Climate Change Adaptation in Agriculture, Forestry & Fisheries by Applying Integrated Water Resources Management Tools

October **2015**

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Draft for Discussion – 11 February 2016

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I. INTRODUCTION

1 Overview

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. A high degree of diversity exists across the Arab Region. The region is particularly vulnerable to climate change. Climate change will pose an additional stress on the ecological and socio-economic 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 future, e.g. movement of ecological belts from south to north accompanied by land use change.

Climate change is a fact and the Arab region will be affected more severely than many other regions in the world. When dealing with climate change we have to distinguish between the 'assessment', i.e. the recording of impacts, the 'adaption' and the 'mitigation'. Adaptation is the process by which individuals, communities and countries seek to cope with the consequences of climate change (IPCC 2014, Cap-Net, 2009). Climate change adaptation should be accompanied by mitigation efforts, i.e. reducing greenhouse gas emissions, as these are complementary options. Adaptation alone is also not a sufficient answer to the problem, as adaptation options have limits, especially if certain levels of warming are exceeded.

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. Water's many different uses — for agriculture, for healthy ecosystems, for people and livelihoods — demands 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 faced. 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 climate change adaptation.

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 availability of water for agricultural purposes is even more difficult in many of the countries of the region, especially under condition of growing demand for water for non-agricultural use, which reduces the share of water available for irrigation purposes (AOAD, 2007). Rainfed farming, animal husbandry, forestry and fisheries receive a much lower attention in most Arab countries than irrigated farming.

The complex interaction of climate change adaptation, water resources management, agricultural production and sustainable development is increasingly understood by Governments in more and more Arab countries, which are beginning to prepare responses to this new challenge.

Capacity development is an urgent need at institutional and political levels, as 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 climate change adaptation and/or mitigation today to avoid even larger problems in future. RICCAR's Pillar 3 called 'Capacity Building & Institutional Strengthening' covers "institutional strengthening and capacity building in knowledge management, modeling, impact analysis, and vulnerability assessment, with focus given to working through existing networks on climate change to enhance capacity in these areas. It will be implemented through (1) Improved capacity and institutional networking for climate change and water resource monitoring and adaptation. (2) UNEP/ROWA assisting countries with their national climate change communications" (quoted from RICCAR's website www.escwa.un.org/RICCAR).

2 TRAINING OBJECTIVES AND METHODOLOGY

Related to the agricultural sector, the objective of the programme is to increase understanding of government officials and regional stakeholders of the impact of climate change on water resources as it relates to rainfed and irrigated crop production, to pasture management and livestock production, to forest management and inland fisheries.
The aim of the training is to enhance capacity of Arab Governments to incorporate IWRM tools into strategies, policies, plans and programmes of water management in order to be better prepared for future climatic conditions, particularly related to food production, to the production of agricultural raw material for industry (e.g. textile industry) and produce for export.
The training material shall be presented and discussed at a training workshop and finalized by incorporating comments and feedback from partners and workshop participants. The training material shall present basic facts e.g. on water conservation in agriculture, IWRM tools and other modern tools needed to adapt to future water demand and hints for decision makers how to close the 'unmet demand' gap. Case studies ('Best Practices' or 'Innovative Ideas') shall be incorporated to learn from experiences of 'real world' projects and programmes.

3 TARGETED STAKEHOLDERS

In general, government officials of related ministries and AWARENET members will be invited to the workshops and training units. In first line Ministries of Agriculture in the various Arab countries are addressed to send officials from agricultural, forestry and fisheries sector, but Ministries dealing with water in general (e.g. irrigation water, reservoir planning etc.) or spatial planning will be invited, too.

II. FRAMING SECTORAL PROBLEMS

Agriculture, forestry and fisheries in the Arab region are facing quite a number of natural and socio-economic problems – even without the impacts of climate change, which differ in magnitude between the countries (e.g. North Africa and GCC regions) and within countries e.g. between river valleys and remote dry lands.

1 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 world will become more and more serious during this century, particularly for the agriculture sector. Population growth, economic activities and an un-adapted lifestyle (at least in some countries) are the main drivers. The competition between the economic sectors (domestic use, industry, agriculture, etc.) is intensifying and most probably less water will be available in future for environmental purposes. Pollution is further aggravating water scarcity by reducing water usability. Shortcomings in the management of water and a focus on developing new resources rather than managing existing ones better are making the physical water crisis worse (Cap-Net 2005a).

Shrinking land resources: Land is the second limiting factor facing sustainable agricultural development in the Arab region. Only 35% of land in the Arab region is regarded as suitable for agricultural production purposes and this share is dwindling on one hand due to the expansion of urban areas and settlements and on the other hand due to desertification and other forms of land degradation, e.g. soil erosion by water (floods).

Land affected by desertification in the Arab region is estimated to be more than 10 million square kilometres (AOAD 2007).
The vagaries of climate: Droughts, floods, sandstorms etc. have impacted all 'green' sectors in Arab region especially during record years.

2 PROBLEMS ARISING FROM SOCIO-ECONOMIC ISSUES

Population: The population of the Arab countries nearly tripled between 1970 and 2010, climbing from 128 million to 359 million. According to UN projection, the Arab Region will have about 600 million inhabitants by 2050, increasing by two-third, i.e. about 240 million more people than in 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, in other countries high fertility persists (UN-DESA 2015).

Urbanisation: The Arab region is one of the most urbanized regions in the world: Between 1970 and 2010 the region experienced 400% urban growth; during the next 40 years a growth of 200% is expected: Whereas in 2010 about 56% of the total population lived in cities, in 2050 the percentage will have been risen to 68%. 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, the importance varying by sub-region (UN-DESA 2014). Water demand of urban dwellers is generally higher than of rural ones, causing the overall water demand to increase.

3 PROBLEMS ASSOCIATED TO GOVERNANCE, LEGISLATION AND ADMINISTRATION

There are a number of problems associated to governance, legislation & administration, farmers and herders in Arab countries have to deal with.

Governance

According to UNDP, "*key elements of good ... governance include equity, transparency, accountability, environmental and economic sustainability, stakeholder participation and empowerment, and responsiveness to socio-economic development needs*" (UNDP 2013)**.** But 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:

- There is often a too low commitment of the government to support rural areas
- Unsatisfactory cooperation between ministries and other governamental bodies, which deal with agriculture, forestry, water resources and environment.
- Fragmented responsibilities in the agricultural, forestry and water sector amongst several ministries and subordinated bodies.
- Missing funds to support applied research which is suitable to solve farmers', herders' and fishermen's problems
- There is a need for Governmental action to implement land capability and land suitability maps to conserve agricultural lands, forests and natural sites to sustain healthy environment, maintain natural habitats, biodiversity and eco-tourism (FAO 2012).
- There is a need for national water resources management and land use master plans (if not yet available) and the installation of a central body that plans, coordinates and oversees related activities

.**Legislation**

- Missing legal and policy framework supporting and materializing government's decisions

- Missing legislation and regulations e.g. regarding land leases, land fragmentation, transmission of inheritance, annexation of land
- Needed acceleration of legal issues and disputes over water and land ownership.
- Missing laws and regulations regarding cadaster of rural areas, one of the main problems of land tenure, land management and agricultural investment.

Administration

- An often too low schooling and training level of farmers and herders,
- Missing funds for agricultural modernization, implementation of rainwater harvesting
- Missing support for an improved, wellfunctioning agricultural extension services
- Need for better land use planning and its implementation to regulate urban expansion and to protect groundwater resources.
- Missing financial incentives to farmers, companies and urban dwellers to improve water efficiency and to apply water conservation.

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4 PROBLEMS OF THE SUB-SECTORS OF ‚AGRICULTURE'

Rainfed agriculture

- Rainfed agriculture is exposed to the vagaries of the rainfall regime and the often occuring dry spells are an important cause for low yield levels.
- The high production risk determines the farmers risk aversion strategy to keep investments in fertilisation and costly improved seed material low. Soil nutrient mining (often associated with soil degradation) and low yields are the consequence. Missing manuring of the fields reduces water holding capacity and plant water uptake potential, i.e. it has a strong impact on agricultural productivity.
- In most Arab countries (exception: 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 based upon a few crops only and often on traditional varieties.
- Suitable, improved varieties are available for many locations, but missing information (problem of agricultural extension services!), risk aversion and lack of funds hinder their use.
- Supplemental irrigation could be helpful, but investments are hardly to be shouldered by most farmers. Another reason is often the steadily declining groundwater table, which pushes up the pumping costs.
- Water harvesting techniques in agriculture hold a great potential, but advice is often missing.
- Land fragmentation due to inheritance laws are another grave problem for gaining a livelihood from agriculture, resulting in out-migration from rural areas.
- The low yield level in rainfed agriculture prevents any increase in food self-sufficiency of most Arab countries and is one reason for the steadily rising food imports.

Irrigated agriculture

- Groundwater tables are sinking, impeding water lifting and increasing the production costs.
- The growing cities demand rising water volumes to satisfy urban water needs on the expense of the water resources for irrigated farming.
- Due to lack of renewable water, fossil water, wastewater and drainage water has to be used in increasing volumes. The generally lower quality of these sources of water can cause problems for agricultural production.
- Salinization of land reduces yield level and may be lethal to plants. In Arab countries salinization has got very different causes which have to be tackled adequately:
    - Use of brackish water or (saline) drainage water for irrigation without leaching,
    - Irrigation (even with good quality water) without sufficient drainage,
    - Expanding irrigation areas in oases without sufficient capacity of the saltwater ponds,

- Over-irrigation (e.g. in oases by pumping fossil water) inducing groundwater table rising near to surface (Fig. 1).
- Available funds dictate often the irrigation method applied, not the needs of the crop or the scarcity of water. The full potential of the irrigation method is rarely tapped.
- Water use efficiency is often low due to inadequate management. ‘More crop per drop’ is too often neglected.
- In many cases conveyance and distribution losses are high.
- Even in arid Arab countries, crops with a very high water demand are cultivated because of the high price paid for the product (e.g. banana production in Jordan, rice production in the Nile delta). This conduct can hardly be tolerated when applying IWRM principles.

