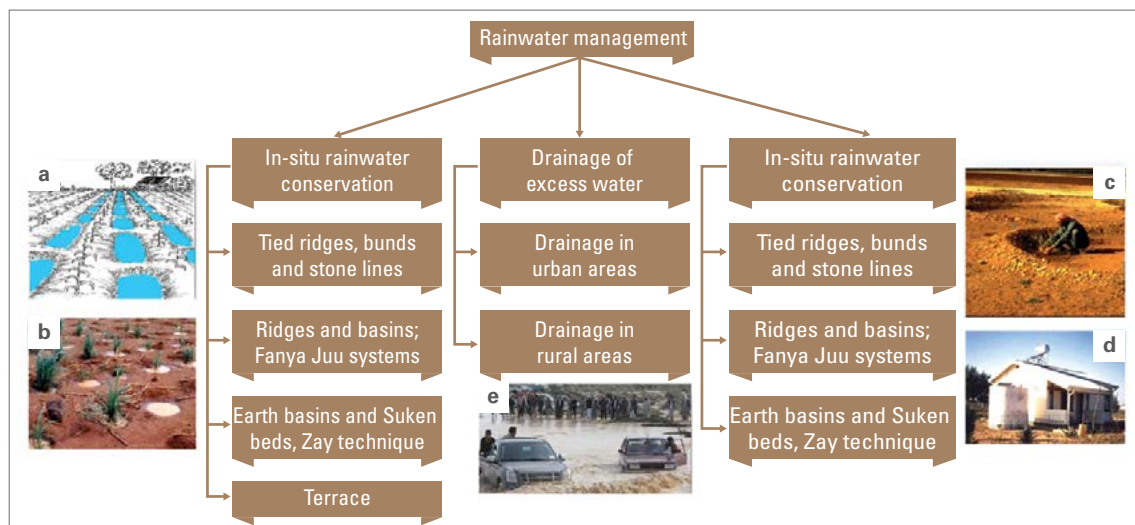
Rainwater is an under-utilized resource and should be included in any water resources planning effort in the Arab region. Rainwater, including overland flow, can be (a) used on-the-spot for agricultural use or recharge (in-situ rainwater management); or (b) collected, concentrated and stored for later uses (rainwater harvesting). These two modes of rainwater use can be complemented by drainage water use, i.e. the catching and intermediate storing of urban, periurban or rural run-off (figure 20).

In-situ rainwater management is part of soil and water conservation, covered in this section. The in-situ rainwater conservation techniques catch the rain where it falls and try to prevent any run-off.

Water harvesting is defined here as the collection and concentration of rainwater and run-off and its productive use for domestic and livestock consumption, for irrigation of annual crops, for pastures and trees and for groundwater recharge. Rainwater harvesting has a long tradition in Arab countries. Oweis et al. (2004) provide an overview of indigenous water harvesting systems in this region.

The basic principle of agricultural water harvesting is to capture precipitation falling on one part of the land and transfer it to another part, thereby increasing the amount of water available to the latter part. Therefore, the main components of any water harvesting system are: (a) the run-off area (catchment); (b) the storage medium (such as soil, cisterns, ponds, reservoirs or aquifers); and (c) the target, i.e. the user of the harvested water.

**Figure 20.** Methods and techniques of rainwater management



(a) SWC-technique tied ridges (photo: Prinz); (b) Zay technique (photo: Prinz); (c) water harvesting technique semicircular bunds (photo: Oweis); (d) rainwater harvesting from rooftop (photo: IRIN); (e) flash flood in Egypt (photo: IRIN).



Rainwater harvesting can be a valuable tool in buffering the impacts of climate change. More water stored in the soil matrix can bridge longer gaps between rainfall events. Rainwater stored in cisterns, ponds or reservoirs can be used for supplemental irrigation during dry periods, particularly at critical plant growth stages. Rainwater harvesting can also mitigate urban flooding, when rooftop and courtyard water harvesting is practiced at a large scale in urban areas or when overland flow in upstream areas is harvested and stored.

Water harvesting application has shown promising results in reducing production risks and improving crop yields, and in pasture regeneration. For CCA, the focus should be on increased water storage and supplemental irrigation of crops.

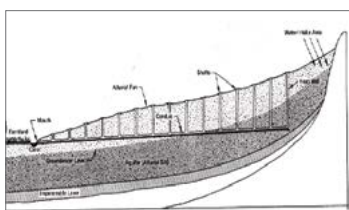
The term water harvesting covers (a) groundwater harvesting, i.e. using groundwater without lifting; (b) rainwater harvesting, i.e. collecting overland flow; and (c) floodwater harvesting. Table 8 compiles information on the various water harvesting methods and possible CCA measures. In rainwater harvesting there is a distinction between microcatchment and macrocatchment water harvesting, depending on catchment size. Within each water harvesting method there are numerous techniques available, fitting to different slope angles, soil depths and other environmental conditions (Prinz, 2014b).

Climate change impacts the application of rainwater harvesting (RWH) by:

(a) shifting the application belts of RWH methods synchronously to the shifting of the ecological belts; and (b) altering the application of techniques, the physical structures and the kind and volume of water storage to fit to the altered climatic conditions.

**Table 8.** Overview of water harvesting methods and relevant CCA measures

### Groundwater harvesting: Qanat/Foggara systems



**Description:** A Qanat is a horizontal tunnel that taps underground water in an alluvial fan without pumps or equipment and brings it to surface. Qanat tunnels have an inclination of 1-2 % and a length of up to 30 km. Qanats can yield substantial quantities of water (5-60 l/s). However, many qanats have fallen dry due to a lowering of the groundwater table caused by tubewell installations.

**CCA measures:** Limiting the number of tube wells to avoid a (further) lowering of groundwater table; initiating the construction of contour ditches and bunds (at the lower side) in the catchment area to facilitate infiltration; and investing in their maintenance.

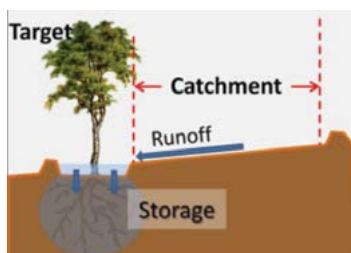
### Rooftop and courtyard water harvesting



**Description:** Rooftop and courtyard water harvesting (WH) describes installations on and around buildings to facilitate rainwater collection. Uses: drinking water / domestic water, irrigation (such as in greenhouses) or for groundwater recharge. In a wider sense, the harvesting of water from roads, bridges, parking lots and other sealed surfaces in urban environments are covered by this technique too.

**CCA measures:** Larger tanks for water storage to bridge dry spells. Incentives are needed to equip as many buildings in cities as possible with WH devices to secure water supply and to avoid floods by stormwater.

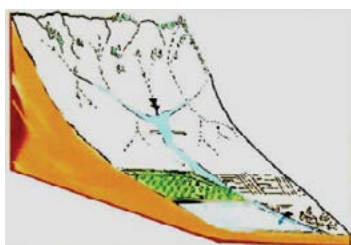




### Microcatchment water harvesting

**Description:** Microcatchment water harvesting is a method of collecting surface run-off (sheet or rill flow) from a small catchment area and storing it in the root zone of an adjacent infiltration basin. The basin is planted with a single tree or bush or with annual crops. The size of a catchment varies between 2 m<sup>2</sup> and 1000 m<sup>2</sup>, and the ratio between catchment area and cropping area (CCR) from 1:1 to 25:1.

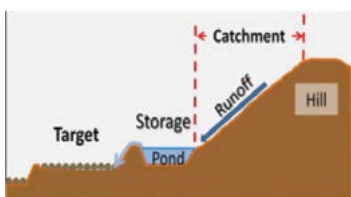
**CCA measures:** Higher rain intensities and more erratic rainfall will demand (a) application of more soil conservation measures within and around the microcatchments; (b) raised and strengthened bunds; (c) trees to be planted on steps to avoid waterlogging; (d) perpendicular bunds in contour systems to avoid break of contour bunds; and (e) increased soil depth for more water storage capacity.



### Macrocatchment Water Harvesting

**Description:** This method is also called “water harvesting from long slopes” or “harvesting from external catchment systems”. Run-off from hillslopes is conveyed to the cropping area located at the hill foot on flat terrain. Normally, the collected water is stored in the soil. Alternatively a pond or a small reservoir may catch the run-off and store it for supplemental irrigation, either during long dry spells within the rainy season or to prolong the growing season. The size of catchment areas varies between 0.1 ha and 200 ha and the flow type is ‘turbulent run-off’. The CCR is between 10:1 and 100:1.

**CCA measures:** (a) Stronger diversion structures; (b) raised and strengthened bunds; and (c) provision of more water storage in ponds for supplemental irrigation.



### Floodwater harvesting (spate irrigation)

**Description:** Floodwater harvesting systems require more complex structures of dams and distribution networks, and a higher technical input than the other two water harvesting methods. The size of the catchment area is greater than 200 ha and the flow type is a channel flow; complex structures are needed. The CCR varies between 100:1 and 10,000:1; precipitation varies from 100 to 400 mm/year and the cropping area is terraced or in flat terrain.

**CCA measures:** Adaptation to more/larger floods can be achieved by (a) increasing size of structures for water diversion; (b) enlarging the impoundment; or (c) designing larger/stronger spillways to evacuate excess water.

As the ecological belts, defined by their rainfall and temperature characteristics, are shifting, synchronously the belts where grazing or rainfed cropping are feasible will shift too. Areas that have been marginally suitable for grazing will become desert (a process, which has been taking place since decades due to overgrazing). Areas marginally suitable today for rainfed agriculture will become grazing areas and so forth. The application zones of the various RWH methods will move with the relevant ecological belt.



### Case study. Using Google Earth to optimize water harvesting for agriculture

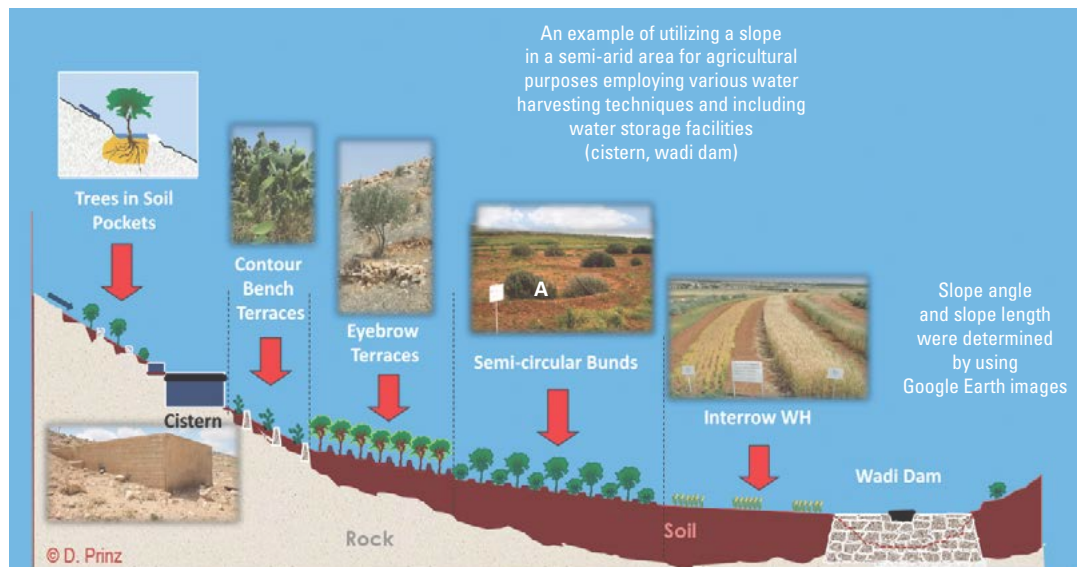
Water experts agree that the importance of water harvesting, i.e. the collection and concentration of rainwater and overland flow/run-off, will rise with the growing impacts of climate change. However, planning water harvesting schemes in rural areas with limited or unreliable topographic data is difficult. The use of the services of Google Earth can facilitate the planning and implementation of water harvesting for agricultural purposes. A project in the West Bank, Palestine, located in Tammun (Tubas Governorate) and Al-Dahriya (Hebron Governorate)

#### Google Earth image overlaid by slope



offers a good example. The project was a collaboration between the USAID-funded 'Middle East Water and Livelihoods Initiative', the International Center for Agricultural Research in the Dry Areas (ICARDA) and the Applied Research Institute – Jerusalem Society (ARIJ) in Bethlehem. Financial means were donated by the German Government (BMZ).

Water harvesting is just one element of the project, but an important one to stabilize crop yields, to produce more fodder for livestock and to store more water for crops, people and domestic animals. Google Earth is a free-of-charge remote sensing tool, well-suited to determining slope length, slope angle, watershed areas and position of structures serving soil and water conservation and water harvesting.



**Source:** Saher Alkhouri, MSc., Research Associate, the Applied Research Institute – Jerusalem Society (ARIJ), West Bank, Palestine, website: [www.ARIJ.org](http://www.ARIJ.org), email: [skhouri@arij.org](mailto:skhouri@arij.org).

Technically, the impacts of climate change have to be met (a) by an increasing the catchment area; (b) increasing run-off coefficients on catchment areas; (c) achieving a higher water use efficiency (such as using an efficient water supply system, cultivating crops in greenhouses, keeping other growing conditions (for example, soil fertility) at high level, covering the soil (with plastic or organic mulch etc.); and (d) by increasing in storage volume.