Animal husbandry

- Due to population growth in rural areas, the number of sheep and goats has been steadily rising, often far beyond the grazing capacity.
- Large-scale overgrazing is the consequence, causing vegetation decline and finally land degradation.
- Water supply (of good quality water) has become a problem in many areas due to the larger number of animals and alienation of water for other purposes.
- Diversification is at 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
- Breeding work has been done by a number of organisations (e.g. ACSAD) and institutes (e.g. ICARDA), but their impact on the majority of flocks and herds in Arab countries has been rather limited.

Forestry

- Firewood and timber are in rural and urban areas often in short supply, causing deforestation
- Protection of still forested areas is rarely an imperative for Governments, however there are some notable exceptions (e.g. in Lebanon)
- Reforestations are carried out using too few species.
- Maintenance of afforestation plantings (irrigation, weeding, protection against damage caused by animals’ herds etc.) is often inadequate.

Inland fisheries and aquaculture play a marginal role in spite of having a great potential (e.g. for fish and shrimps species suitable for brackish water),

- Applied research in aquaculture is rarely done until now in Arab countries.
- Production of fingerlings is well developed in Egypt, but in most other Arab countries still in an infancy stage
- The same applies to the cold storage infrastructure and processing industry in most Arab countries.

III IMPACT OF CLIMATE CHANGE AND VULNERABILITY ASSESSMENT OF THE SECTOR BASED ON RICCAR OUTPUTS

Actions needed to assess the climate change and vulnerability impact 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 programmemes; (2) Strengthening national research and training institutions in order to ensure the sustainability of the capacity-building programmemes; (3) Developing and enhancing technical capacities and skills to carry out and effectively integrate vulnerability and adaptation assessment into sustainable development programmemes and develop national adaptation programmemes of action. (4) Enhancing public awareness (level of understanding and human capacity development) on climate change impacts, mitigation and adaptation. (4) Supply the financial means to implement the programmeme of climate change adaptation (and mitigation).* (Based on recommendations of the UN Framework Convention on Climate Change)

1 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 Arab region will be aggravated by ensuing climate change, with serious implications on socio-economic development. Climate change threatens agricultural production through higher and more variable temperatures, changes in precipitation patterns and increased occurrences of extreme events like droughts and floods. Reduced precipitation in combination with higher temperatures leads to an increase in the demand for water, which surpasses the renewable supply already strongly. 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 impacts groundwater quality by seawater intrusion (IPCC 2014). The already existing problems of food security and dependence on imports will aggravate strongly (Solh and Saxena 2011).

When discussing the impacts of climate change on agriculture, three orders have to be distinguished (Fig. 2).
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 or larger floods etc.

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 (Fig. 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, economic losses.
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 climate change and result from human activities (socio-economic factors) (UN-ESCWA 2011, pp.62-64).
The expected climate changes impact on precipitation in the various parts of the Arab region is shown in figure 4, and for temperature in figure 5. The biophysical and socio-economic impacts of climate change on food production can be found in table 2.
A detailed description of the impacts of climate change on agriculture is given in the Annex A.

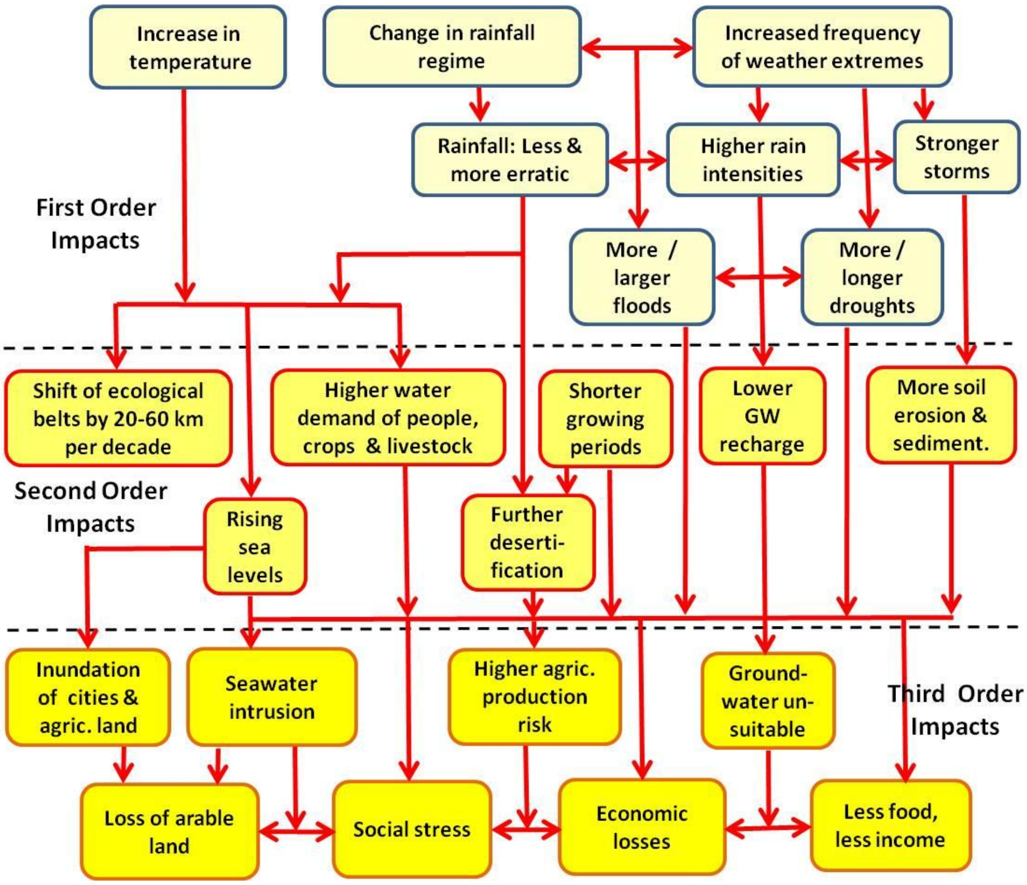

Fig. 2: First, second and third order impacts of climate change on agricultural production in Arab region

Fig. 3: Forest resources are also endangered by climate change, such as the cedar forests in Lebanon
Photo: Prinz

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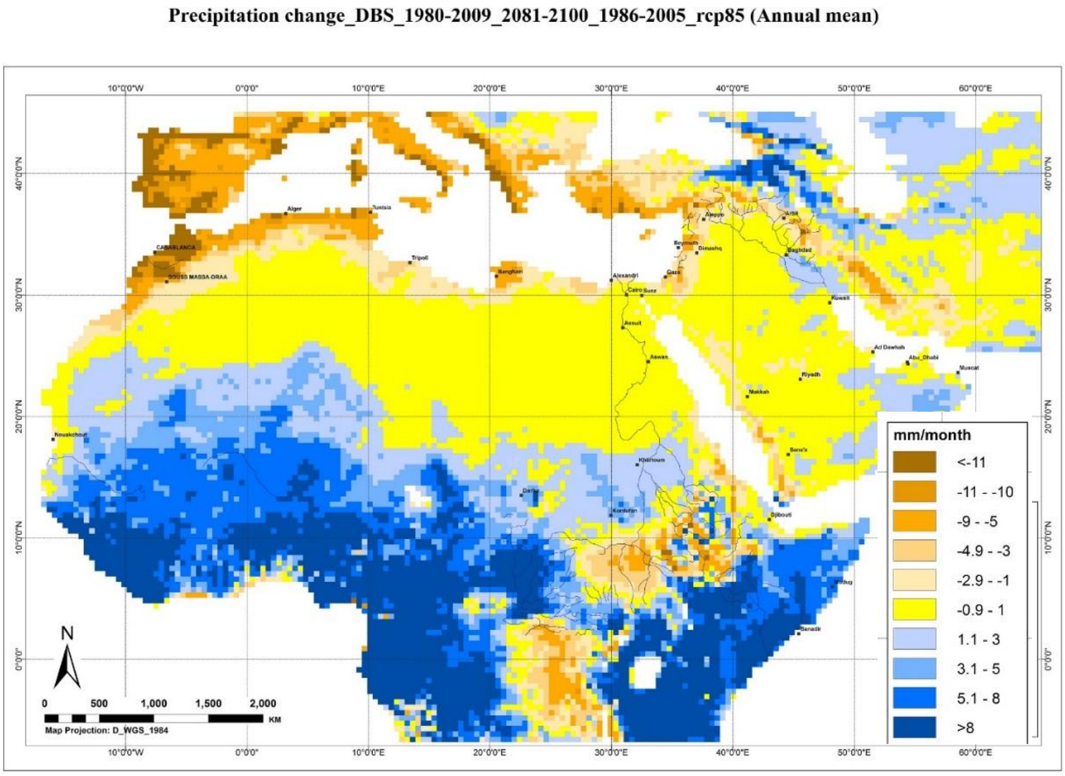


Fig. 4: Precipitation changes (in mm/month) expected for the period 2081 – 2100, compared to precipitation data recorded during the period 1986 to 2005, (Source: RICCAR)