Higher rain intensities and more erratic rainfall require several measures, including a larger catchment-to-cropping-area ratio and a strengthening or raising of water harvesting structures (bunds, dams, walls, etc.).

In their 2013 publication entitled “Water Harvesting: Guidelines to Good Practice”, Mekdaschi Studer and Liniger compiled hundreds of case studies on water harvesting projects worldwide, demonstrating the wide range of effective application of water harvesting techniques.

Regarding the economy of water harvesting interventions, the World Overview of Conservation Approaches and Technologies arrived at the following conclusion in its publication on WOCAT Database: Technologies: “In the short term, costs can be higher than the benefits even though in more than one third of the cases benefits are already perceived to be positive to very positive in the first years. In the long term, the benefits strongly outweigh the establishment and maintenance costs. Macrocatchments may require higher establishment and also maintenance costs, due to more demanding engineering structures.” (WOCAT, 2012, p. 15.)

## Adaptation measures: rainfed farming and general issues of crop production

Most Arab countries’ food production happens in rainfed areas: nearly 83 per cent of seasonal crop areas are rainfed (table 9). The total rainfed area of seasonal crops was more than 35 million hectares in 2011, while the irrigated area of seasonal crops was 7.9 million hectares in size. In addition, there are more than 5 million hectares of permanent crops in rainfed areas and nearly 3 million hectares under irrigation. Most farmers in rainfed areas are smallholder farmers, and agriculture and/or herding are the main sources of their livelihoods (FAO, 2011c).

The contribution of rainfed farming to food security in Arab countries can be substantially enhanced through increased adoption of currently available technologies supported by enabling policy and institutional environments (Khouri et al., 2011). Rainfed farming can contribute more significantly towards new targets of food security if the desired investment levels are realized. On-farm results show the huge potential for improving land and water productivity and profitability of smallholder rainfed agriculture. On the other hand, rainfed farming will remain inherently risky, as rainfall will be even more variable and water demand will increase due to higher temperatures (FAO, 2011c).

### Techniques, crops and varieties

In all arid regions a major challenge is to manage water appropriately. The purpose of such management is to obtain water, conserve it, use it efficiently, and avoid damage to the soil. In arid areas, a decrease of 6 per cent in wheat yield is estimated against an increase of 1°C in seasonal average temperature. As the annual wheat production in the Arabic region is about 25 Million tons, the loss is then estimated at about 1.5 million tons of wheat per 1°C increase.

In addition, the increase in temperature and CO<sub>2</sub> and presence of humidity favour the growth of weeds, pests, fungi, viruses, bacteria and insects, which in turn harm the crop yield and in some cases increase the soil salinity. Wheat rust is another disease that threatens food security, and is considered a result of climate change (figure 21).

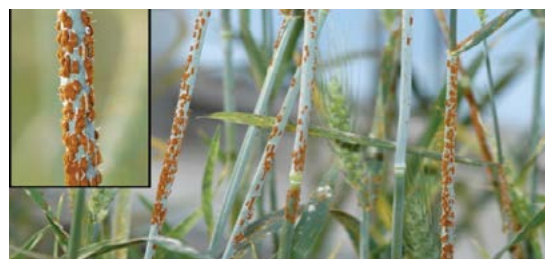
In order to face these problems, several programmes were launched by regional and international organizations such as ACSAD and ICARDA to develop varieties that are resistant to such diseases, and tolerant to drought and salinity. These new varieties are genetically modified seeds that give high yield values, stable productivity, salinity and drought tolerance and disease resistance. The main goals of these kinds of programmes are:

**Table 9.** Area of seasonal crops under rainfed cropping in Arab countries (percentage)

Country	2010	2011	Average
<b>Jordan</b>	67	69	68
<b>Tunisia</b>	83	83	83
<b>Algeria</b>	87	88	87.5
<b>Sudan</b>	92	93	92.5
<b>Syrian Arab Republic</b>	70	66	68
<b>Somalia</b>	86	86	86
<b>Iraq</b>	35	34	34.5
<b>Lebanon</b>	34	34	34
<b>Morocco</b>	87	79	83
<b>Yemen</b>	64	52	58
<b>Total</b>	83	82	82.5
<b>Additional useful startistics (million ha)</b>			
<b>Seasonal crops irrigated areas</b>	6.99	7.89	7.44
<b>Seasonal crops rainfed areas</b>	35.31	35.63	35.47
<b>Permanent crops irrigated areas</b>	2.69	2.96	2.82
<b>Permanent crops rainfed areas</b>	5.02	5.14	5.08

Source: Shideed et al., 2013.

1. Establishing a genetic bank for all the varieties that showed stable productivity and are fit to the environmental conditions of the Arab region.
2. Avoiding planting of water demanding and long-cycle varieties.
3. Focusing on early harvesting and fast filling grain period varieties.
4. Developing varieties that are resistant to yellow rust disease: temperature rise encourages the emergence of this disease, also in insect-resistant varieties.
5. Applying suitable crop rotations which aim at (a) timely weeding (weeds compete for crop nutrients); (b) maintaining soil fertility, including micronutrients; (c) applying crop protection, such as to prevent insect infestations; and (d) alleviating the need for nitrogen, such as by cultivating leguminous crops.

**Figure 21.** Importance of resistance to various pests and diseases for adapted varieties

Source: ACSAD.

### Improvement of wheat production in the Arab region

ACSAD implemented a project in several Arab countries that aims to improve wheat production under rainfed and irrigated agriculture to assure food security. Improved wheat seeds from ACSAD varieties were cultivated in the participant countries (Algeria, Jordan, Iraq, Lebanon, Libya, Morocco, Saudi Arabia, the Sudan, the Syrian Arab Republic and Yemen) in collaboration with the Islamic Bank for Development (IBD). Twenty-two varieties of soft and hard wheat were developed during the project, and 120 tons of these seeds were at the ACSAD research centre in Deir Elzour and were tested in the participant countries. The total cultivated area was 3,461 hectares, and the project was accompanied with a capacity-building programme for the technical and scientific staff involved in it.



**Source:** ACSAD (2015). The Annual Technical Report: For the Year 2015. Available at: [http://www.acsad.org/images/pdf/tqaryr/annual\\_report\\_en\\_2015.pdf](http://www.acsad.org/images/pdf/tqaryr/annual_report_en_2015.pdf) "

**Photo:** ACSAD.

### Cultivation and production of fruit tree cultivars adapted to drought

The Arab region is characterized by various types of fruit trees that are famous for their growth ability and adaptation in most of the region. These fruit trees are drought tolerant and can be adopted as alternatives to less tolerant species. Olive, pistachio, almond and fig trees are of big economic, social and ecological importance, and well known for their adaptation capacity in growing and producing in a poor marginal environment, and calcareous and sandy lands, where they can contribute in improving the environment, increasing the vegetation cover and fighting desertification. The environmental conditions in Arab countries are vary widely; therefore it is crucial to study the site conditions – especially meteorological conditions – before choosing tree species and varieties.

The tree species vary in their ability to withstand droughts:

- The drought tolerance of the almond tree comes from the ability of its root system to penetrate deep in the soil, seeking moisture, and its strong growth and ability to achieve water balance through dropping part of its leaves during severe heat;
- The pistachio tree can tolerate drought because of the waxy nature of its leaves, the thickness of its bark and its ability to produce roots that withstand shallowness of soil;
- The fig tree is considered more tolerant to drought and water deficits than any other tree because of its capacity to absorb moisture from the soil even if its water content is very low, because of its branched and deep root system. The tree shows positive response to regular irrigation through its fast growth and early fruiting and the good quality and quantity of the crop;
- The olive tree is characterized by its small, hard and evergreen leaves, which have small thorns. Its cracked bark helps it in adapting to large variations in temperature between summer and winter. In addition, its deep root helps in extracting more soil moisture (figure 22).

These trees offer many economic, ecological and social benefits, which can be summarized as follows:

- They show wide adaptability to the dry areas of the Arab region;
- Their cultivation in poor, marginal, calcareous land and saline soil is possible;





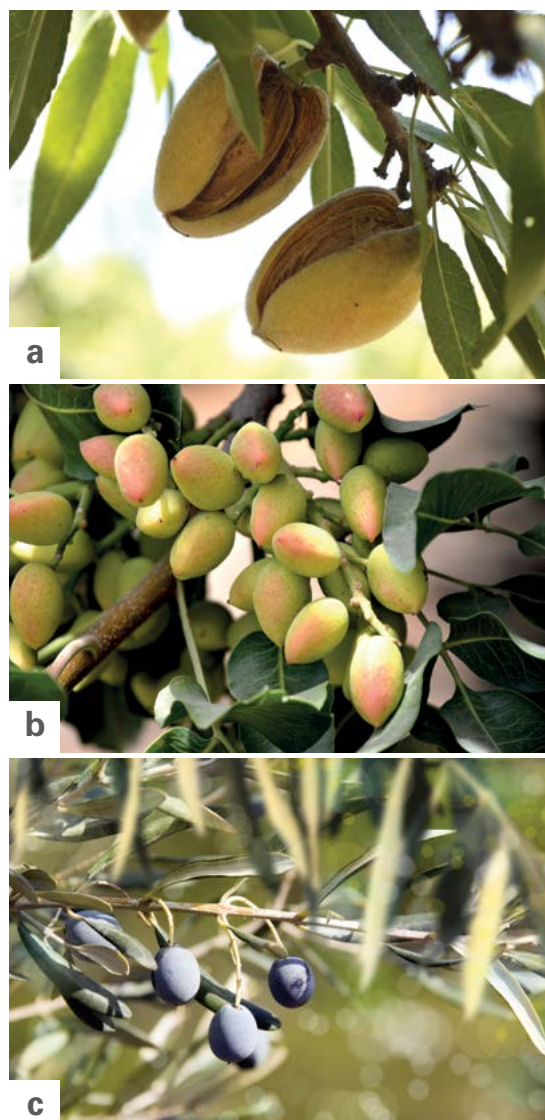
- Their fruits are highly demanded in Arab and international markets;
- The residues of pistachio and olive milling can serve as fertilizer or animal feed, and as a source of bio-energy;
- The application of the value chain approach in cultivation processes and fabrication provide for new job opportunities;
- These trees contribute to assuring food security in the Arab region.

## Conservation agriculture

Conventional agricultural practices such as intensive tillage and burning of residues have resulted in the degradation of soil resources and inefficient resource use. Conservation agriculture (CA) aims to achieve sustainable and profitable agriculture and subsequently to improve livelihoods of farmers through the application of three principles (FAO, 2011a):

- **Minimal soil disturbance:** ploughing operations are not practiced in CA. Moisture loss and soil compaction that follow tillage are avoided, infiltration and percolation of water through the soil increase are practiced instead, leading to better root development and crop growth;
- **Permanent soil cover:** This refers to mulch from crop residues, other organic mulch materials or living crops, including cover crops. The level of soil cover should ideally be 100 per cent of the soil surface, but never less than 30 per cent. Direct sowing is done through the soil cover;
- **Crop rotation:** Deep rooting cereal-legume combinations are preferred.

**Figure 22.** (a) almonds, (b) pistachios and (c) olives



**Source:** (a) Almond Tree, Ennira © Fotolia\_90065695  
(b) Pistachio tree, Ennira © Fotolia\_66633873  
(c) Olive tree File, jokerpro © Fotolia\_128950969

Climate resilience is directly linked to CA because of the short-term and long-term impact on crop water balance. In the short-term, the water balance is modified by increasing infiltration and reducing soil water evaporation due to the presence of crop residue. In the long term, the practice is to modify the infiltration rate, and to increase soil biological activity, soil organic matter and the water holding capacity. The retention of soil moisture results in less severe, less prolonged crop water stress and in an increased availability of plant nutrients and mitigation of temperature and rainfall variations caused by climate change (ACSAD and FAO, 2001; Ekboir et al., 2002).

In North Africa, no-tillage systems have been promoted, particularly in Morocco and Tunisia. In 2008, 4,000 ha of no-tillage have been reported in Morocco and 8,000 ha in Tunisia (FAO,

2011b). In West Asia, so far only in the Syrian Arab Republic there has been a significant adoption over some 18,000 ha, while Lebanon and Jordan are supporting pilot activities in CA (FAO, 2011b).

In their extensive review entitled “Conservation agriculture in the dry Mediterranean climate”, Kassam et al. (2012) describe the potential and the limitations of CA. Regarding a spreading of CA in Arab countries, they mention that:

- Low biomass production in drylands limits soil cover;
- There is acute competition between animal fodder needs and soil cover in the dry season;
- As CA is normally based on the use of machinery (figure 23), small farmers often need to rent machinery (direct seeders) from owners. This unavailability of low-cost CA equipment is hindering a further spreading of this type of farming. As one possible remedy, animal-drawn direct seeders are manufactured in India and Brazil;
- Weed control is more demanding and can be done mechanically or with herbicides;
- CA has not been introduced into irrigated agriculture to any significant degree in Arab countries although in Egypt, successful experiments were carried out in the Nile delta on irrigated rice-berseem-wheat cropping systems (FAO, 2008).

**Figure 23.** Tractor-mounted direct seeder sowing wheat into rice residues in Egypt



Source: FAO, 2008.

## Soil and water conservation

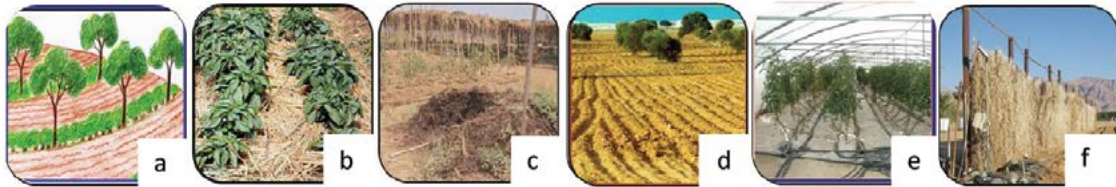
There are always strong links between measures for soil conservation and measures for water conservation, and in most cases, measures contain an element of both. When dealing with improved on the spot rainwater use, the term in-situ moisture conservation is often used. Its main aim is to minimize the run-off losses and to increase the available soil moisture for crop growth, which is of utmost importance when dealing with CCA in agriculture through maximizing the benefits of rainwater.

Soil and water conservation practice is broken down into two broad areas, namely agricultural/biological and mechanical measures. Agricultural/biological methods include:

- Improving crop husbandry: by correctly timing the sowing and harvesting;
- Improving crop selection: by using preferably short-cycle crops (such as millets), crops with deep root systems being low in water demand and crops with drought dormancy (such as *sorghum*);
- Contour cropping/farming: contour farming orients crop furrows following the contour lines of the farmed area, which reduces run-off. Contour farming was practiced by the ancient Phoenicians, and is effective for slopes of 2-10 per cent inclination. Contour ploughing can increase crop yields by 10-50 per cent, partially as a result of greater soil retention;
- Improving infiltration and water storage capacity of soil: organic mulching, applying farm yard manure and mineral fertilizer, conservation tillage or no-tillage (or ploughing-in of organic matter), removal of hard pans in the soil and legume-rich crop rotation help to increase organic matter content of soil. Rainwater infiltration and water retention in the soil matrix are improved accordingly;



**Figure 24.** Agricultural/biological methods of soil and water conservation: (a) contour farming (agroforestry); (b) organic mulch soil cover; (c) farm yard manure; (d) conservation tillage (Tunisia); (e) greenhouse production of tomatoes (Tunisia); (f) windbreak made of dry date palm leaves



Photos: Prinz.

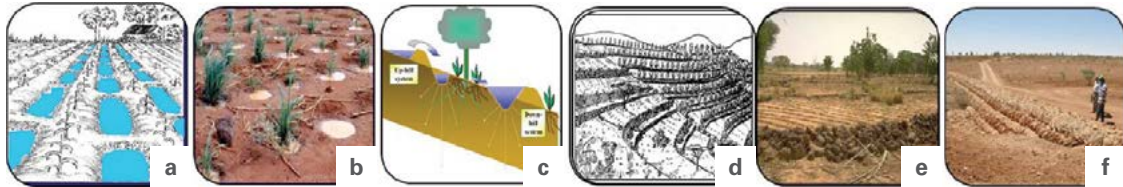
- Reducing evaporation from soil surfaces: surface mulching with organic material: (a) provides protective cover of soil surface; (b) reduces evaporation; (c) impedes weed growth; (d) improves infiltration; and (e) potentially reduces soil temperature. Possible disadvantages of organic mulches are: (a) problems of pest, disease, or nitrogen lock-up; (b) the lack of implements that can plant or drill through the mulch; and (c) organic mulches that are liable to be rapidly degraded in high temperature conditions. Plastic mulches reduce evaporation, too, and protect against heavy rains;
- Lowering transpiration losses of plants: this can be achieved by (a) shading the crop with shade trees (agroforestry); (b) cultivating crops in greenhouses or plastic tunnels; (c) regular weeding; or (d) reducing wind speed (wind may also cause mechanical damage to crops and erode fertile soils). The latter can be achieved by shelterbelts (lines of trees perpendicular to the direction of prevailing winds) and other types of windbreaks. Some useful tall species are the tamarisk *casuarina equisetifolia*, and *eucalyptus camaldulensis*. Drawbacks of a windbreak are however that they may also rob crops of light, water and nutrients. In addition, *casuarina* and *eucalyptus* have allelopathic properties. Thus, the advantages of a windbreak must be weighed against the disadvantages in any particular environment. Windbreaks can also be constructed out of dead organic or plastic materials (figure 24). Future higher wind velocities have to be taken into account when planning windbreaks. According to Rockstroem (2004), as much as 50 per cent of water use in rainfed cropping is lost as unproductive evapotranspiration, i.e. from bare soil evaporation, and transpiration losses of crops because of wind and weeds (FAO, 2011c).

Mechanical/engineering methods include:

- Minimizing run-off losses by constructing:
  - Tied ridges: a tied ridge system can double crop yields in dry areas, while simultaneously preventing soil erosion. The water storing capacity in a tied ridge system amounts to 40-70 mm;
  - Pits, furrows and basins: cultivating crops in (manured) pits (Zay system), in furrows, earth basins and sunken beds makes best use of rainfall by impeding run-off. Under high-rainfall conditions (and clay-rich soils), water logging may occur;
  - Bunds, ridges and combined ridge-ditch systems, such as Fanya Juu: these techniques hinder the flow of run-off and promote water retention in the field;
  - Terraces: it is the practice of creating either level or slightly inclined strips in a hillside area. Different types (such as bench terraces, conservation terraces and graded terraces) serve different purposes.



**Figure 25.** Mechanical/engineering methods of soil and water conservation: (a) tied ridges; (b) Zay (pit) system; (c) Fanya Juu/Fanya Chini system (ditch-ridge system); (d) conservation terraces; (e) stone lines in a wide valley; Zay technique is applied in between the lines; (f) check dam in a wadi (north-east Libya)



Photos: (a), (b), (c), (e), (f): Prinz; (d): Hurni.

- Reducing or slowing down overland flow in valleys and in wadis:
  - Stone lines, following contour, perpendicular to water flow in broad valleys;
  - Check-dams, preventing the widening and deepening of a narrow wadi, and assisting in filling it up with sediments. They reduce the velocity of run-off in the wadi (figure 25).
- Dealing with excess water: “Grassed water ways” channel and dissipate run-off through surface friction, impeding surface run-off and encouraging infiltration of the slowed surface water. Excess water not infiltrating has to be collected in ponds for later use or for groundwater recharge.

The above-mentioned methods and techniques are core elements of IWRM and future water management has to pay even more attention to them than is currently the case as effective CCA measures. Many of these measures will provide quick positive results, and it has long been recognized that conservation measures must have visible benefits soon after implementation for the farmer to accept such measures (Hudson, 1987).

## Supplemental irrigation

Shortage of soil moisture in the dry rainfed areas often occurs during the most sensitive growth stages of the crops. As a result, rainfed crop growth is poor and yield is consequently low. Supplemental irrigation (SI) may be defined as “the addition of small amounts of water to essentially rainfed crops during times when rainfall fails to provide sufficient moisture for normal plant growth, in order to improve and stabilize yields” (Oweis and Hachum, 2012). In addition to yield increases, SI also stabilizes rainfed crop production from one year to the other. The amount and timing of SI are scheduled not to provide moisture stress free conditions throughout the growing season, but to ensure a minimum amount of water availability, particularly during the critical stages of crop growth (see deficit irrigation), that would permit optimal instead of maximum yield.

Harvest results from farmer’s fields showed substantial increases in crop yield in response to the application of SI. The area of wheat under SI in the northern and western parts of the Syrian Arab Republic (where annual rainfall is greater than 300 mm) has increased from 74,000 ha in 1980 to 418,000 ha in 2000, an increase of 465 per cent. SI caused rainwater productivity in the north-west part of the country to increase from 0.84 kg of grain per  $m^3$  to 2.14  $kg/m^3$ . Similarly, for biomass water productivity, the obtained mean value was 3.9  $kg/m^3$  for deficit SI. In the Syrian Arab Republic, average wheat yields under rainfed conditions are only 1.5 t/ha, and this is one of the highest figures in the region. With SI, the average grain yield was up to 3 t/ha. In 1996, over 40 per cent of rainfed areas were



under SI and over half of the 4 million tons of national production was attributed to this practice. Supplemental irrigation does not only increase yield but also stabilizes farmers' production.

The irrigation water is in most cases applied by sprinkler irrigation, sometimes also by surface irrigation. Preconditions for SI are therefore (a) either the ownership or the chance to rent a movable sprinkler irrigation system; and (b) the access to groundwater or to some source of surface water.

## Adaptation measures: irrigated farming

### Water productivity and water use efficiency

Today, irrigated agriculture in the region is threatened by significant water stress. Climate change is worsening the situation even further. Insufficient water supply for irrigation will be the norm rather than the exception, and irrigation management will shift from production per unit area towards maximizing the production per unit of water consumed, the water productivity.

The term water productivity in irrigation indicates the efficiency performance of an irrigation system. It entails four components: storage efficiency, conveyance efficiency, distribution efficiency and application efficiency (on-farm efficiency). To know these efficiencies, it is useful to identify the sources of water loss, compare different irrigation systems and the best irrigation scheduling strategy, and analyse the water saving performance of irrigation systems and respective management.

The term water use efficiency can be defined as the ratio of the biomass produced by a plant to the water depth delivered to the plant (by rainfall or irrigation water), expressed in kg/m<sup>3</sup>. In agronomy a wider definition is often applied, where water use efficiency is the yield of useful biomass (such as grain) produced by a crop to the volume of water applied to the root zone of that crop during its life cycle.

The two indicators of water use mentioned above have the potential to be very useful for water resource planning and management at the farm and scheme levels. For farm irrigation, indicators for the uniformity of water distribution are still of great usefulness. Therefore, it is necessary to perform a rigorous analysis of on-farm water management practices and their possible improvements in order to develop a sustainable, efficient irrigated agriculture, which tends to preserve the environment through a more rational use of the scarce water resources (Karam et al., 2007).

### Irrigation methods and management

Traditional surface irrigation prevails in irrigated agriculture because it is low-cost, easily implemented and does not need skilled labour or advanced techniques. Modern irrigation systems comprise modern irrigation techniques (sprinkler and localized) and improved surface irrigation. A border system (basin and/or delimited flood irrigation) involves wetting almost all the land surface and is normally not an efficient irrigation method. Furrow irrigation does not wet the entire soil surface, and is still not considered an efficient irrigation method. However, if the water conveyance system consists of pipes instead of open canals, in such a way to deliver water into the furrows by means of gated pipes or siphons, the efficiency of the system could be improved.

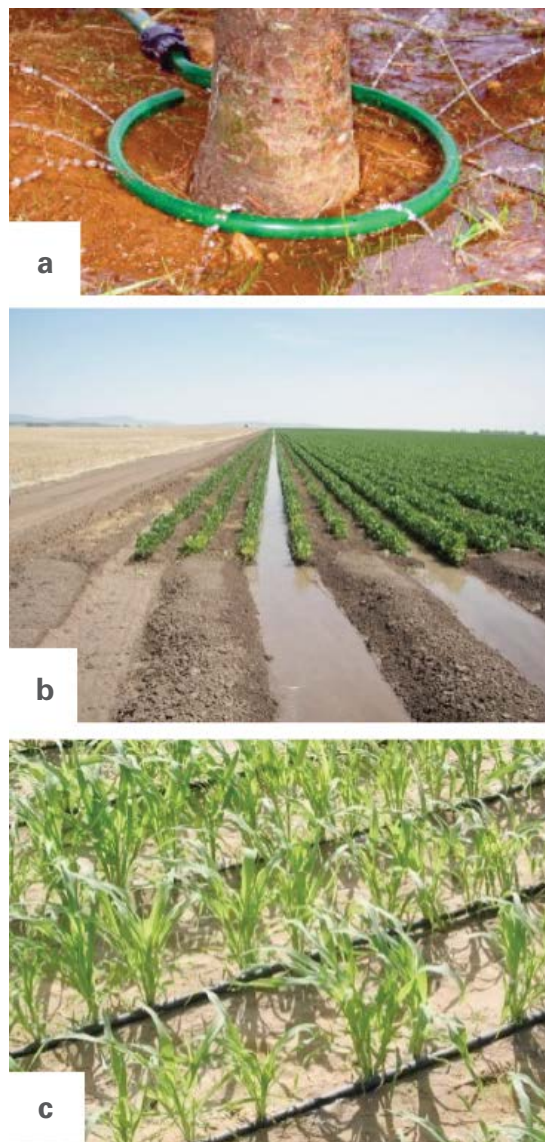
Due to its high application efficiency and distribution uniformity, drip irrigation has the advantage to be the most efficient technique because it irrigates more lands with less water volumes in comparison with other irrigation techniques. When a drip method is used, water is given directly to the root zone, and is not influenced by the climatic factors that increase water evaporation from the soil, as in sprinkler and surface irrigation. Moreover, drip irrigation tends to reduce weed development and control by restricting the wetted surface area to a small zone. Furthermore, drip irrigation requires less pumping pressure and energy cost in comparison with sprinkler and surface irrigation techniques. When initial investments are provided, drip irrigation seems to be more profitable to farmers and to the farming system (figure 26).

In traditional irrigation, total efficiency of water use is not more than 50 per cent, where the efficiency is expressed as the relation between plant water consumption for physiological processes and water withdrawal from the source. At scheme level, overall efficiency (storage and conveyance efficiencies) does not exceed 40 per cent. At farm level, water use efficiency, which includes distribution uniformity and application efficiency of the irrigation method, could vary from 50 per cent with surface irrigation techniques, to 70 per cent with sprinkler irrigation, to 85 per cent with drip irrigation. As mentioned, irrigation efficiency is related to all its components, and as such if it is possible to achieve a canal conveyance and delivery efficiency of 80-95 per cent, the irrigation efficiency figure will decline to 40-50 per cent or less under surface irrigation, which has several negative features including (Kaisi et al., 2007):

- Wasting a large portion of irrigation water in conveyance and delivery canals;
- On-farm irrigation water loss due to low field-irrigation application efficiency;
- Occasionally (such as in oases), a high water table level and soil salinity.