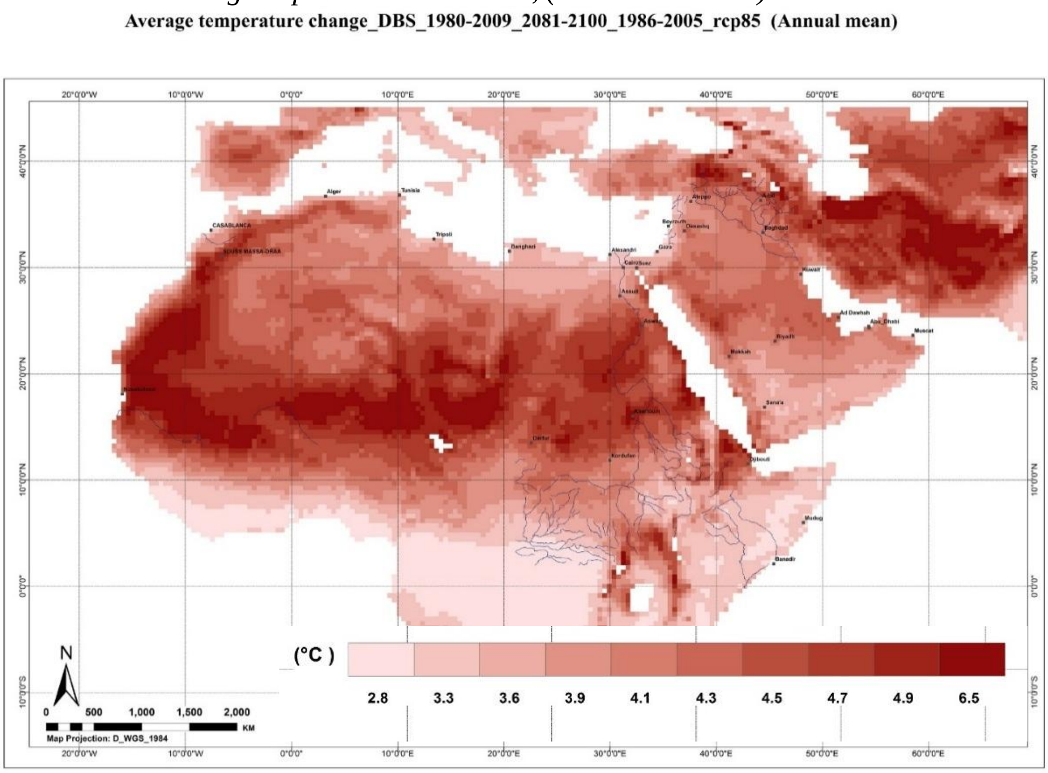


Fig. 5: Changes in temperature (in °C) expected for the period 2081 – 2100, compared to temperature data recorded during the period 1986 to 2005 (Source: RICCAR).

The biophysical and socio-economic impacts of climate change on food production are shown in Table 2.

Table 2: Biophysical and socio-economic impacts of climate change on food production
Source: Adapted from FAO 2007

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

2 VULNERABILITY ASSESSMENT

Vulnerability is understood to be the function of a system's climate change exposure, sensitivity and adaptive capacity to cope with climate change effects (IPCC 2007; Fig. 6).

According to the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC, AR4), these terms are defined as follows and illustrated in figure 7:
Exposure refers to changes in climate parameters that might affect socio-ecological systems. Such parameters are for example temperature, precipitation and wind speed, which climate change alters with regard to their quantity and quality as well as their spatial and temporal distribution.

Sensitivity tells us about the status quo of the physical and natural environment of the affected systems that makes them particularly susceptible to climate change. For example, a sensitivity factor could be topography, land use land cover, distribution and density of population, built environment, proximity to the coast, etc.
Potential Impact is determined by combining exposure and sensitivity to climate change on a system.

Adaptive capacity "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."

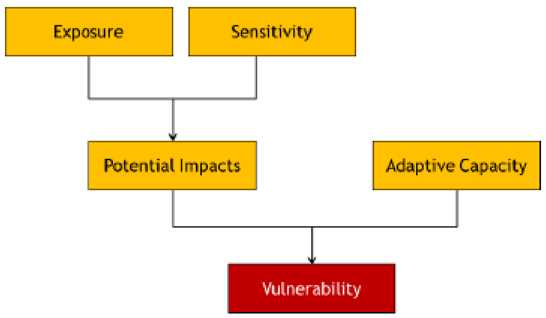


Fig. 6: The components constituting vulnerability based on IPCC AR4 approach
Source: IPCC 2007

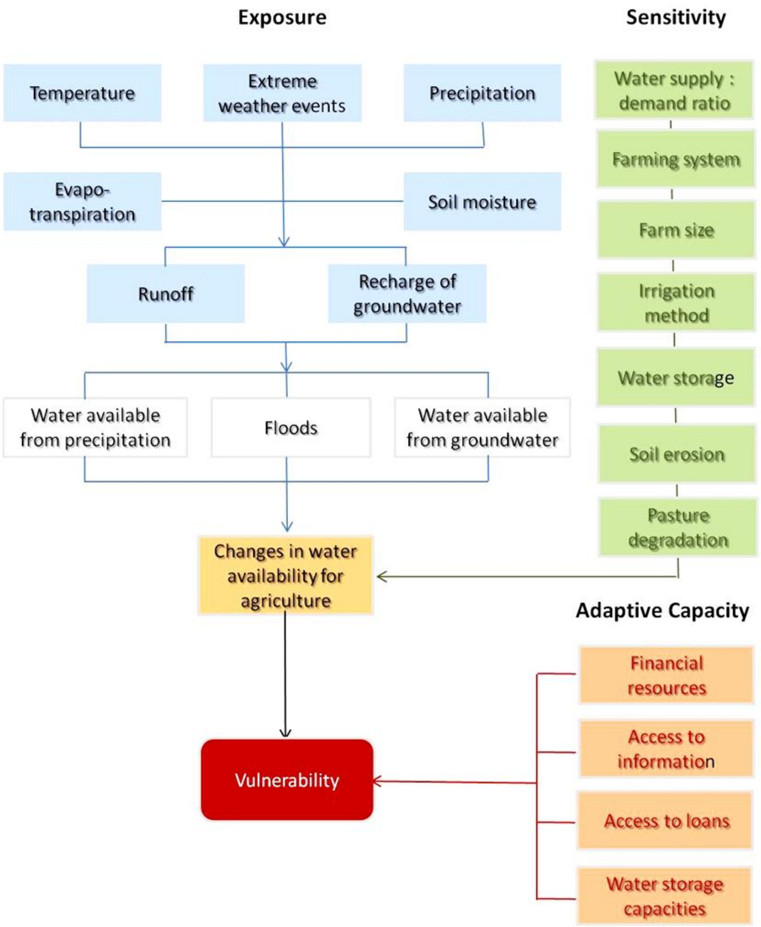


Fig. 7: Vulnerability chart of the agricultural sector in Arab region. Exposure, sensitivity and adaptive capacity determine the vulnerability .

Source: Prinz/European Academy of Bozen/Bolzano (EURAC).

Fig. 7 tries to examplify the vulnerabilty approach. The 'exposure' section shows the impact of the most relevant climate parameters (affected by climate change) on water-related parameters important for agriculture. The 'sensitivity' section contains parameters which decide on robustness or weakness of a farming system towards exposure to climate change impacts. The degrees of exposure and sensitivity determine the potential impacts of climate change on this specific farming system.
However, to determine the vulnerability the adaptive capacity has to be known, which is related to (socio-) economic and financial parameters.

Crop production
Expected climatic changes will lead to region-specific impacts on land and water resources, greatly affecting crop productivity and the agricultural sector in the coming decades. Vulnerability of rainfed cropping is highest as their adaptive capacity is very low. Vulnerability of irrigated agriculture with a secure water supply (e.g. sufficient water storage capacities) is lowest and rainfed cropping with means for Supplemented Irrigation is somewhere in-between.

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 add additional stress and increase vulnerability. The availability of sufficient fodder is always the key question for livestock producers. If financial means are available to buy fodder from other sources, it will decrease its vulnerability.

Inland fisheries
Inland fisheries are affected by climate change too. Some expected impacts of climate change on fisheries and aquaculture include stress due to increased temperature and oxygen demand, deteriorated water quality, reduced flows, etc. which increase vulnerability.

Table 3 supplies an overview over exposure and sensitivity of various farming systems in Arab countries, indicating their vulnerability level.

Table 3: Climate change impacts on farming systems of the Arab region

Farming system	Exposure: expected climate-related changes	Sensitivity: likely impacts on farming systems
Irrigated	• Increased temperatures • Reduced supply of surface irrigation water • Dwindling groundwater recharge • Loss of production in low-lying coastal areas	• More water stress • Increased demand for irrigation and water transfer • Reduced yields when temperatures are too high • More difficulty in agricultural planning • Salinization from reduced leaching • Reduction in cropping intensity
Highland mixed	• Increased aridity • Greater risk of drought • Possible lengthening of the growing • Reduced supply of irrigation water	• Reduction in yields • Reduction in cropping intensity • Increased demand for irrigation period
Rainfed mixed	• Increased aridity • Greater risk of drought • Reduced supply of irrigation water • Loss of production in low-lying coastal	• Reduction in yields • Reduction in cropping intensity • Increased demand for irrigation • More difficulty in agricultural planning area
Dryland mixed	• Increased aridity • Greater risk of drought rangeland • Reduced supply of irrigation water	• System very vulnerable to declining rainfall; some lands may revert to • Increased demand for irrigation
Pastoral	• Increased aridity • Greater risk of drought • Reduced water for livestock and fodder	• Very vulnerable system, where desertification may reduce carrying capacity significantly • Increase in nonfarm activities, exit from farming, migration

Source: Verner 2012

Adaptation should be coupled with mitigation. Agriculture is offering promising opportunities for mitigating emissions through carbon sequestration in soil (organic matter) and trees or other perennial plants.

3 RICCAR INDICATORS AND OUTPUTS THAT FEED INTO THE IDENTIFICATION OF ADAPTATION MEASURES

RICCAR, a methodology for conducting an integrated assessment of vulnerability to climate change in the Arab region, was developed by UN-ESCWA and RICCAR partners, 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', 'Change in Run-off'
(2) Sensitivity indicators such as 'Population Density', Share of Population Employed in Agriculture' or 'Total Renewable Water Available per Capita', and

(3) Adaptive capacity indicators, such as ‘Literacy Rate’, ‘Number of University Graduates’, ‘Share of GDP Expenditure on R&D’‘, ‘Area Equipped for Irrigation’.