In general, drip irrigation might be the most suitable for arid and semi-arid regions such as the Arab region, especially under climate change conditions. In sprinkler irrigation, a considerable volume of water is lost by wind drift in windy places, so that undesirable plots are wetted, leading to high water waste. Under drip irrigation, such waste does not exist since water application is localized near the plant's stem. Water quality is of primary importance in the design, operation and maintenance programme of sprinkler and drip

**Figure 26.** Irrigation methods: (a) microsprinkler for tree irrigation; (b) furrow irrigation; (c) drip irrigation



Source: ACSAD.



systems; because clogging induces growths of slime and bacteria in the sprinkler head, emitter orifices or supply lines, as do heavy concentration of algae and suspended solids. The most serious clogging problems occur with drip irrigation systems. For this reason, suspended solids should be removed as much as possible before water reaches the drippers, using sand and screen filtrations (figure 27).

All plants need water to grow and produce good yields, but when plants are water stressed they close their stomata and cannot photosynthesize effectively. Best growth can be achieved only if plants have a suitable balance of water and air in their root zones. Some stages in the growth of a crop are particularly sensitive to moisture stress.

High-yielding varieties (HYVs) are more sensitive to water stress than low-yielding varieties; for example, deficit irrigation has a more adverse effect on the yields of new maize varieties in comparison to traditional varieties. In order to ensure successful irrigation, it is necessary to consider the water retention capacity of the soil. In sandy soils, plants may suffer from water stress more quickly than in deep soils of fine texture, which have ample time to adjust to low soil water matric pressure, and may remain unaffected by low soil water content. Under water scarcity conditions, agronomic practices may require modification, such as decreasing plant population, applying less fertilizer, adopting flexible planting dates and selecting shorter-season varieties.

The goal of an effective scheduling programme is to supply the plants with sufficient water while minimizing loss to deep percolation or run-off. Irrigation scheduling depends on soil, crop, atmospheric conditions, irrigation system and operational factors. Proper irrigation scheduling requires a sound basis for making irrigation decisions. The level of sophistication for decision-making ranges from personal experience to following neighbours' practices and techniques based on expensive computer-aided instruments that can assess soil, water and atmospheric parameters. Irrigation scheduling techniques can be based on soil water measurement, meteorological data or monitoring plant stress. Conventional scheduling methods are to measure soil water content or to calculate or measure evapotranspiration rates. However, research in plant physiology has led to scheduling methods by monitoring leaf turgor pressure, trunk diameter and sap flow.

The many different methods of collecting soil moisture include neutron probe, time domain reflectometry (TDR), gravimetric, neutron probe, tensiometers, electrical resistance blocks and the hand feel method (figure 28).

The annex provides an exercise on irrigation in the semi-arid conditions prevailing in the

**Figure 27.** Incrustations in a water pipe



Source: ACSAD.

**Figure 28.** Measuring soil moisture with tensiometers



Source: ACSAD.



Syrian Arab Republic and the need to shift away from wasteful irrigation methods, especially as water scarcity is expected to increase. How the institutional, legislative and economic frameworks can help make this shift is considered in exercise 3: Optimizing agricultural water use in a semi-arid country.

## Deficit irrigation

To achieve high water use efficiency under water scarcity conditions, an irrigation strategy called deficit irrigation is applied. The basis of this strategy is the knowledge about the sensitivity of the various growth phases of a crop to water stress and the impact of this water stress on the yield level. In deficit irrigation, plants receive full irrigation during drought-sensitive growth stages and lower than usual quantities of water outside these periods, often the vegetative stages and the late ripening period. Deficit irrigation allows for a reduction of the irrigation water input without significant reduction in yields. Therefore it is an important tool to achieve the goal of efficient irrigation water use.

Preconditions are: (a) farmers' knowledge about the sensitive phases of each of the crops cultivated, which entails a well-functioning agricultural extension service (Kirda and Kanber, 1999); and (b) technical means to operate the irrigation system according to the crop's need.

### Case study. Development of organic agriculture in Saudi Arabia

More and more consumers worldwide, and also in Arab countries, are interested in purchasing organic, healthy food. By request of the Saudi Arabian Ministry of Agriculture, the German GIZ started to support the development of organic agriculture (OA) in April 2005. The overall mission of the Organic Farming Project was to establish a functioning and sustainable organic agriculture sector in Saudi Arabia, boost the organic market, support all sector stakeholders and raise awareness on organic food. Within a mere eight years, the project has turned organic agriculture in Saudi Arabia into a success story. The four objectives are: (a) to increase agricultural productivity and the number of small organic farms; (b) to produce healthy food; (c) to achieve conservation of natural resources; and (d) to reduce irrigation water consumption in agriculture, which is crucial in any CCA measure.

Awareness raising for farmers and the public on measures in organic production, research, training, marketing, certification, legislation, policy development were initiated and a national organic action plan was developed. Saudi Arabia is the first country in the Arab region with a national organic agriculture support policy. Up to mid-2014, more than 100 Saudi organic farms were certified and new farmers are continually converting their production systems to organic. While these farms are located all over Saudi Arabia, most of them are located around Jeddah, Riyadh and Dammam, where demand is highest.

The successful Saudi Arabian example (in its full dimension) can only be copied by other rich countries (such as the Gulf countries). However, small-scale organic farming is feasible even without any State support; the availability of a financially strong segment of the society, ready to pay more for healthy food, is a precondition for market production.



**Source:** GIZ (2014). Organic Farming Development Project. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, International Services. Eschborn, Germany, in cooperation with the Ministry of Agriculture of Saudi Arabia.

**Link:** <http://www.saudi-organic.org.sa>.



## Adaptation measures: forestry and agroforestry

### Forestry

Forest ecosystems occupy about 89.64 million hectares of land area in Arab countries (FAO, 2007; FAO, 2010a; Abido, 2010). Forests are central to human well-being and they have diverse ecological functions; namely conservation of soil and water, positive effect on local climate, mitigation of global climate change (storage of huge amounts of carbon; see case study on tree cropping), improvement of urban and peri-urban living conditions, energy source for many rural and indigenous communities, generation of employment and recreational opportunities (Zomer et al., 2006). Further, forests play a major role in the conservation of biodiversity. Forest biodiversity is vital for the continued health and functioning of these ecosystems. Trees regulate the water table (biodrainage), provide shade to people, crops and animals, and stabilize coastal areas (such as through mangrove stands) (figure 29). Forests themselves are sensitive to climate and other changes in their environment.

Climate change policies must therefore: (a) encourage forest protection (see case study on capacity development); (b) promote afforestation activities including maintenance (using a wide variety of tree species); (c) install forest fire management systems; (d) strengthen

#### **Case study.** Capacity development for forest ecosystem-based adaptation to climate change

Due to the vast biodiversity and richness in endemic species the ecosystems of the Mediterranean basin figure among the world's biodiversity hotspots. Mediterranean forests provide a wide range of goods and services, but overexploitation, overgrazing, forest fires, and rapid urbanization etc. endanger forest functions. This means, putting the provision of forest goods and services at risk and increasing the vulnerability of ecosystems and society. The key question remains: What is the most promising approach to protect the forest resources, suffering from the impacts of population growth and climate change?

The GIZ project 'Adapting Forest Policy Conditions to Climate Change in the Middle East and North Africa Region' tries to give an answer: Capacity development for cross-sectoral approaches to adaptation, i.e. to link those engaged in forest management with local stakeholders as well as with non-forest actors from other sectors.

Barouk Cedar Park, Lebanon

In order to mainstream the GIZ approach into the policies and strategies of the forest administrations and their partner sectors and to strengthen the inter-sectoral cooperation, a capacity development process is supported which entails: (a) carrying out field missions and training workshops; (b) publishing brochures to raise awareness; (c) implementing measures; and (d) establishing a community of practice in the Arab region for exchange of lessons learned. Collaborating countries are Algeria, Lebanon, Morocco, the Syrian Arab Republic, Tunisia and Turkey.



**Source:** R. Alexander Kastl, German Agency for International Cooperation (GIZ) Morocco, Reinhard.Kastl@giz.de, <http://www.giz-cpmf.org>.  
**Link:** <https://www.giz.de/en/worldwide/14279.html>.

**Figure 29.** Examples of forest functions: (a) productive forest; (b) Al-Jabal al-Akhdar, Libya, rich in biodiversity; (c) alley with shade trees (north-west Libya); and (d) trees cultivated for biomass production growing on untreated wastewater



**Photos:** (a): UN Environment; (b) and (c): Prinz; (d): FAO.

extension and awareness on forest and climate change issues; and (e) amend institutional and legal structures to facilitate adaptation and mitigation actions (FAO, 2011d; FAO, 2013b).

The impacts of climate change have to be taken into account when developing forest strategies and management plans. At the forest management unit level, both adaptation and mitigation require:

- Conservation of forest carbon stock and sustainable management of production forests through afforestation, reforestation and forest restoration, and more sustainable production of wood fuels;
- Harmonization of the needs of the local population with forest conservation;
- Protection of biodiversity of standing forests and plantation of species tolerant to CC impacts;
- Enhancement of the resilience of forests through an appropriate forest structure and composition;
- Implementation of forest management practices that reduce vulnerability to extreme events such as storms and fires and establishment of fire brigades and corridors to help species migrate.

## Agroforestry

Agroforestry integrates farming, animals, and trees or bushes in the same space, resulting in overall improved production and higher standards of living. Investigations by the World Agroforestry Center (ICRAF) have shown that agroforestry is a preferred production mode under climate change impacts (ICRAF, 2012; FAO, 2013a). Examples are given in table 10. Trees on farms can have considerable effects on smallholder livelihoods, both by improving ecosystem services or functions and by increasing or diversifying farm income and food and nutritional security. These features improve farmers' capacities to cope with climate (and other) shocks while providing important mitigation co-benefits by sequestering carbon from the atmosphere in tree biomass. Agroforestry can therefore be considered as "climate-smart" because it combines improved livelihoods with mitigation of and adaptation to climate change (adapted from the ICRAF website: <http://worldagroforestry.org/>).

## Adaptation measures: livestock management

Arab countries have a huge animal wealth in terms of numbers and species-specific animal diversity. According to FAO (2011), the livestock production of the 22 member countries of the Arab League is estimated at a total of 56.5 million heads of cattle and buffaloes, 259.4 million sheep and goats, 14 million camels, as well as 1.037 billion poultry and birds. The majority



### Case study. Tree cropping in arid areas for mitigation and adaptation to climate change

Trees always played a significant role in Arab agriculture – for example the olive tree (*Olea europaea*) and the date palm (*Phoenix dactylifera*). For centuries, different tree species have been selected to meet the local needs.

Under climate change conditions carbon sequestration becomes an important parameter: The goal is a high growth rate (biomass gain) by marginal water input in quantity and quality. Various trials have shown that Eucalypt species (such as *E. camaldulensis*, *E. gomphocephala*, *E. grandis*, *E. occidentalis*) have a great potential, when water quantities of 50 to 80 per cent ETo and water qualities up to 5.0 dS/m are applied. These trees can be planted in plantations on marginal land (to gain emission reduction certificates) or serve as windbreaks, in green belts around cities, etc.

In Tunisia, the Institut des Regions Arides (IRA) in cooperation with the German agency GIZ has carried out research work on the use of marginal water (mainly drainage water from oases) to establish tree and bush vegetation around Kebili in central Tunisia.

Main purposes were: (a) to make productive use of the marginal water; (b) to apply bio-drainage; and (c) to protect the villages and infrastructures against dust storms.

Good quality water is needed to raise the seedlings. Marginal water is applied for 2-3 years; once the trees mature, their roots can reach the near-surface groundwater.

Restoring vegetative cover of arid-zone lands by using marginal water supports mitigation and adaptation to climate change.

Large monocultural tree stands should be avoided and a patchwork of different types of plant cover (including agricultural crops and grazing) is preferred whenever possible.

**Source:** FAO (2010). Forests and Climate Change in the Near East Region, Working Paper 9, Rome, Italy.

**Link:** <http://www.ira.agrinet.tn>.

In the Kebili area, Tunisia, large volumes of drainage water from oases are available for afforestation works



(89.8, 73.3, 91.2 and 60.6 per cent of the groups mentioned) is kept in 10 African member countries of the Arab League.

Livestock breeders need new technologies, training and technical support to deal with climate change. Governments need to develop better policies and stronger institutions to sustainably manage natural resources.

The productivity of the livestock sector in the Arab region is hampered by the scarcity of natural resources, in particular of feed and water. Lack of supporting infrastructure and services and arbitrary policies have affected the sector negatively.



**Table 10.** Various types of agroforestry systems and relevant CCA measures in Arab countries**Photo:** Prinz (location: north-east Libya).**Non-irrigated agroforestry, combining field crops and trees**

Forest trees (except eucalypts) are often planted in perpendicular belts around agricultural fields. They perform different functions, such as wind protection, soil conservation, and provision of shade. Agricultural field crops include wheat, barley and winter legumes, often combined with agricultural fruit trees and shrubs (pistachios, almonds, figs, grapes, olives).