The collected data sets were classified and normalized. 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’. A correlation of this factor with the ‘Adaptive Capacity’ yields the level of ‘Vulnerability’.
As outcome of impact assessment, maps for the Arab region are prepared; their spatial resolution is presently 50 km x 50 km (Sadek 2014).

4 OTHER INFORMATION TOOLS AVAILABLE FOR THE ‘WATER & CLIMATE’ NEXUS

The **RICCAR Regional Knowledge Hub for Water and Climate** is currently under development and its **main objective** is providing an interactive, on-line platform that provides access to information and knowledge on climate change-related analysis and water resources and socio-economic vulnerability assessment tools for informing climate change adaptation 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 and exchange. (3) To support awareness raising for national and local stakeholders. (4) To provide capacity building support. (5) To develop an early warning platform by establishing a simple disaster early warning component (Sadek 2014). Additional information on the Regional Initiative RICCAR is available at: www.escwa.un.org/RICCAR

IV IDENTIFICATION OF ADAPTATION MEASURES AND OPTIONS (IWRM TOOLS) FOR THE SECTOR

(1) The climate change projections call for immediate action, 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) to create a total resource view with water as a cross-sectoral input to development.
(4) Climate change will require upgrading disaster risk management for floods and drought.
(5) Nonconventional supply options, storage, and conveyance capacity can enhance resilience in the face of droughts and floods.
(6) More elaborated water demand management is required to achieve sustainability and reduce the need for expensive water-supply infrastructure.
(7) Enhanced regional economic integration will encourage water investment in less developed Arab countries and facilitate trade in water-intensive products from more water-endowed countries.
(8) Investments should be made in developing an information base and in climate change research and development.
(9) To protect water resources from pollution, governments should enact and enforce water laws and regulations.
(10) Overall water governance needs improvement at all levels, including the full participation of stakeholders

1 LINKING CLIMATE CHANGE ADAPTATION TO IWRM

1.1 *Future water demand*

Future demand of managed water will largely be determined by population increase, urbanization, lifestyle and extent of climate change. By 2050 it is expected that the demand for fresh water in the Arab region

will increase (at least) by 50 percent, coupled with a halving of the per capita water availability (World Bank 2007; UN ESCWA 2006). Currently, nearly 75 percent of the water resources in the Arab region is allocated to agriculture, 22 percent to domestic use, and 3.5 percent to industries (FAO 2012).
Fig. 8 shows the presumed water demand and supply in Arab region until 2050, based on climate change scenario AVG.

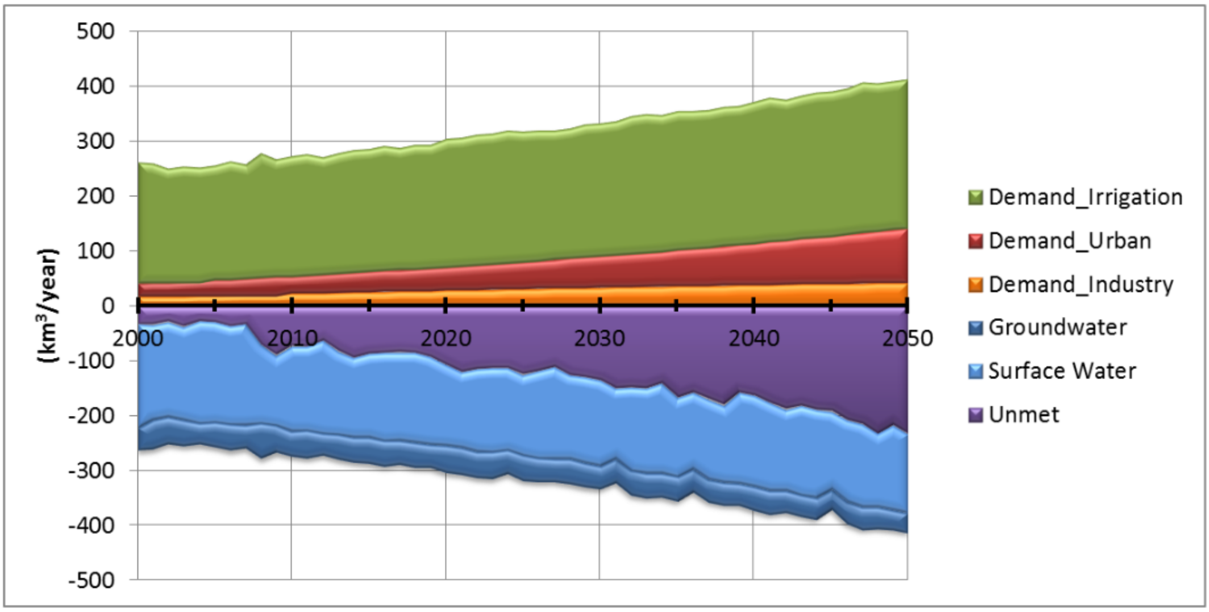


Fig. 8: Water demand and supply in Arab region, based on climate change scenario AVG
Source: World Bank 2011

While the water demand is continuously rising, the groundwater and surface water supply is lightly diminishing, leaving a steadily rising gap of 'unmet demand', which is the real challenge ahead. This graph does not include usable rainwater resources (on the supply side) and the 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 to aquaculture, hydropower generators, and for irrigation in succession. 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 lowest in comparison with industry and municipalities.

1.2. *Options to satisfy future water demand*

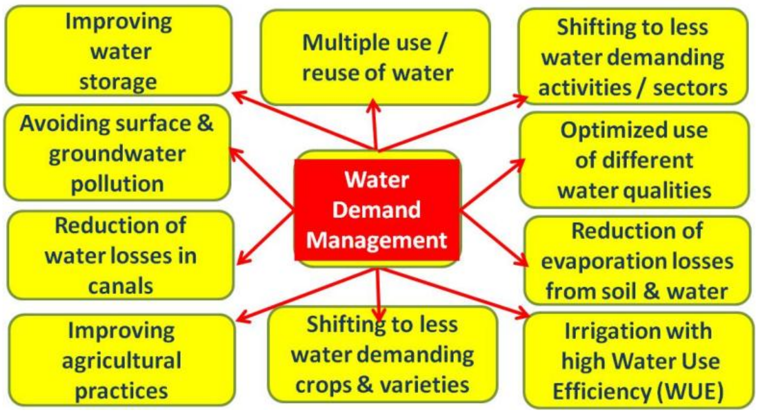
Looking at the topic of satisfying future water demand from a wider perspective, we have to give attention to:

- good governance,
- human resources development,
- institutional structures,
- public finance and
- natural resource management (UNDP 2013).

- Good governance / adapted policy includes
    - a water policy favouring water **demand** management, development of marginal water sources, water (supply) pricing, decentralized water storage, etc.
    - support to improved water use in water conveyance, irrigation, crop selection, animal husbandry etc.

- Measures to improve safety from floods, droughts and other calamities
- Adjustment in commodity and trade policy ('Virtual Water' aspect).
- More support to reduce post-harvest losses of grain and other food commodities (e.g. in national depots)
- Strengthening agricultural extension and communication systems
- Supporting pilot farms for applied research and demonstrations
- Cadastre development, etc.

- Human resources development, including capacity building, which includes e.g.
  - Support to reduce analphabetism and lift up general education level.
  - Offering training courses for farmers and herders
  - Keeping stakeholders informed and allowing participation in decision making
  - Awareness campaigns to reduce general water use at all sectors, including drinking water consumption and industrial water use; 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 habits, etc..
- Institutional structures such as
  - Water boards
  - River basin organizations
  - Farmers' cooperatives
  - Water user associations etc.
- Public finance, e.g.
  - to establish hydraulic structures (for reservoirs, etc.)
  - to support incentives for water conservation



  - to supply cheap loans for improvement of irrigation systems, water harvesting etc.
  - to establish an early warning system for flood waves, etc.
- Natural resource management, which includes e.g.
  - Protection of surface water resources
  - Protection of groundwater resources (e.g. by land use planning and its enforcement)
  - Artificial groundwater recharge
  - Protection of wetlands
  - Soil protection to avoid any form of land degradation (soil erosion, salinization etc.)
  - Minimizing groundwater over-abstraction
  - Efficient use of renewable and fossil water resources, etc.

In a more narrow view, the general fields of options to close the gap between future water demand and water supply are:

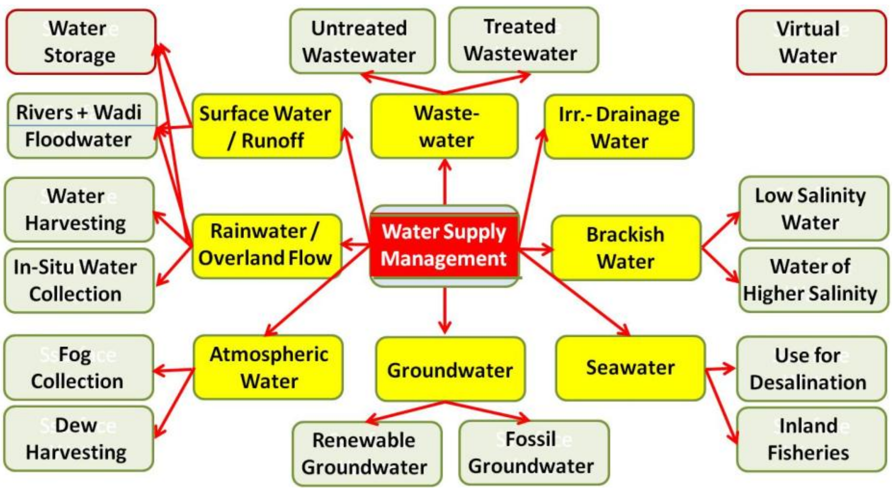
(a) **Demand Management:** It is heading for a decrease in water use, e.g. by (1) education and training, (2) water pricing and other economic measures and (3) making use of technical options. An overview on these technical options is given in Fig. 9.

(b) **Supply Management**: It tries to increase the available quantity of water by making best use of all sources of water in reach, e.g. (1) surface water of permanent rivers or ephemeral streams (wadis) (2) groundwater sources, (3) rainwater and overland flow, (4) atmospheric water (fog and dew), (5) unconventional water such as wastewater, drainage water, brackish water and seawater and finally virtual water (Fig. 10).

(c) The challenge for the Arab countries is to react sustainably by closing the gap between projected water supply and future water demand.

Fig. 9: The most important elements of water demand management in the agricultural sector to combat the impacts of climate change. A reduced domestic water demand will also be helpful to cover the demand.

Fig. 10: In order to increase the usable water quantity, a number of water supply management tools are available.



2 IWRM TOOLS TO BE APPLIED IN CLIMATE CHANGE ADAPTATION

The concept of 'Integrated Water Resources Management' (IWRM) is based on **three principles**:

(1) Social equity: ensuring equal access for all users (particularly marginalised and poorer user groups) to an adequate quantity and quality of water necessary to sustain human wellbeing.

(2) Economic efficiency: bringing the greatest benefit to the greatest number of users possible with the available financial and water resources.

(3) Ecological sustainability: requiring that aquatic ecosystems are acknowledged as users and that adequate allocation is made to sustain their natural functioning.

The management instruments for IWRM are the tools and methods that enable and help decision-makers to make rational and informed choices between alternative actions.

According to IPCC (IPCC 2007: p. 869), adaptation to climate change can be defined as "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". The term '**autonomous adaptation'** is used for measures occurring spontaneously, whereas '**planned adaptation'** measures 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 takes place before impacts are apparent (Cap-Net 2009).

Fig. 11 shows the IWRM goals, objectives, approach and tools of our project.

The management instruments for IWRM are the tools and methods that enable and help decision-makers to make rational and informed choices between alternative actions. The first and prominent tool is capacity building, the core element of this UNDA project, followed by water policy and planning, which have to be adapted to the national needs. Further tools are stakeholder participation, water conflict resolution and environmental management.

The goal of adaptation measures is to improve water management in order to balance multiple uses – including social, economic and environmental benefits – of water resources. The social and environmental value of water is hardly recognized by economic policy-makers and its importance for national economies is largely unaccounted for.

Adapted planning is an important IWRM tool. Table 4 is a compilation of measures serving directly or indirectly the purpose of climate change adaptation in agriculture. When dealing with IWRM, reducing the impact of water abstraction and pollution on natural environments and ecosystems must keep a high priority. The same applies to the duty to reduce the vulnerability of populations to extreme events such as droughts, floods and storms.

There is a strong nexus between water, energy and food production (UN-ESCWA 2015). All adaptation measures have to comply with this nexus to be resource-efficient.

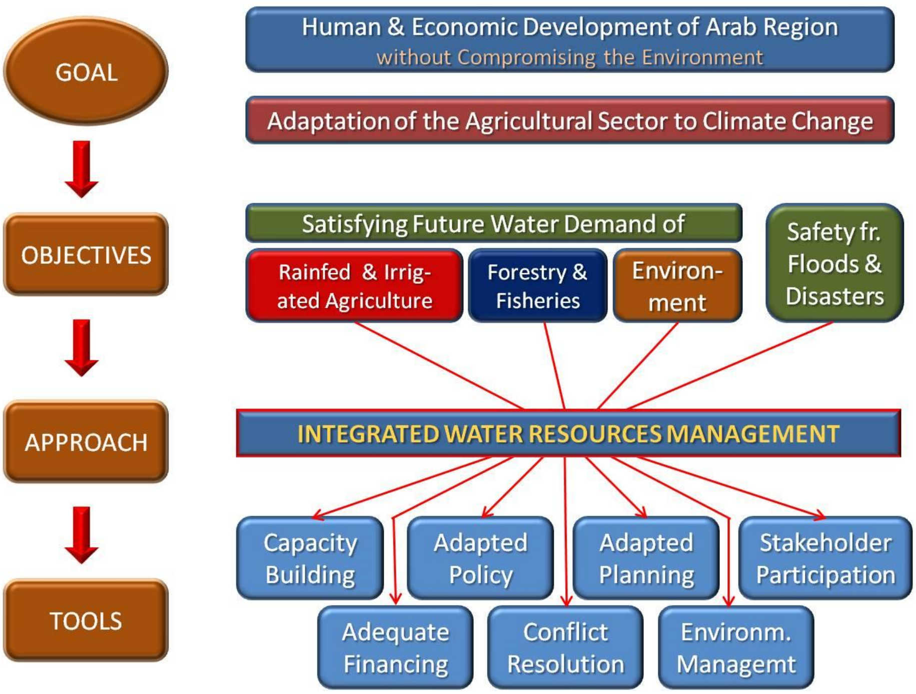


Fig. 11: Application of the IWRM concept for climate change adaptation to the 'Agriculture' sector. Source: Prinz 2014a, adapted

Table 4: Adaptation measures in rainfed and irrigated agriculture (Overview)

Adaptation Measure	Remarks	Adapt. Type*
Increasing available water quantities: See Chapter "Water resources & their potential"		
Improving water storage : See Chapter "Water storage"		
Protecting water resources		
Avoiding surface water contamination	By point source (e.g. 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 (Canals are often used for solid waste dumping)	Awareness campaigns and alternative places for solid waste collection are needed.	RA
Reduction of water losses		
Lower losses in conveyance & 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 & catching water	
'Water Harvesting' (Microcatchments, Macrocatchments, Floodwater harvesting)	Collecting rainfall and overland flow and storing it either in the soil volume or in ponds	RA
Evaporation losses from soil surfaces	Using (plastic) mulch, windbreaks, shelterbelts	RA
Cultivation in 'Protected Environments'	Cultivation in greenhouses & plastic tunnels reduces evapotranspiration	RA
Irrigation with high Water Use Efficiency (WUE)		
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 reference evapotranspiration 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
Improving agricultural practices		
Change of sowing dates, and depth	Applied agricultural research helpful	RA
Better plant nutrition	Appl. of organic manure, mineral fertilizer	RA
Use of less water demanding, well adapted crops and varieties and crop diversification	Needed: Breeding work, seed distribution; a motivated Agricultural Extension Service	AA
Combination of cropping with animal husbandry	Crop residues as fodder, manure for crop nutrition	RA/AA
'Conservation Agriculture'	Mainly for mechanized agriculture	AA
Additional measures		
Establishment of Early Warning Systems	*AA = Anticipatory adaptation; RA = Reactive adaptation	AA
Drought monitoring		AA
Education in water management, Soil and Water Conservation, water harvesting etc.		AA

3 MODERN TOOLS FOR IWRM

3.1 General

The hydrological cycle has several components: rainfall, runoff, infiltration, which recharges the ground-water, evaporation from soil and water bodies and evapotranspiration (Fig. 12).

Effective water management is essential, and this requires appropriate decision support systems, including modeling tools. Modeling methods have been widely used over 40 years for a variety of purposes. Arid and semi-arid areas have particular challenges that have received little attention.

Several models are used in IWRM, some deal with climate, others deal with surface and groundwater; modeling crop growth is also a main issue in IWRM.

The tasks for which rainfall-runoff models are used are diverse, and the scale of applications ranges from small catchments, of the order of a few hectares, to that of global models.

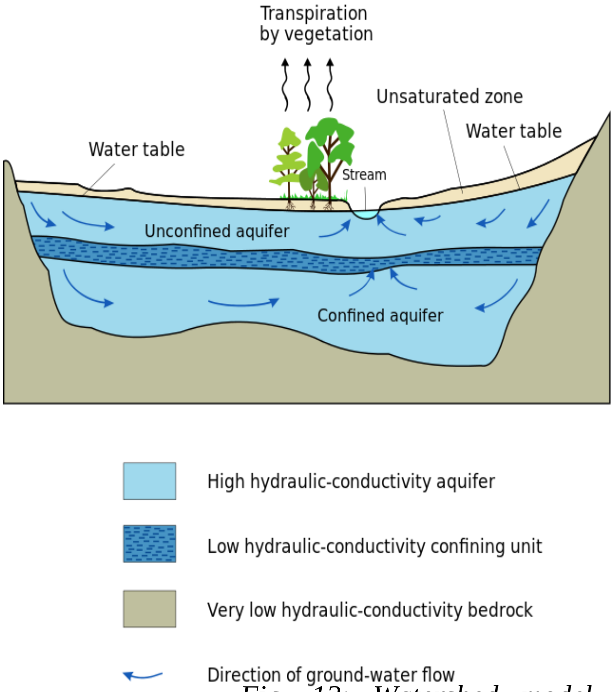


Fig. 13: Cross-section of river valley
Source: http://www.centralbasin.org

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

- simple empirical methods (e.g., curve number and regression equations);
- large scale energy-water balance equations (e.g. Budyko curve);
- conceptual rainfall-runoff models (e.g. SIMHYD, Sacramento, AWBM);
- landscape daily hydrological models (e.g., VIC, WaterDyn);
- fully distributed physically based hydrological models which explicitly model hillslope and catchment processess (e.g. SHE, TOPOG).

Hydrological models are usually used to design rainwater harvesting construction like dams and mountain lakes.

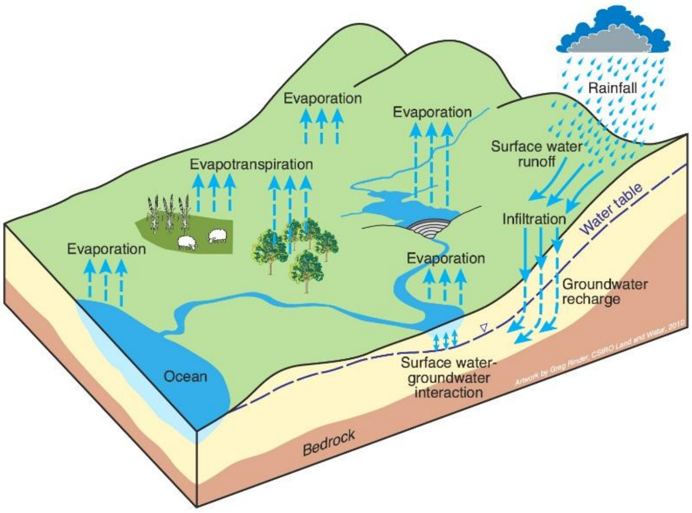


Fig. 12: Watershed model showing the components used in hydrological modelling

3.2 Modeling 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, so modeling the ground water aquifers allow the sustainable use of this precious resource.