**CCA measures:** Higher plant diversity lowers vulnerability. Planting density will be lower in future to avoid competition for water, particularly between trees and annual crops.

**Photo:** Prinz (location: north-east Libya).**Irrigated agroforestry, combining field crops and trees (market production)**

Strips with fruit trees (such as olive trees, apple trees) alter with strips planted to irrigated annual crops, such as pepper, tomatoes, cucumbers, melons (for market production). Sprinkler irrigation or drip irrigation, using groundwater, is applied. (The sunflower plants in the foreground of the photo are used as water stress indicators – a reliable method in the absence of instruments to choose the right instant of time to start irrigating the crop).

**CCA measures:** Excellent method to avoid water competition. Too high fertilizer doses have to be avoided not to harm groundwater quality.

**Photo:** Prinz (location: north-east Libya).**Agroforestry system combining trees and bushes with domestic animals**

The tree/bush species typically used are *Pistacia atlantica*, olive trees, almond, hawthorn, tamarisk and others. This system can be established (a) in the form of belts and perpendicular forest enclosures around pastoral lands, or (b) with trees scattered over the grazing area. In the latter case grazing may start only after 2-3 years (if irrigated). Suitable animal species: sheep, goats, cows, camels etc.

**CCA measures:** The interaction between agricultural crops and domestic animals reduce vulnerability. Water storage and Supplemental Irrigation can further stabilize the system.

**Photo:** Prinz (location: north-west Libya).**Dryland agroforestry system with trees, annual crops and domestic animals**

Combining all three elements of agroforestry can yield, when planned well, the highest output per unit land. During the winter season, when the crops are in the fields, the animals are either fed with straw, hay or crop residues or are grazing outside the farm. During the rest of the year the animals are grazing in the fields, getting shade (and fruits) from the scattered trees.

**CCA measures:** Water harvesting, water storage in ponds (or underground), and Supplemental Irrigation can reduce vulnerability further. Soil and water conservation measures are even more important in future.



**Photo:** Prinz (location: Nile river island, Egypt).

### Irrigated agroforestry system combining trees, field crops and domestic animals

The most complex agroforestry system with (a) firewood trees, (b) fruit trees (almond, apple, nuts and grapes, etc.), (c) field crops, (d) forage crops and (e) domestic animals (cows, sheep, goats, camels, horses, rabbits and poultry). Crop residues are utilized for feeding the animals. When integrating more tree species (such as almond, oak, sidr (*Ziziphus spina christi*), sumac (*Rhus sp.*), figs or grapes), the economic basis can be consolidated.

**CCA measures:** A higher water use efficiency has to be strived for.

In most cases, men own the animal wealth whereas women are in charge of feeding them and providing all forms of care. Moreover, women do not receive any training or extension services related to animal breeding or even poultry husbandry.

Due to continually increasing population and prosperity, the demand for milk and meat is rising. Simultaneously, climate change is decreasing rainfall and increasing temperature and desertification is spreading in Arab region. As response to these challenges, the productivity of animal husbandry must be improved so that the same value (or more) of animal products can be produced with a smaller number of animals (figure 30).

The use of animal bi-products such as milk, wool, and manure is a viable means to establish related industries and create job opportunities for women and youth.

### Livestock and water

ACSAD has established an applied programme for improving the care of sheep and goats (small ruminants) in the Arab countries, which represents the main part of the Arab region's animal wealth. Within this programme, numerous measures are implemented in many sheep and goat stations which could lead to optimal use of animal resources in the participating Arab countries.

Water forms about (75 per cent) of the animals' body composition. Farm animals ingest water directly from available drinking water or through feed containing water. In case of lack of water, the animal's body converts ('burns') fat to produce metabolic water. Water is the medium where all the metabolic processes take place in the body, and it subtracts the digestion products of the body in urine, as well as in the form of sweat, so that the water is involved in the thermal regulation of the animal body. Insufficient water hampers all physiological processes in the body. Therefore, the water requirement of the animal must be fully secured in order to maintain health and productivity.

**Figure 30.** Sheep at water hole in Sudan



**Source:** Ihab Jnad, ACSAD.

**Table 11.** Relationship between ambient temperature and consumed water by dairy cows

Ambient temperature (°C)	Live weight (kg)	Daily milk production (kg)	Fat content in milk (%)	Water requirements (litre/cow)
+4.5	529.8	14.58	4.4	56.5
+10.0	540.6	17.87	4.4	90.0
+15.6	540.6	17.05	4.3	94.5
+21.1	542.0	16.82	4.2	99.0
+26.7	539.7	15.55	4.1	94.5
+32.2	544.8	11.61	4.2	85.5

Source: ACSAD.

The ambient temperatures that surrounding animals affect the amount of water they consume (table 11). The following table presents the relationship between ambient temperature and consumed water by dairy cows.

However the amount of water that an animal drinks also varies depending on the method of delivery. A cow that receives water from an individual automatic trough drinks 48.14 litres water a day, while a similar cow that receives water from a common trough twice a day drinks only 28.14 litres water. The same trend was observed in sheep.

## Genetic improvements

The genetic improvement to develop the productive and reproductive performance of some local sheep and goat breeds in the Arab countries is one of the priorities of the animal wealth department at ACSAD. This is done either through genetic selection for milk production or for meat production depending on the breeding value for each animal, or through targeted crossbreeding between local Arab breeds that are distinguished in a specific production trait with the Awassi sheep breed that has been improved for milk - or for meat trait (or for both traits), or with the improved Damascus goat breed that is distinguished in high milk production and twinning rate (figure 31).

These methods contribute to an accelerating of the genetic improvement programmes of some promising breeds in Arab countries. Genetic breeding raises the productivity of herds and reduces the numbers required to breed, thus relieving the pressure on pasture and feed demand and water used for breeding herds and irrigation of forage crop.

## Feed management (animal nutrition)

Feeding strategies in arid and semi-arid areas vary according to such factors as production systems, animal species, household income, social categories, and distance to the city centre (transportation costs). In all production systems, there are many diseases that have a negative effect either on animal health or on animal productivity. Controlling animal diseases, especially epidemiological diseases, thus becomes a critical component of livestock management, such as through optimal herd health management practices that include the string implementation of vaccination programmes and repeated anti-parasites treatment.



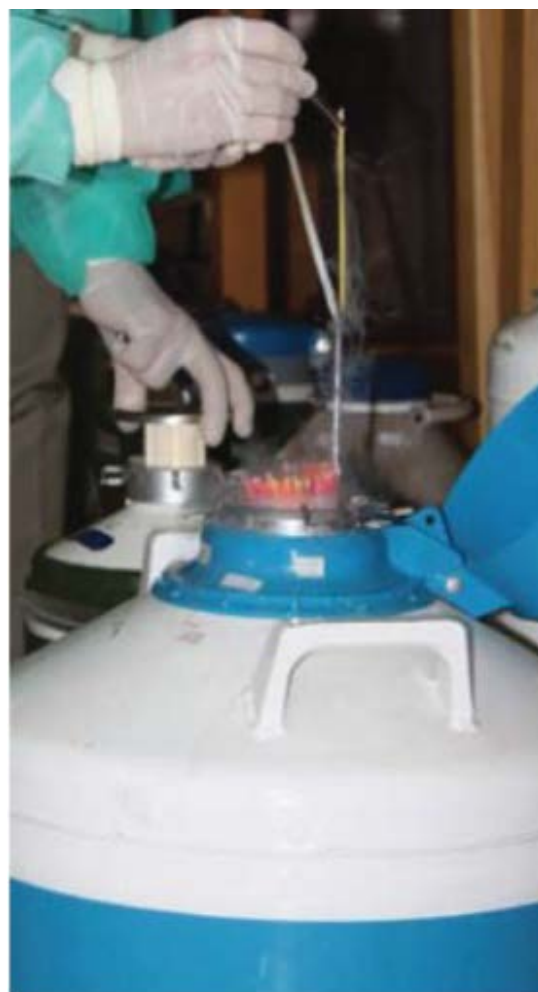
## Management of mating season (animal reproduction)

The regular production of newborns is essential for the provision of replacement animals, while successful reproduction is also necessary for milk production. More efficient reproduction can be achieved when breeding takes place at a physiologically optimal time, which can be exactly determined through simple methods. Artificial insemination (AI) is a modern biotechnology that can be easily implemented when the optimal mating time is determined, and which accelerates the genetic improvement of animal wealth. Artificial insemination is the most important reproductive technology in many livestock production systems in almost all regions, but it is especially suitable for livestock in peri-urban areas. Advantages of AI are that farmers do not have to undergo the costs or hazards of rearing breeding males, and have access to a very wide range of elite males. Furthermore, many infectious reproductive diseases can be controlled through the use of AI.

## Optimal raising of newborns

Another part related to the reproduction process is the rearing of newborn and young animals, thereby increasing income sources. Generally, the choice of an animal breed depends primarily on the adaptation tolerance; the breed should be adapted to local conditions in order to obtain optimal results in form of animal products. Imported foreign high-performance breeds require expensive care, concentrate feeds and special housing, and when imported breeds are introduced to local conditions they are often found to be even less productive than local animals. Therefore, local breeds that can be easily improved through intensive selection of the best local animals (sire/dam selection) in the herd represent the optimal way to manage genetics, with AI providing ideal tools to achieve the desired results.

**Figure 31.** Milk analysis at a laboratory



Source: ACSAD.

## Adaptation measures: pasture management and fodder production

Herders and others engaged in agriculture and grazing in the Arab region have proven that traditional methods are able to adapt to climate variability. Furthermore, support and assistance as well as tenure or land use rights reinforce the ability to successfully adapt to climate change. Over the centuries, different measures have been taken to cope effectively with climate changes, such as the seasonal movement of livestock, mixed agriculture based on integrated crop-livestock and water harvesting. Researchers and policy-makers should take such capabilities into account



when investigating and developing technologies for adaptation to climate change and related future strategies.

However, the current rate of climate change is greater than the ability of livestock producers to adapt to such changes. Governments in the Arab region need to invest in research, development and creation of legislation and policies that on the one hand encourage those who follow sustainable methods of production and on the other hand discourage those who practice unsustainable methods of production. Once practitioners have learnt about plant species environment and plant communities in pastoral land, appropriate adoption of agricultural technology can effectively improve rangeland and organize its exploitation in a scientific and rational manner (figure 32).

### Rainwater harvesting in pasture management

Precipitation is the most important factor that determines the vegetation type and its productivity. The development of vegetation cover is impacted not only by the volume of annual rainfall, but also by the rainfall intensity and its spatiotemporal distribution and the relative humidity of the atmosphere. Rainwater harvesting is one of the most important techniques for several reasons:

- Helps the development of natural pastures;
- Accelerates the rehabilitation of natural vegetation;
- Increases the availability of soil moisture for plants for relatively long periods;
- Raises the efficiency of the production of forage and pasture;
- Provides natural feed for animals;
- Provides water storage for animals' drinking water needs;
- Fights desertification in arid and semi-arid areas.

The most widely used water harvesting technique for pasture rehabilitation is the Vallerani type. Microcatchments of about 4 m length are constructed by a special plough mounted on a tractor, and can be an economical method if large areas are covered (Oweis et al., 2012). Per day 10 to 15 hectares can be covered; the costs are in the range of \$100 per hectare.

### Pasture rehabilitation

ACSAD developed and implemented several pasture rehabilitation projects in different Arab countries, including Algeria, Oman, Saudi Arabia and the United Arab Emirates. Rehabilitation of pastures can be done in two ways.

#### Natural rehabilitation

A natural method in rehabilitating pastures consists of several points:

- Prevent grazing or postpone it for a certain period of time until the pasture regains its productivity;

**Figure 32.** Grazing Area in West Bank



Source: Alaa Kanan.



- Reduce the grazing load in medium deteriorated pasture with fixing grazing periods, which can enable the perennial plants to flower and set fruits and for seed dispersal;
- Prevent grazing during certain seasons during which the excellent species are sensitive to grazing;
- Restrict grazing of animals that prefer certain palatable types of plants that are about to become extinct from the pasture, and allow other types of domestic animal to graze, which prefer invasive species that proliferate at the expense of high-yielding species;
- Introduce new high yield and high nutrition values grazing plants with good adaptive capacity to the harsh environments.

### Artificial rehabilitation

This kind of rehabilitation is used when the main perennial species are lost. Two ways are used for restoring degraded pastures: transplanting and seeding. Good pastoral shrubs species are deteriorated not only by overgrazing but also by wooding, as such types of plants need a long time for rehabilitation.

Pastures rehabilitation by transplanting or by seeding require establishment of nurseries and a pastoral reserve to conserve the plants' genetic origins to reproduce the seeds and conserve biodiversity.

Some of the most important plant species used in the rehabilitation of pastures across the Arab region are: *Salsola vermiculata* L., *Atriplex* spp. (Syrian *Atriplex* such as *A. leucoclada*, *A. halimus* L., *A. canescens*), and others (figure 33).

### Fodder production

A large number of annual or perennial herbaceous crops and tree crops are cultivated for fodder purposes. The most important ones under irrigation are *Alfalfa* (*Medicago sativa*) and *Berseem* (*Trifolium alexandrinum*), but there are numerous other crops that are planted solely for fodder production or which also serve other purposes, such as shelterbelts, sand dune fixation or soil erosion control (such as *Albizzia lebbek*, *Acacia saligna*, *A. tortilis*, *Prosopis cineraria*).