Groundwater models may be used to predict the effects of hydrological changes (like groundwater abstraction or irrigation developments) on the behavior of the aquifer (Fig. 13) and are often named groundwater simulation models. Also nowadays the groundwater models are 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 runoff, soil moisture, evapotranspiration and groundwater recharge. Flows through the unsaturated zone that couple surface water to soil moisture and ground-water can be upward or downward, depending upon the gradient of hydraulic head in the soil, can be modeled using the numerical solution of Richards' equation partial differential equation, or the ordinary differential equation Finite Water-Content method as validated for modeling groundwater and vadose zone interactions.

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

- The total volume that may be withdrawn annually from the aquifer.
- The location of pumping and artificial recharge wells, and their rates.
- Decisions related to groundwater quality.
- Groundwater contamination by:
  - Hazardous industrial wastes
  - Leachate from landfills
  - Agricultural activities such as the use of fertilizers and pesticides.

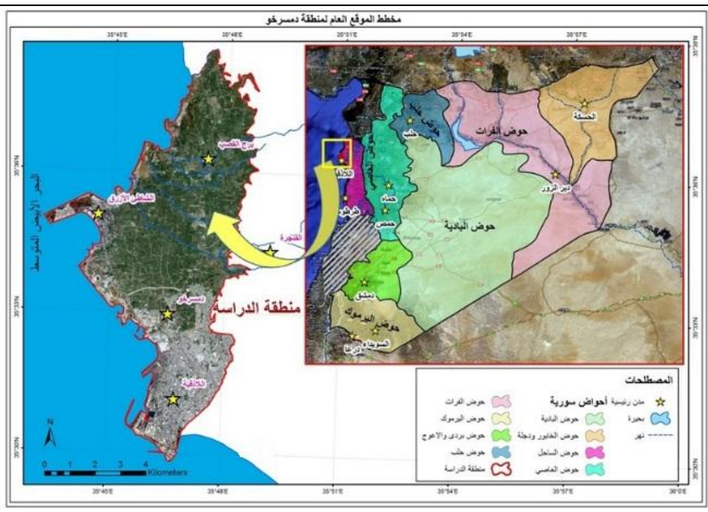
The crop water need (Actual evapotranspiration ET_{cropc}) is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally.

- 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 favorable 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:

- the climate: in a sunny and hot climate crops need more water per day than in a cloudy and cool climate
- The crop type: crops like maize or sugarcane need more water than crops like millet or sorghum
- The growth stage of the crop; fully grown crops need more water than crops that have just been planted (Fig. 14).

The influence of the climate on crop water needs is given by the reference evapotranspiration (ET_0). The influence of the crop type and growth stage on crop water needs is expressed in the crop factor (K_c).
Therefore, in order to estimate the water requirement of a crop we first need to measure the evapotranspiration rate. The reference rate, ET_0, is the estimate of the amount of water that is used by a well-watered grass surface that is roughly 8 to 15 centimeters in height. Once ET_0 is known, the water requirement of the crop can be calculated.



Using groundwater modeling to study seawater intrusion in Demserkho/Syria

Demserkho is a coastal are in Syria, the seawater intrusion started to appear recently in this area in form of salinization of some wells. The project assesses 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 prepared model was implemented at the ministry of water resources in Syria 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 of the project at ACSAD and the Ministry of Water Resources in Syria, www.acsad.org

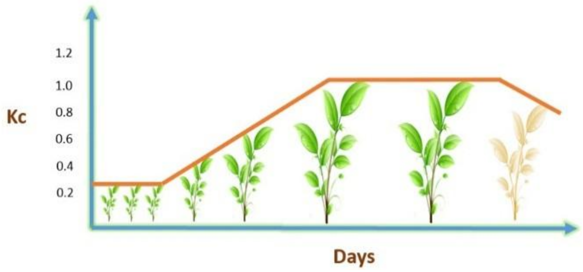


Fig. 14: The four growth phases of annual plants
Source: http://www.smart-fertilizer.com/

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 scheme water supply 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.
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: the soil, with its water balance; the crop, with its development, growth and yield; the atmosphere, with its thermal regime, rainfall, evaporative demand and CO2 concentration; and the 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.

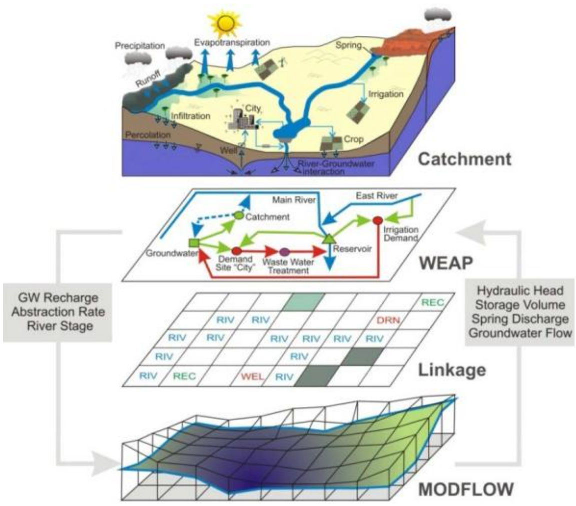


Fig. 15: 3-dimenional water resources planning in WEAP.
Source: http://www.bgr.bund.de

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 & 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 the right tool to solve this problem. As an example on DSS systems, WEAP (Water Evaluation And Planning System) is a software 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.

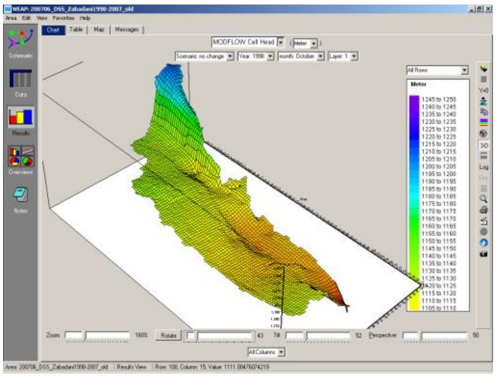
WEAP approach is operating on the basic principle of water balance accounting, WEAP is applicable to municipal and agricultural systems, single sub-basins or complex river systems. Moreover, WEAP can address a wide range of issues, e.g., sectoral demand analyses, water conservation, water rights and allocation priorities, rainfall runoff and baseflow, groundwater and stream flow simulations, reservoir operations, hydropower generation, water quality, ecosystem requirements, and project benefit-cost analyses (Fig. 15).

Application of WEAP (decision support system) in Zabadani basin in Syria

A water competition exists in the Zabadani Basin 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 involved 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 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 stockholders. The results showed that it can be stated that the linked WEAP-MODFLOW DSS is able to calculate realistic groundwater, surface and soil water balances as well as hydraulic heads. The scenarios have been developed within the project deal with realistic assumptions on domestic and agricultural demands as well as influences of climate change and consecutive drought years.



References:

http://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/TZ/Acsad/dss_fb_en.html?nn=1546392

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 FAO's products 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 costs.

3.3. The potential of Remote Sensing (incl. Google Earth) in CC adaptation

Remote sensing can provide data that help identify and monitor crops. When these data are organized in a Geographical Information System 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, in order 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.

Remote Sensing and Geo-Information Technologies could be used for several application in agriculture:

- **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 heavily rely 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 in this form can 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.

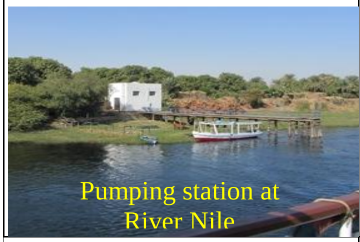
Google earth is a powerful tool for crop identification with its high resolution images and the digitizing tools included in the software which allow to digitize the polygons and take them in some accepted GIS formats like “klm” which creates an integrated environment between it and the GIS softwares (Fig. 16).

Fig. 16: Pivot irrigated areas
Source: Google Earth (ACSAD)

4 RESPONSE MEASURES: WATER RESOURCES

Adaptation to climate change in the framework of IWRM means making use of the full potential of the various water resources in an integrated way, paying due attention to environmental needs (Table 5).

Table 5: Overview of the various types of water resources being available for agriculture

	***Groundwater*** Measures to reduce a further lowering of (renewable and fossil) groundwater (GW) levels are: (1) GW recharge of surplus water during the rainy season, (2) GW recharge of floodwater, collected in large basins, (3) Construction of percolation dams, (4) Quota, licenses etc. to limit GW extraction, (5) Water demand management,. *Readings: Margane, 2003; Source of photo: Al Torbak (2011)*
	***Surface Water*** Most permanent rivers in 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 (1) better awareness and professional training of farmers, (2) support of farmers to have access to (cheap) loans for investments, (3) a functioning agricultural extension service, etc. *Readings: Photo: Prinz*
	***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 e.g, up to 50 liters per m² 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; Photo: Prinz*
	***Wastewater*** Only in rare cases untreated wastewater is safe to be used in agriculture or forestry (Fig. 15). Wastewater (of domestic origin only) should have passed at least an oxidation pond for treatment. Higher treatment levels are fitting better to 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;* *Photo: Prinz (Photo was taken in the West Bank, Palestine)*
	***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 discharges into the drainage canals have to be avoided to allow drainage water reuse. Its quality determines which crops can be irrigated. *Readings: Tanji & Kielen, 2003. See Case Study on the ACCWaM Pilot Study* "Enhancing the Overall Efficiency." *Photo: Dalia Gouda (ACCWaM)*
	***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 & GTZ, 2003; Photo: Prinz (Photo showing cooling pond in Tunisia)*
	***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**;** Photo: © Herman Gunawan*

Case Study: Enhancing the Overall Efficiency of Irrigation Water Usage through the Reuse of Drainage Water (ACCWaM Pilot Project Egypt)

The Egyptian Government has developed a **national climate change adaptation** strategy. One of the most expedient measures is the reuse of drainage water to ease the problem of irrigation water shortage. The uncontrolled reuse of drainage water, however, often results in the accumulation of salts and toxic substances in the soils of the irrigated areas.