The cactus *Opuntia ficus indica* is gaining more and more importance: The fruits generate income and the biomass is harvested (often silaged) and fed to ruminants or cattle (figure 34).

### Feed sources

Agricultural residues are considered as one of the most important feed sources in the Arab region's arid and semi-arid areas upon which breeders rely to feed their animals, and which are indispensable for the feeding of the ruminant animals due to their importance in the physiology of digestion. However, the climatic changes in the arid and semi-arid regions and the repeated drought episodes that are accompanied by a severe shortage of fodder, pasture and water, negatively impact the availability of animal feed in such areas, making it necessary to search for forage alternatives at economically acceptable costs. One solution is to use agricultural wastes and by-products on a large scale after improving their nutritional value and using some simple techniques that also help breeders to adapt to such climate changes and ensure that they continue the productive process in the breeding and care of ruminants.

### Rehabilitation of degraded area in North Kordofan State (the Sudan)

The over exploitation of natural resources in the Sudan led to land degradation and desertification acceleration. This phenomenon has taken environmental, economic and social dimensions, which required the rehabilitation of degraded land to secure food production. The implementation of this case study was carried out in the North Kordofan State in cooperation between ACSAD and the Ministry of Agriculture and Forestry in the Sudan. Selected activities were implemented to rehabilitate the degraded rangeland, improve the productivity and vegetation cover, activate the participatory approach and find additional sources of income generation for the local population. The applied methodology included soil conservation, vegetation rehabilitation, natural resources protection and sand dunes fixation. The results show positive indicators such as stabilization of moved sand, increasing vegetation cover and rangelands productivity, and a general positive shift in the stability of the area's ecosystem, all of which indicate the success of the implemented activities and technologies.

#### The area before and after rehabilitation



Source: ACSAD – Land and water use department- desertification monitoring and combat programme.

The process of improving the nutritional value of agricultural residues can be done through several techniques:

- Silaging the green or wet agricultural residues;
- Manufacturing feed blocks from dry forage wastes;
- Straw and hays treatment with urea or urea and molasses, if available (figure 35).

Such techniques are characterized as one of the basic tools for adaptation to climate changes. Moreover, the choice of such techniques in improving the nutritional value of the waste agricultural by-products has the advantage of being available in large quantities in arid and semi-arid areas.

Implementing such techniques requires securing some of the necessary supplies to ensure success, including agricultural wastes at their place of origin, securing equipment needed to chop and mix agricultural residues and prepare them to be formed into integrated

**Figure 33.** Atriplex and Salsola are the most widely used plant genera for artificial pasture rehabilitation



Source: ACSAD.





feed or filler feed (straw and hay) with improved nutritional value. Dry wastes should also be collected and shredded in production areas (agriculture crop areas) or areas where the wet residues of the agricultural processing industry are available (sugar factories or canneries).

## Adaptation measures: fisheries and aquaculture

Marine waters border the Arab region on all sides: the Arabian Sea to the east, the Atlantic Ocean to the west, the Mediterranean Sea to the north, and the Indian Ocean to the south.

In addition, rivers (mainly the Nile, the Tigris, and the Euphrates) and the natural and man-made lakes constitute inland water resources, which represent a very important potential for fisheries. Inland fishery resources in the Arab region, which include lakes, rivers, marshlands, swamps, reservoirs, and natural and man-made lakes, are estimated to cover about 1.5 million km<sup>2</sup> (figure 36).

The major states where these are available are Egypt, Iraq, the Sudan and the Syrian Arab Republic. The lakes in the Egyptian Delta region are the main fish production water bodies in addition to lake Nasser in the south, lake Qarun, and the Nile river. In the Sudan, the main inland fisheries are in the Blue and White Niles, in addition to the main stem of the Nile river. Iraq's main fisheries are located on the Tigris and Euphrates Rivers as well as some man-made reservoirs. Other rivers with smaller size fisheries exist in Jordan, Lebanon, Mauritania and the Syrian Arab Republic. Most of the inland fisheries in the Arab countries are characterized by subsistence fishing to meet immediate food supply needs of populations living in the vicinity of the water bodies.

Fish production (including aquaculture) in the Arab region was estimated at 4.3 million tons in 2013 (2.6 per cent of the total world production), of which 33.9 per cent from Egypt, mostly in the form of aquaculture. Developing fish cropping in both sea and inland aquaculture remains a major challenge. In the Arab region, Egypt is the first country in aquaculture with one million tons per year, with Saudi Arabia coming in at a distant second place with 26 thousand tons of fish (table 12).

**Figure 34.** Commercial production of Opuntia in Palestine (West Bank)



Source: Prinz.

**Figure 35.** Various techniques to improve the nutritional value of agricultural residues



Source: ACSAD.

In Egypt, aquaculture accounts for about 65 per cent of all fish produced in the country. Of these about 85 per cent are obtained from semi-intensive culture technology employed in brackish water. About 10 per cent come from cage culture in fresh water and about 5 per cent from rice-fish culture (FAO, 2010b).

The Arab Organization of Agriculture Development (AOAD) is preparing a strategy for the Arab countries to develop aquaculture to increase its portion of fish husbandry from 25.7 per cent to 50 per cent.

Whereas (renewable and non-renewable) good quality water ( $< 1.5$  dS/m) becomes scarcer year by year, there are large volumes of brackish groundwater of different salinity levels available, which can be best utilized for aquaculture if suitable fish species or other types (such as shrimps, prawns etc.) are selected.

### Climate change impacts and adaptation

Fisheries and aquaculture are threatened by changes in temperature and, regarding freshwater ecosystems, in precipitation. Storms may become more frequent and extreme, imperilling habitats, stocks, infrastructure and livelihoods. Greater climate variability and uncertainty complicate the task of identifying impact pathways and areas of vulnerability, requiring research to devise and pursue coping strategies and improve the adaptability of fishers and aquaculturists.

**Figure 36.** Aquaculture contributes to food security and income generation



Source: <http://www.abc.net.au/news/image/4022248-3x2-940x627.jpg>.

**Table 12.** Fish production in Arab countries, 2011-2013 (in thousand tons)

Country	2011		2012		2013			% of total production
	Fishing	Cultivation	Fishing	Cultivation	Fishing	Cultivation	Both	
<b>Egypt</b>	375.4	986.8	354.2	1017.7	434.9	1017.7	1452.6	33.9
<b>Morocco</b>	956.7	0.3	1164.5	0.4	1169.4	0.4	1169.8	27.3
<b>Mauritania</b>	644.3	-	644.3	-	646.7	-	646.7	15.1
<b>Oman</b>	158.6	0.2	191.6	0.2	195.5	0.2	195.6	4.6
<b>Yemen</b>	146.3	14.3	146.1	13.6	146.1	11.8	157.8	3.7
<b>Tunisia</b>	110.5	4.3	112.5	4.3	112.8	4.4	117.2	2.7
<b>Algeria</b>	93.4	1.8	101.8	1.8	100.4	1.8	102.2	2.4
<b>Saudi Arabia</b>	59.4	16.1	64.0	26.1	66.0	26.4	92.3	2.2
<b>Other Arab countries</b>	292.8	27.3	306.2	36.1	312.5	36.6	349.1	8.1
<b>Arab region</b>	2837.3	1051.0	3085.1	1100.1	3183.2	1100.1	4283.3	100.0
<b>World</b>	90500	62700	90800	74400	90500	70500	161000	

Fish can provide opportunities to adapt to climate change by, for example, integrating aquaculture and agriculture, which can help farmers to cope with drought while boosting profits and household nutrition (see case study on aquaponics – an integrated aqua-agriculture system). Fisheries management must move from seeking to maximize yield to increasing adaptive capacity.

The climate change impact on inland fisheries can be summarized as follows:

- Higher inland water temperatures may reduce the availability of wild fish stocks by harming water quality, worsening dry season mortality, bringing new predators and pathogens, and changing the abundance of food available to fishery species.
- Increasing seasonal and annual variability in precipitation and resulting flood and drought extremes are likely to be the most significant drivers of change in inland aquaculture and fisheries. These impacts are likely to be felt most strongly by the poorest aquaculturists, whose typically smaller ponds retain less water, dry up faster, and are therefore more likely to suffer shortened rain seasons, reduced harvests and a narrower choice of species for culture. However, aquaculture may also provide opportunities for improving water productivity in areas of worsening water scarcity.
- Extreme weather events such as cyclones and their associated storm surges and inland flooding can have serious impacts on fisheries, and particularly aquaculture, through damage or loss of stock, facilities and infrastructure. Structural responses such as constructing artificial flood defences and maintaining natural ones can provide protection that is significant but incomplete.

- Building greater adaptive capacity will entail approaches such as mixed livelihood strategies and access to credit, by which aquaculturists can cope financially with sudden losses of investment and income. Other considerations for coping strategies in high-risk areas include monitoring and assessing risk and promoting aquaculture species, fish strains, and techniques that maximize production and profit (FAO, 2014).

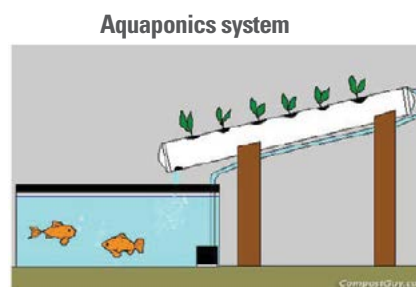
## Screening of adaptation measures

An outcome of this training module is evaluation and prioritizing the proposed adaptation measures, which should be criteria based. Methods and tools should be carefully selected, mainly to their relation with IWRM and also to the required data, area of application and constraints of application. However, it is important to note that the prioritization of measures is always location-specific. A measure with top priority in one location can be of inferior priority in another location. Therefore, a sound problem analysis followed by a resource analysis should always be the first steps for any prioritization of measures. Stakeholders should rate each adaptation measure based on criteria such as those found in table 13, after which different measures can be prioritized. For further information, refer to the annex (exercise 4: Prioritizing different adaptation measures based on screening criteria).

### Case study. Aquaponics – An integrated aqua-agriculture system

Food production in urban environments becomes more and more important. One interesting solution is the introduction of 'Aquaponics', which combines conventional aquaculture (raising aquatic animals such as fish or prawns in tanks) with hydroponics (cultivation of plants in water) in a symbiotic and controlled environment.

Water is in circulation between the two elements of the system. Nutrients, which are excreted directly by the fish or generated by the microbial breakdown of organic wastes, are absorbed by plants cultured hydroponically (without soil). Fish feed provides most of the nutrients required for plant growth. The material inputs to the aquaponic system are essentially fingerlings (young fish), fish feed, seedlings and water. Another cost input to the aquaponic system is power supply to run the water pump and air pump.



Source: <http://www.compostguy.com/images/aquarium-aquaponics.jpg>.

#### Aquaponics application in Gaza



Aquaponic systems offer several advantages such as: (a) Increase of farm productivity and profitability without any net increase in water consumption; (b) re-use of water and nutrients otherwise wasted; (c) reduction of net environmental impacts; and (d) increased output without need for additional agricultural land.

In cooperation with FAO, aquaponic food production units were installed on the rooftops of 15 (mostly poor and female-headed) households in Gaza. In most cases, families were able to grow enough tomatoes, peppers and eggplants during three summer months to meet all their household needs, plus up to 20 kilos of fish during a nine-month growth cycle.

Source: [http://www.fao.org/fileadmin/templates/FCIT/PDF/Fact\\_sheet\\_on\\_aquaponics\\_Final.pdf](http://www.fao.org/fileadmin/templates/FCIT/PDF/Fact_sheet_on_aquaponics_Final.pdf).

Further Reading: <http://www.agramiddleeast.com/en/Media-Centre/Press-Releases/PressRelease13>.



**Table 13.** Screening criteria

No.	Criteria	Notes	Rating
<b>I</b>	Does it promote IWRM?	This is clearly a priority, and can be considered to be a mandatory criterion in almost all cases	
<b>II</b>	Does it consider the impacts of climate change?	From evaluator's point of view and experience	
<b>III</b>	Is there any evidence of application?	From evaluator's point of view and experience	
<b>IV</b>	How widely is it used in arid areas?	From evaluator's point of view and experience	
<b>V</b>	Does it consider relevant social, environmental and economic issues and impact analysis?	Fundamental, because adaptation must be in line with and promote sustainable development	
<b>VI</b>	Does it consider issues related to gender and minority groups?	This may not seem relevant in all cases, but because vulnerability is differential – in other words it is not the same for different groups of people – it is likely that women and minority groups will be the most vulnerable to climate change in many cases	
<b>VII</b>	Does it consider cost-benefits and cost-efficiency?	This may not always be relevant, but in order to be sustainable and long-term, and to avoid turning into a maladaptation, adaptation needs to be cost beneficial and efficient	
Total			(from 7 to 21)

**Rating:** Completely =3; moderately =2; indirectly=1.



CH.

5

**Adaptation Measures  
Implementation Matrix**





# Adaptation Measures Implementation Matrix

Lessons learned can offer practical advice about how to advance CCA in order to assist stakeholders in successfully adapting to climate change.

**Focus on an immediate, recognisable threat.** Consider issues that already exist and that are relevant to local communities.

**Recognise local values, and be flexible.** Where multiple options exist, be prepared to respond to the needs of impacted communities.

**Start with an existing process.** Integrating adaptation measures to existing processes facilitates the institutionalisation of such processes, thereby ensuring the sustainability of measures.

**Utilise local activists.** Local stakeholders that are engaged can provide continuity as government staff and elected officials may move on to other positions.

**Look for leadership in unexpected places.** Champions may be found within a wide variety of stakeholders, whether directly or indirectly impacted by climate change.

**Involve government officials early.** Support and endorsement by officials is instrumental, and can help work through bureaucratic delays and barriers.

**Work with the right department, and dedicated staff.** Ensuring that selected adaptation measures are interlinked with the relevant government department will strengthen continuity, process integration and other success factors.

**Reach out to the community.** Open channels of communication with impacted local communities and stakeholders are key to fostering acceptance, trust and participation.

**Facilitate peer-to-peer learning, and offer positive examples.** Stakeholders may learn better through success stories from counterparts in another country or jurisdiction.

**Recognise limited capacity.** Constraints of resources, time and adaptive capacity in general suggest initial steps that are modest in scale.

**Do not get trapped by climate debate.** Certain stakeholders may be alienated by technicalities or abstract nature of the climate debate.

**Use outside expertise that has legitimacy with leaders, that understands community organising, and provides technical details.** Outside expertise can help especially if it has a successful track record and is a capable community organiser that is politically savvy and that can draw on technical experts.

**Do not wait for perfection.** It is important to start taking action as soon as possible without waiting until plans are perfect, especially as strategies will be revised over time.

**Use economic and fiscal arguments.** It may be possible to counter arguments against adaptation measures through financial savings.

**Make use of regional compacts.** Clustering of local governments may provide economies of scale through greater access to technical assistance and other forms of resources, and provide ways to leverage their position relative to central governments.

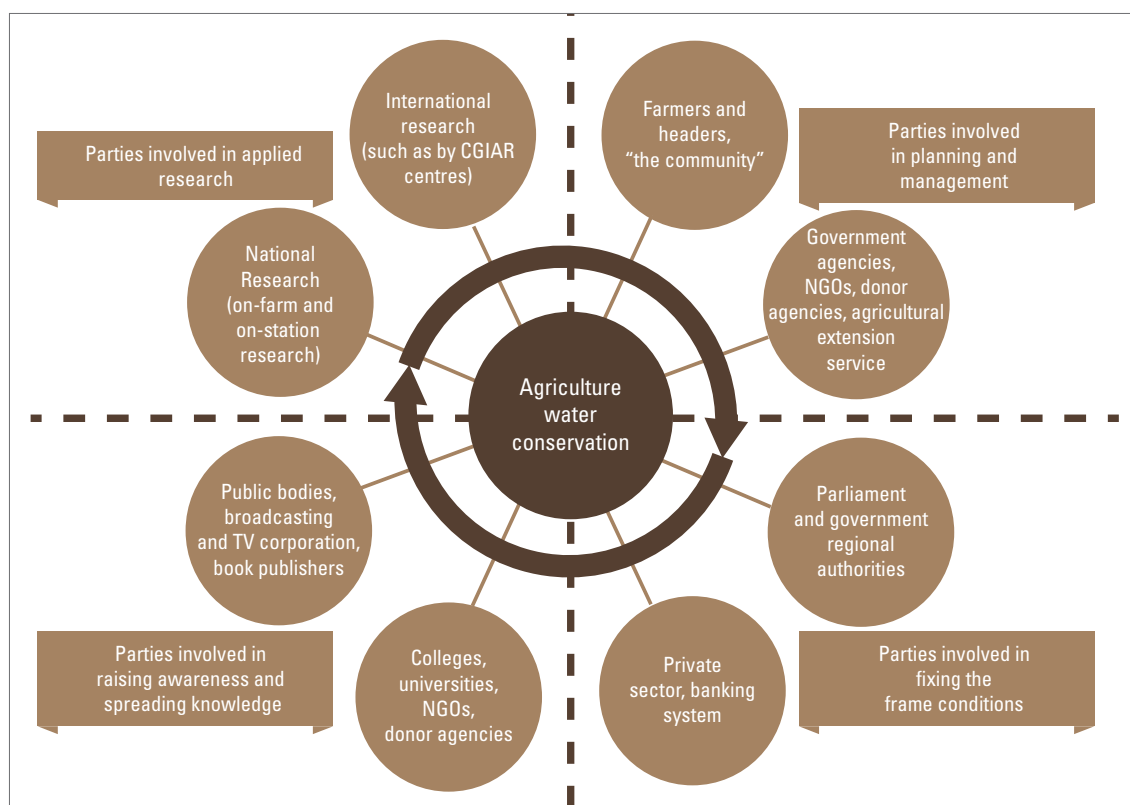
Adapted from *Implementing Climate Change Adaptation: Lessons Learned from Ten Examples* (2012). Headwaters Economics.

## Stakeholders and their role in water management

Successful implementation of feasible options for water management (WM) related to CCA depends on how different stakeholders play their roles. There are many stakeholders (national, regional and international organizations) dealing with various elements of CCA. The government ministries, especially those dealing with water, agriculture, irrigation agriculture, land, environment and natural resources are charged with various aspects of WM. In many countries, WM falls under either the ministry of water (and irrigation) or the ministry of agriculture, which provide policy and legislative frameworks, coordinate related WM interventions, implement various national programmes and projects, regulate activities of other stakeholders, and provide capacity-building, technical backstopping and extension services.

Additionally, various NGOs operating at local, national or regional levels are involved in community-based interventions aimed at improving the livelihoods of farmers, water and food security, poverty reduction and disaster mitigation, all of which have water management as core or partial activity. NGO interventions are based on capacity-building, technology transfer, research and technology development, extension services, credit provision, community empowerment, policy advocacy and integrated rural development programmes. Micro-finance institutions and other private sector counterparts dealing with agricultural credit schemes, supply of agricultural inputs, extension services, crop processing, and marketing should also be brought on board. Figure 37 shows the different stakeholder entities and their core areas of activities. In most cases the sphere of influence goes well beyond the indicated area. All entities are somehow connected with each other and coordinated actions are a precondition for success.

**Figure 37.** Stakeholders involved in agricultural IWRM in the Arab region



Source: Adapted from Prinz, 2014a.

**Table 14.** Options for CCA in agriculture in the Arab region

OPTIONS	Field / farm	Irrigation scheme	Water- shed / aquifer	River basin	National
<b>Land, water and crop management</b>					
On-farm water storage/water harvesting	x		x		
Groundwater development	x				x
Avoiding groundwater pollution	x	x	x	x	x
Modernisation of irrigation infrastructure		x			x
Reducing pollution of surface and canal water	x	x	x	x	x
Breeding for resistance (drought and floods)	x				x
Dam construction/enhancement		x	x	x	
Drainage	x	x	x	x	
Introduction of appropriate fish species	x				x
Forest establishment and maintenance	x				x
Enhancing soil moisture retention capacity	x	x			
Changing crop pattern/crop diversification	x	x			
Adapting cropping calendar	x	x			
Improved plant nutrition/fertigation	x	x			
Soil and water conservation	x	x	x	x	x
Reducing evapotranspiration losses	x	x	x		
conservation agriculture	x	x			x
Supplementary irrigation	x				x
Deficit irrigation		x			
Cultivation in protected environments	x				x
Flood and drainage management		x	x	x	x
Irrigation scheme operation improvement		x		x	x
Wetland protection/habitat restoration	x		x	x	x
<b>Policies, institutions and capacity-building</b>					
Climate proofing of irrigation and drainage infrastructure		x	x	x	x
Reallocation of water within/between sectors	x	x	x	x	x
Strengthening land/water right access	x	x	x	x	x
Crop insurance	x				x
Capacity development in water management, SWC, water harvesting etc.				x	x
Improved weather forecasting capacity	x	x	x	x	x
Improved hydrological monitoring	x	x	x	x	x
Flood/drought monitoring and forecasting			x	x	x
Establishment of early warning systems					x
Review of food storage strategies					x
Improving produce marketing and export					x

Source: Based on FAO, 2013c.

The annex includes a group exercise (exercise 3: optimizing agricultural water use in a semi-arid country) set in the Syrian Arab Republic, as a typical example of an Arab semi-arid environment. This exercise deals with the general planning and implementation process, focusing on decision-making at various levels for a case of shifting from spring/summer fully irrigated crops to supplemental irrigated winter/spring crops. The exercise takes three stakeholder types, namely the ministry, technical planners, and farming community through a series of steps, including computing what water savings can achieve (through such tools as GIS) and determining how change can be facilitated, and how long the transition is expected to last.

## Increasing adaptive capacity

The degrees of exposure, sensitivity and adaptive capacity determine the vulnerability of a community, a farming system or a forest area. To keep vulnerability at a low level, the adaptive capacity has to be increased. Measures to achieve this goal include the following examples:

- Providing better access to information on
  - weather forecasts
  - new technologies
  - new crops and varieties and their cultivation
  - better plant protection and plant nutrition
  - measures against soil erosion and droughts
  - marketing opportunities
  - agricultural techniques, machinery, etc.
- Providing access to affordable loans
- Supplying information and / or subsidies to construct water storage units (cisterns, ponds, reservoirs)
- Providing better health care for people and livestock, etc.

These services might be supplied by the State directly or indirectly (such as by the meteorological service, an agricultural extension service, and agricultural research stations), newspapers, radio and television stations, marketing organizations, commerce and industry, and cooperatives or NGOs.

The adaptation capacity is also related to farm size (FAO, 2011a):

- The adaptive capacity of many small farms will be limited to changing varieties, improving their animals or constructing rainwater cisterns. In the short term, these changes may allow survival for a number of years, but in the long run many of them will give up farming/ herding and migrate to the cities.
- The adaptive capacity of medium-sized farms is much better when farmers have access to suitable information and to soft loans for small investments. Diversification of crop production, low-level processing, production of silage etc. will allow farmers to stay on their land. Water supply or floods may cause problems, which farmers cannot overcome without support from the government or NGOs.
- The adaptive capacity of large farm is undoubtedly the best and normally they have access to all relevant information, loans and State support. State support is needed in securing water supply (water storage), preventing floods, improving infrastructure, establishing a cadastre service, obtaining agricultural research results etc.

In conclusion, collective irrigation and agriculture projects are of high adaptive capacity in large farms compared with small ones. This experience is widely applied in Arab countries in North Africa, such as Morocco and Tunisia, and was recently launched in other countries, such as the Syrian Arab Republic.

# CH. 6

**Areas for Action:  
Suggestions for Follow-up**





# Areas for Action: Suggestions for Follow-up

## National policy level

Adaptation is successful if it reduces the vulnerability of poorer countries and people to the existing climate variability, while also developing the potential to anticipate and react to further changes in climate in the future. The evidence from past experiences suggests that adaption is best achieved through mainstreaming and integrating climate responses into development and poverty eradication processes, rather than by identifying and treating them separately (Adger et al., 2003). The rationale for integrating adaptation into development strategies and practices is underlined by the fact that many of the interventions required to increase resilience to climatic changes generally benefit development objectives. Adaptation requires the development of human capital, strengthening of institutional systems, and sound management of public finances and natural resources (Adger et al., 2003). Such processes build the resilience of countries, communities, and households to all shocks and stresses, including climate variability and change, and are good development practice. Over recent years, several countries and regions have developed vulnerability and adaptation assessments, as well as practical policy proposals and strategic implementation plans to address climate change. This knowledge needs to be integrated into development support so as to manage climate vulnerability along with other non-climate risks in project design and implementation.

An examination by Osman et al. (2007) of community development efforts in the Sudanese villages of Bara Province in North Kordafan, El Fashir in North Darfur and Arbaat in the Red Sea State demonstrates that development and adaptation to climate risks can be strongly complementary. Strategies for disaster risk reduction, water resource management and food security should highly feature in local and national development planning in order to strengthen adaptation and resilience to climatic shocks. Access to the latest climate change information and knowledge must be also provided to enable communities to plan for adaptation strategies. Community development projects implemented in the villages must integrate multiple strategies to improve livelihoods, quality of life, and sustainability of resource use within a context of recurrent drought. Using measures of changes in household livelihood assets (human, physical, natural, social and financial capital), the holistic approach to development taken in the study areas has succeeded in increasing the capacity of households to cope with the impacts of drought. Community participation in the projects and reliance on indigenous technologies for improving cultivation, rangeland rehabilitation and water management that are familiar to the communities are found to be important factors for success. The sustainable livelihood approach appears to be a viable model for integrating development and adaptation to climate hazards at the community scale.

Although adaptation must be a locally driven process, it should be supported by national policies and frameworks. The primary objective of adaptation activities must be to build resilience and further adaptive capacities in vulnerable local communities that need to adapt to climate change already. Local approaches for adaptation could be further developed and built upon. Learning from these tested strategies can be used to inform local and national planning. To address the impacts of climate change on poor and vulnerable communities within

these countries, there is a need to move from support for projects to support for national adaptation plans and development interventions. Over time, support will need to move towards the strategic integration of CCA measures into the design and implementation of national development plans, poverty reduction strategies and sectoral policies and strategies, if these are to be sustainable in the face of climate change. Capacity-building and sharing of best practices will be important in this process. Adaptation should not be viewed as a separate sector with separate structures, frameworks, tools and approaches, but as an integral component of sustainable development. Adaptation is needed in sectors that are crucial for wider development issues and for poverty reduction. Coordination between institutions and between different ministries will therefore be important. Traditional systems for adapting to climate variability include a range of livelihood strategies, from individual to collective savings mechanisms and migration. Social networks play a fundamental role for the poor by providing safety nets as an immediate response to adverse climate conditions (Osman-Elasha, 2006).