Mobile pump units under operation
Photo: K. Kheireldin

The GIZ pilot project "**Increasing Water Efficiency through Drainage Water Reuse**" located in Damanhour in the Northern part of the Nile Delta, tries to avoid these problems. The **ACSAD**-supported a project covers an area of about 6000 feddan, cultivated by 3000 farmers, organized in 3 Water User Associations (WUAs). A mobile pumping unit allows the local communities to mix drainage water with irrigation water under controlled conditions.

Preconditions for a safe application are (1) a close cooperation of national and local level water authorities, the beneficiaries and a funding agency, (2) an acceptable quality of the drainage water plus an ample quantity of irrigation water, (3) permanent monitoring of water and soil quality, which demands adequate laboratory facilities, (4) training of farmers and pump operators.

Contact: Dr. M. Bartels (matthias.bartels@giz.de) or Dr. G. Lichtenthaeler (gerhard.lichtenthaeler @giz.de), ACCWaM Program of GIZ (German Agency for International Cooperation)

Link: http://www. water-energy-food.org/documents/giz/factsheet_project_egypt.pdf

The volumes of the various water resources available per capita or per country and other important water features are given on FAO AQUASTAT website: www.fao.org/nr/water/aquastat/dbases/index.stm.

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Fig. 17: Using treated wastewater and sludge in some ACSAD's 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 runoff will decline under CC impacts, and that groundwater recharge will do likewise. Decreasing runoff will affect salinity by reduction of dilution flows. 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 once a year or every two years. Leaching could be performed by flood or sprinkler irrigation but not by the drip irrigation to cover the whole area and not part of it.

5 RESPONSE MEASURES: WATER STORAGE & QUALITY ASPECTS

5.1 Water storage aspects

The impacts of climate change **demand more water storage** in rural areas. Water storage allows to bridge dry spells during the rainy season and allows prolongation of the cropping period into the dry season (Van Steenbergen 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 (as happened in Morocco).

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 both 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 (Fig. 18). However, all water storage options are also potentially vulnerable to the impacts of climate change (McCartney & Smakhtin 2010*).*

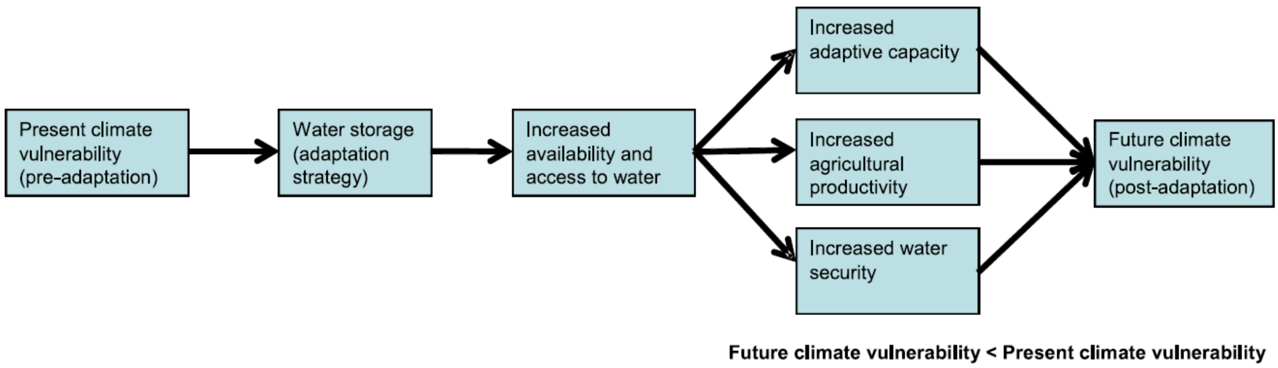


Fig. 18: Water storage as an adaptation strategy to reduce climate variability
Source: McCartney & Smakhtin (2010)

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; Fig. 19).

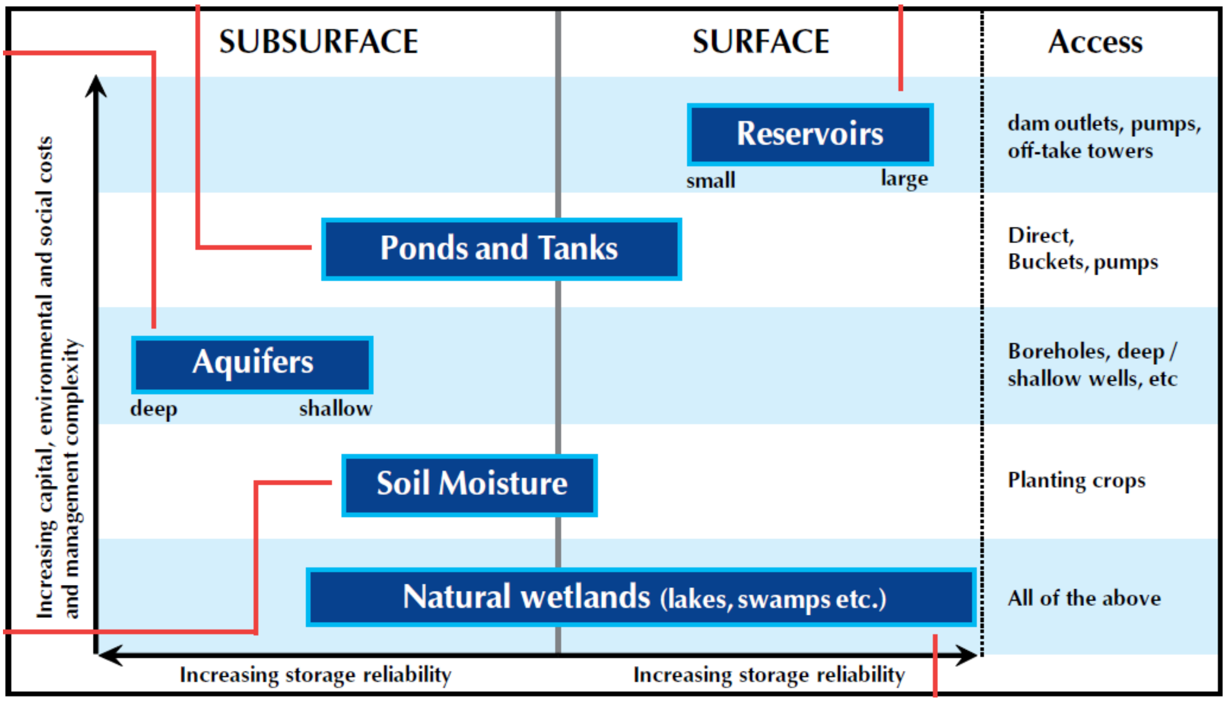


Fig. 19: The continuum of water storage options
Source: IWMI 2009

The case study on "Rooftop Water Harvesting for Greenhouse Production in Lebanon Mountains" describes a project carried out by the 'Green Plan' agency, where rainwater is 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.

Case Study: Rooftop Water Harvesting for Greenhouse Production in Lebanon Mountains

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

In the Lebanese mountains there is a high potential for **production of flowers and vegetables in greenhouse**s, but water supply is a problem. 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.

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

The **'Green Plan' agency**, an autochthonous authority under the Lebanese Ministry of Agriculture, (and partially financed by international donors), started a program 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^2; pond size is 1700 m^2; 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 between 18 and 39% of the total costs only and receive soft loans (annual 1% interest rate) for it.. Drawback for wider application is the limited availability of Government funds.

Publication: *Republic of Lebanon (2012). Hilly Areas. Sustainable Agricultural Development (HASAD). Project Design Report. Prepared by IFAT. Beirut, Lebanon.*

Link: www.greenplan.gov.lb

Table 6 gives an overview on possible biophysical risks associated with climate change in regard to various storage types.

Table 6: Storage types and relevant biophysical risks associated to climate change

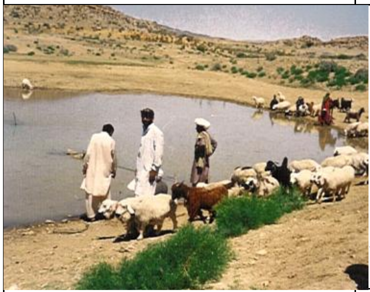
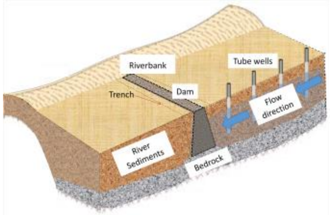
Storage Type	Possible biophysical risks associated with climate change
Reservoirs	• Reduced inflow, resulting in longer periods between filling • Higher evaporation, increasing the rate of reservoir depletion • Infrastructure damage as a result of higher flood peaks • Improved habitat for disease vectors (e.g., mosquitoes) • Increased risk of eutrophication and salinization • Increased siltation
Ponds and tanks	• Reduced inflow, resulting in longer periods between filling • Higher evaporation, increasing rates of pond/tank depletion • Infrastructure damage as a result of higher flood peaks • Improved habitat for disease vectors (e.g., mosquitoes) • Increased risk of eutrophication and salinization • Increased siltation
Soil moisture	• Reduced infiltration resulting from modified rainfall intensities • Waterlogging resulting from modified rainfall intensities and duration • Longer dry periods resulting from altered temporal distribution of rainfall • Depleted soil moisture arising from higher evaporative demand • Soil erosion resulting from modified rainfall intensities and duration • Reduced soil quality (including water holding capacity and nutrient status) resulting from modified rainfall and temperature
Aquifers	• Reduced recharge resulting from modified rainfall intensities • Reduced recharge resulting from land-cover modification and increased soil moisture deficits • Saline intrusion in near-coast aquifers • Increased percolation through frequent flooding

Source: IWMI 2009

The various modes of water storage, their characteristics and possible climate change adaptation measures are given in Table 7.