According to Hugh Turral (FAO, 2011), the following steps are recommended to reach at the best adaptation options under prevailing (local) conditions:

- Define climate change impacts on water resources availability;
- Define (account for) current water resources use, and projected use for current development goals;
- Determine climate change impacts on future water availability and implications for future allocations;

### **Rural women play a key role in managing natural resources and sustaining livelihoods**

Women often rise to the challenge of coping with harsh changes and have proven to be the protectors of social existence in exceptionally tough situations as the case of women under siege and sanctions in Iraq, and under the multifaceted violence afflicting Iraq, Lebanon, Palestine and the Sudan (UNDP - RBAS, 2006). The agricultural work traditionally performed by women in Arab countries has long been invisible, as a crucial but seldom acknowledged contribution to household and national income (FAO, 2005a; Osman, 2016). Women work on their own farms and as labourers on other farms, but most of them are not paid for their efforts. About 75 per cent of women working in agriculture in Yemen are unpaid, as are 66 per cent in the Syrian Arab Republic, 45 per cent in Palestine (FAO, 2005), and 70 per cent in Egypt (Egyptian Organization for Development Rights, 2011). Yet the female role in livelihood and natural resource systems is crucial; the work women perform is central to ensuring food security for the family and community and maintaining adequate levels of productivity among the rural labor force (FAO, IFAD, and ILO, 2010). Even in harsh conditions, that is when drought strikes, women are usually the last to migrate. Men usually leave their lands first in search of work and income, leaving women and children behind. Women shoulder the responsibility of households and manage the dwindling resources (Osman-Elasha, 2007).

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- Define the production status and potential of current agricultural (cropping) systems under selected climate change scenarios;
- Examine the water and land use implications of alternative combinations of agricultural development activities, incorporating rainfed agriculture; irrigated agriculture; agroforestry; rangeland; and integrated mixed farming;
  - Match options to likely scale and nature of farming in the future in recognition of current and likely levels of urban migration and remaining rural population;
  - Evaluate mitigation options for synergy, practicality and cost effectiveness;
- Define resources and adaptation actions needed to maintain current levels of output and productivity;
- Define resources and adaptation actions required to meet future demands;
- Assess impacts on ecosystems and on the sustainability of the existing or proposed farming system;
- Cost alternatives;
- Prioritize options.

The packages of adaptation options include (1) adapted crops and domestic animals (breeding); (2) soil and water conservation and water harvesting techniques; (3) nutrient management (organic manure and mineral fertilizer); (4) improved irrigation modes (full, deficit, supplemental); (5) technology (water storage; forestry, agroforestry).

According to Turrall, the decisions on best suited adaptation options should be based on:

- Observation, assessment and promotion of appropriate and effective innovations developed by farmers at field level;
- Well-targeted research that addresses the specific climate change and socioeconomic context (as defined through this process);
- Experience and knowledge transferred from similar contexts.

## Regional policy level

The successful integration of CCA into regional policy, plans and programmes depends on a number of enabling conditions, such as:

- Meaningful and sustained stakeholder engagement
- Use and dissemination of appropriate information
- Awareness raising
- Monitoring, evaluation and review
- Successful management of multi-level governance

The key stages for the elaboration of regional adaptation policy are: (a) prepare the ground; (b) assess vulnerability of the region; (c) set strategic direction; and (d) plan and implement concrete adaptation measures (figure 38).

A key publication dealing with the Arab regional policy level is “The Arab Regional Strategy for Water Security” that includes a section on rural water security/irrigation. This strategy, which was drafted by the Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD) and adopted in 2010, functions as a framework for joint action between 2010 and 2030. This strategy and its action plan were adopted by the Arab Ministerial Water Council (AMWC). One of the strategy objectives is to promote “cooperation among Arab states for the management of shared water resources”. Last but not least is the RICCAR initiative, which is the outcome of a collaborative effort

between the United Nations and the League of Arab States (LAS), including its respective specialised organisations, that responds to a request of the AMWC and the Council of Arab Ministers Responsible for the Environment (CAMRE). RICCAR seeks to deepen understanding regarding the impact of climate change on water resources and the associated implications for socioeconomic vulnerability in the Arab region. The development of vulnerability assessment capabilities as well as the implementation of an integrated mapping tool serve to stimulate cooperation among scientific institutions, knowledge exchange and data sharing. The outcomes of such assessments are meant to provide a common platform for addressing and responding to climate change impacts on freshwater resources in the Arab region. The establishment of the Regional Knowledge Hub for Climate and Water is one of the activities of RICCAR (ACCWaM, 2011).

**Figure 38.** A schematic diagram of regional adaptation strategy to climate change



Source: Ribeiro et al., 2009.

**References and Further Readings >>>**

**Annex >>>**



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# Annex

## Exercises

### Exercise 1. Dealing with sea level rise and seawater intrusion in a densely populated river delta

**Location:** Nile River Delta, Egypt

**Background:** The Nile river delta is the backbone of Egypt's agriculture, endangered by rising sea level and encroaching seawater. Another problem is the insufficient supply of unpolluted irrigation water to the Delta.

**Questions:**

1. Which changes in groundwater quality and and surface water are predicted to occur during the coming decades?
2. Which changes in land use and agricultural production are adequate to counteract the creeping seawater intrusion and sea level rise?
3. Which actions and which decisions have to be taken to overcome the impacts? And when and by which authority?
4. Which role should farmers' organizations play?

### Exercise 2. How to manage horticultural production in a desert area with marginal water sources

**Location:** Arabah Valley, Jordan

**Background:** Larger cities are in need of an uninterrupted supply of vegetables and fruits. It is assumed that a new agricultural production centre shall supply sufficient horticultural produce to the City of Aqaba in order to reduce the need for long-distance transportation and/or further imports. The human and land/soil resources are available, but the needed water resources are in short supply. Impacts of climate change have to be taken into account.

**Questions:**

1. Which management decisions have to be taken by whom to install such a production centre?
2. How to deal with the available water resources (small quantities of good quality spring water, brackish groundwater and treated wastewater) in quantity and quality to satisfy the demand of humans, crops and the settlement (parks, lawns)?
3. To what extent is the blending of water resources and desalination necessary?
4. Which methods of water conservation (use of greenhouses, tunnels, soil cover, windbreaks etc.) ought to be installed to reduce the water demand?
5. Which horticultural crops can be recommended? Do hydroponics or aquaculture offer benefits?

### Exercise 3. Optimizing agricultural water use in a semi-arid country

**Location:** The Syrian Arab Republic (as an example for other semi-arid countries with similar environmental problems)

**Background:** The five-year drought forced people to flee the parched countryside and exacerbated the Syrian conflict. An important element of agricultural production in pre-war time was cotton production under full irrigation in summer, using a wasteful basin ('flood') irrigation method. This unsustainable compartment needs to be changed (as others, too), particularly under even stronger water stress conditions in future (due to climate change).

**Questions:**

1. Which legal, economic, juridical decisions have to be taken in order to initiate the change to a more sustainable water future, such as to shift from full summer irrigation to supplemental irrigation in winter/spring time or from surface irrigation to sprinkler or drip irrigation?
2. How can any reduction in cotton production (and export) be compensated by another commodity? What steps are to be taken to implement the shift?
3. How to deal with widespread over-pumping in the rural areas?

### Exercise 4. Prioritising different adaptation measures based on screening criteria

**Location:** An entire country, a smaller administrative unit such as a governorate or district, or a river basin, or a watershed/aquifer.

**Background:** Methods and tools should be carefully selected, mainly with regard to their relation with IWRM and also to the required data, area of application and constraints of application (refer to chapter 4). However, it is important to note that the prioritization of measures is always location-specific. A measure with top priority in one location can be of inferior priority in another location. Therefore, a sound problem analysis followed by a resource analysis should always be the first steps for any prioritization of measures

**Question:**

1. Review the table below and add/modify/delete the adaptation measures based on an assessment of the exposure and sensitivity of your sector activities to climate change impact.
2. Provide a rating for each adaptation measures based on the criteria described in chapter 4.
3. Add the rating of all criteria for each adaptation measure to compute the Total Rating for each adaptation measure.
4. Prioritize the adaptation measures. The Total Rating is a score that is classified in three levels as per the following ranges:
  - 15-20: Highly prioritized adaptation measure
  - 11-14: Moderately prioritized adaptation measure
  - 7-10: Relatively prioritized adaptation measure

Adaptation measure	Criteria							Total rating
	I	II	III	IV	V	VI	VII	
1. Water resources								
Reduce a further lowering of (renewable and fossil) groundwater levels								
Higher water use efficiency in agriculture (and a lowering of urban water demand)								
Fog collection, dew harvesting and cloud seeding								
Use of wastewater in agriculture or forestry								
Use of drainage water to supplement available good quality water resources								
Use of brackish water in irrigation								
Use of seawater for desalination and aquaculture								
Provide more drainage facilities								
Leaching agricultural areas to restore soil quality								
2. Water storage and quality aspects								
Water storage								
Pumping surface water directly into an aquifer and/or enhancing infiltration								
Rooftop water harvesting								
Soil and water conservation (SWC) techniques such as contour bunds, contour ditches and small basins								
Cisterns								
Ponds								
Hafairs								
Reservoirs								
Subsurface dams								
Water quality aspects								
Human waste needs to be totally separated from any water source								
Animal waste collection and manuring								
Wastewater collection system and treatment plant for new rural settlements								
Control of filling stations in rural areas								

Supervise industries in rural water sensitive areas								
Control of release of heavy metals								
Limit use of water of drinking water quality								
<b>3. Water harvesting</b>								
Groundwater harvesting (Qanat)								
Rooftop and courtyard water harvesting								
Microcatchment water harvesting								
Macrocatchment water harvesting								
Floodwater harvesting (spate irrigation)								
<b>4. Rainfed farming and general issues of crop production</b>								
<b>Techniques, crops and varieties</b>								
Establishing a genetic bank for varieties								
Avoiding planting of water demanding and long cycle varieties.								
Focusing on early harvesting and fast filling grain period varieties.								
Developing of varieties resistant to yellow rust disease								
Applying suitable crop rotations								
<b>Cultivation and production of fruit tree cultivars adapted to drought</b>								
<b>Conservation agriculture</b>								
Minimal soil disturbance								
Permanent soil cover								
Crop rotation								
<b>Soil and water conservation</b>								
Improving crop husbandry								
Improving crop selection								
Contour cropping / farming								
Improving infiltration and water storage capacity of soil								
Reducing evaporation from soil surfaces								
Lowering transpiration losses of plants								
Tied ridges								
Pits, furrows and basins								

Adaptation measure	Criteria							Total rating
	I	II	III	IV	V	VI	VII	
Bunds, ridges and combined ridge-ditch systems								
Terraces								
Stone lines, following contour, perpendicular to water flow in broad valleys								
Check dams								
Dealing with excess water								
<b>Supplemental irrigation (SI)</b>								
<b>5. Irrigated farming</b>								
<b>Water productivity and water use efficiency</b>								
Irrigation water productivity								
Storage efficiency								
Conveyance efficiency								
Distribution efficiency								
Application efficiency (on-farm efficiency)								
<b>Irrigation methods and management</b>								
Drip irrigation								
Irrigation scheduling								
Deficit irrigation								
<b>6. Forestry and agroforestry</b>								
<b>Forestry</b>								
Conservation of forest carbon stock and sustainable management of production forests								
Harmonizing the needs of local population with forest conservation								
Protection of biodiversity of standing forests and planting species tolerant to CC impacts								
Enhancing resilience of forests through appropriate forest structure and composition								
Implementing forest management practices								

<b>Agroforestry</b>								
Non-irrigated agroforestry, combining field crops and trees								
Irrigated agroforestry, combining field crops and trees (market production)								
Agroforestry system combining trees and bushes with domestic animals								
Dryland agroforestry system with trees, annual crops and domestic animals								
Irrigated agroforestry system combining trees, field crops and domestic animals								
<b>7. Livestock management</b>								
<b>Genetic improvements</b>								
Genetic selection or crossbreeding								
<b>Feed management (animal nutrition)</b>								
Feeding strategies								
<b>Management of mating season (animal reproduction)</b>								
Reproduction at a physiologically optimal time								
Artificial insemination (AI)								
<b>Optimal raising of newborns</b>								
Rearing of newborn and young animals								
<b>8. Pasture Management and Fodder Production</b>								
<b>Rainwater harvesting in pasture management</b>								
Rainwater harvesting (Vallerani-type: microcatchments)								
<b>Pasture rehabilitation</b>								
Prevent grazing or postpone it for a certain period of time								
Reduce the grazing load in medium deteriorated pasture								
Prevent grazing during certain seasons								
Restrict grazing of animals that prefer certain palatable types of plants								
Allow certain types of domestic animal to graze								
Construct small fences across the pasture								



Adaptation measure	Criteria							Total rating
	I	II	III	IV	V	VI	VII	
Introduce new high yield and high nutrition values grazing plants								
Transplanting								
Seeding								
<b>Fodder production</b>								
Cultivation of annual or perennial herbaceous crops and tree crops for fodder purposes								
<b>Feed sources</b>								
Silaging green or wet agricultural residues								
Manufacturing feed blocks from dry forage wastes								
Treating of straw and hay with urea or with urea and molasses								
<b>9. Fisheries and aquaculture</b>								
Constructing artificial flood defences and maintaining natural ones								
Aquaponics								
Mixed livelihood strategies and access to credit								
Monitoring and assessing risk and promoting aquaculture species, fish strains, and techniques								



## **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  
Using Integrated Water Resources Management Tools