Table 7: Storage types, their characteristics and possible CCA measures

	**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, 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 climate change adaptation in agriculture and Agriculture Extension Services should be well trained on SWC. *Readings: McCartney & Smakhtin 2010. Photo: Prinz*
	**Cisterns** Cisterns are constructed fully or partially subsurface; their capacity ranges from 10 to 1000 m^3 or more. Modern cisterns are often built using reinforced cement concrete (see photo). Main problems of cisterns' use is maintenance and the right of water use: Beneficiaries should sign a contract on rights and duties (e.g. cleaning the sedimentation tank) prior to construction. Standard designs for future higher runoff should be available, adaptable to local needs. In general a very important element of CCA. *Readings: Akhtar et al., 2009; Photo: Saher Khouri, ARIJ*

	Ponds Ponds fill by surface runoff 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 (e.g. with white, Ultra Violet 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 runoff volume; siltation traps can reduce sedimentation. *Readings: Oweis et al. 2012; Photo: Prinz (Pond in the West Bank, Palestine)*
	**Hafairs** Hafairs are either ponds in natural depressions or excavated tanks. They fill by surface runoff 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: Oweis / ICARDA*
	**Reservoirs** Reservoirs are water impounded behind small and large dams constructed across streams and rivers. They *tend to* be shallow with relatively large surface areas so that, in common with many ponds, 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 & Smakhtin 2010 ; Photo: S. Wolfer (Tunisia)*
	**Subsurface Dams** The groundwater flow within the wadi bed lasts for weeks after a rainfall event. Subsurface dams are build 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: Predominantly coarse sand, availability of expert knowledge. They are also well adaptable to CC conditions. *Readings: Nissen-Petersen 2006; RAIN 2008; Drawing: Prinz*

Where very high intensity (extreme) events are likely, it may not be possible to capture adequate proportions of the peak flows with available or affordable infrastructure.
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).

5.2 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 drop in river flow or reservoir filling increases vulnerability towards 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, e.g. 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 waste water collection system and a 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 may not be located in water sensitive areas and they have to be supervised not to contaminate surface or groundwater. Their wastewater should be separately treated before being released and not mixed with wastewater from settlements (to allow its later 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 does contaminate soil and water, damaging health of humans and livestock.
- Under water shortage conditions water of drinking water quality should not be 'wasted' for 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 (Fig.20).

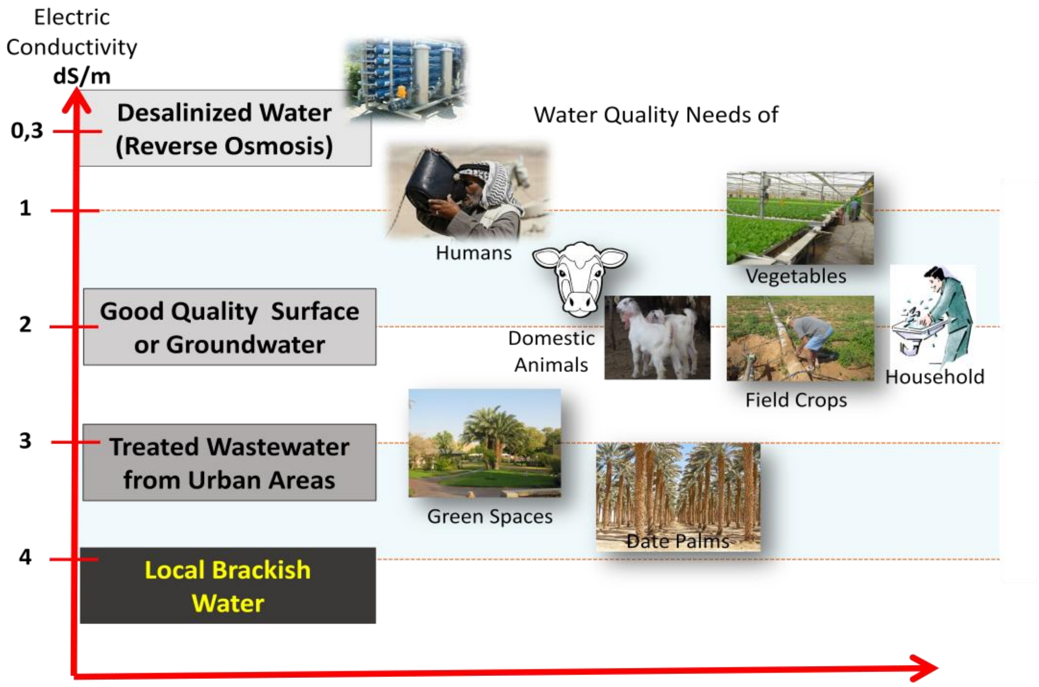


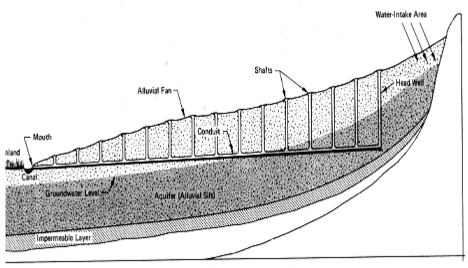
Fig.20: Quality of various water sources (in regard to salt content) and water quality needs of people, domestic animals and crops in Arab countries (Average values)

6 RESPONSE MEASURES: WATER HARVESTING

The term 'Water Harvesting' covers here (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 **climate change adaptation measures**. In 'rainwater harvesting' we distinguish between **micro-**catchment and **macro-**catchment water harvesting, depending on catchment size.

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

Table 8: Short overview over 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, 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.

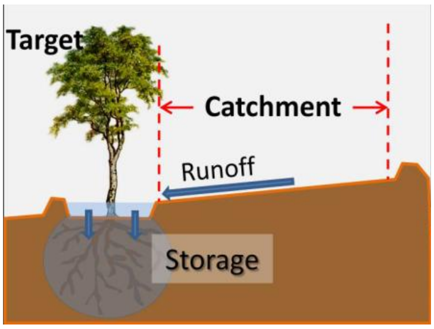
Climate Change Adaptation (CCA): Limiting the number of tube wells to avoid a (further) lowering of groundwater table; initiate the construction of contour ditches and bunds (at the lower side) in the catchment area to facilitate infiltration and invest in their maintenance.

Rooftop and Courtyard Water Harvesting (WH)

Description: Rooftop and Courtyard Water Harvesting' describes installations on and around buildings to facilitate rainwater collection. Uses: drinking water / domestic water, irrigation (e.g. 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.

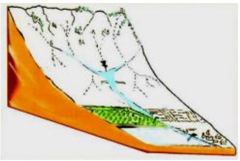
Climate Change Adaptation (CCA): Larger tanks for water storage to bridge dry spells. Incentives are needed to equip as many buildings in cities as possible with WH devices to secure water supply and to avoid floods by stormwater.

Micro-Catchment Water Harvesting

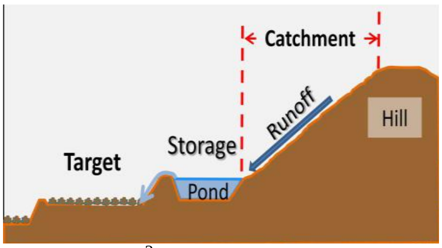


Description: Micro-Catchment Water Harvesting is a method of collecting surface runoff (sheet or rill flow) from a small catchment area and storing it in the root zone of an adjacent infiltration basin. The basin is planted with a single tree or bush or with annual crops. Size of catchment is 2 m²- 1000 m² and **R**atio between **C**atchment area and **C**ropping area (**CCR**) is from 1 : 1 to 25: 1.

Climate Change Adaptation (CCA): Higher rain intensities and more erratic rainfall will demand (a) application of more soil conservation measures within and around the micro-catchments, (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, (e) a larger soil depth than presently to increase water storage capacity.

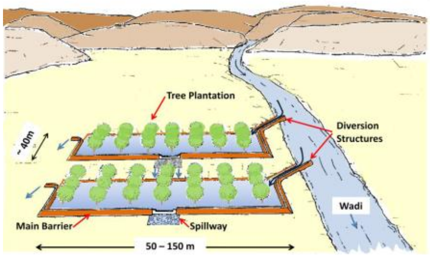


Macro-Catchment Water Harvesting



Description: This method is also called "water harvesting from long slopes" or "harvesting from external catchment systems". Runoff 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 runoff and store it for supplemental irrigation either during long dry spells within the rainy season or to prolong the growing season. Size of catchment is from 1000 m^2 to 200 ha and flow type is turbulent runoff; CCR: 10:1 - 100:1

Climate Change Adaptation (CCA): (a) Stronger diversion structures, (b) raised and strengthened bunds, (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. Size of catchment is greater than 200 ha and flow type is channel flow; complex structures needed; CCR: 100:1 - 10,000 :1 (and more); Precipitation is from 100 to 400 mm / year and cropping area is terraced or in flat terrain.

Climate Change Adaptation (CCA): Adaptation to more/larger floods can be achieved e.g. (a) by increasing size of structures for water diversion, (b) by enlarging the impoundment and (c) by designing larger / stronger spillways to evacuate excess water.

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 / runoff, will rise with growing impacts of Climate Change. But planning water harvesting schemes in rural areas with limited or unreliable topographic data is awkward. The use of the services of **Google Earth** can facilitate the planning and implementation of Water Harvesting for agricultural purposes.

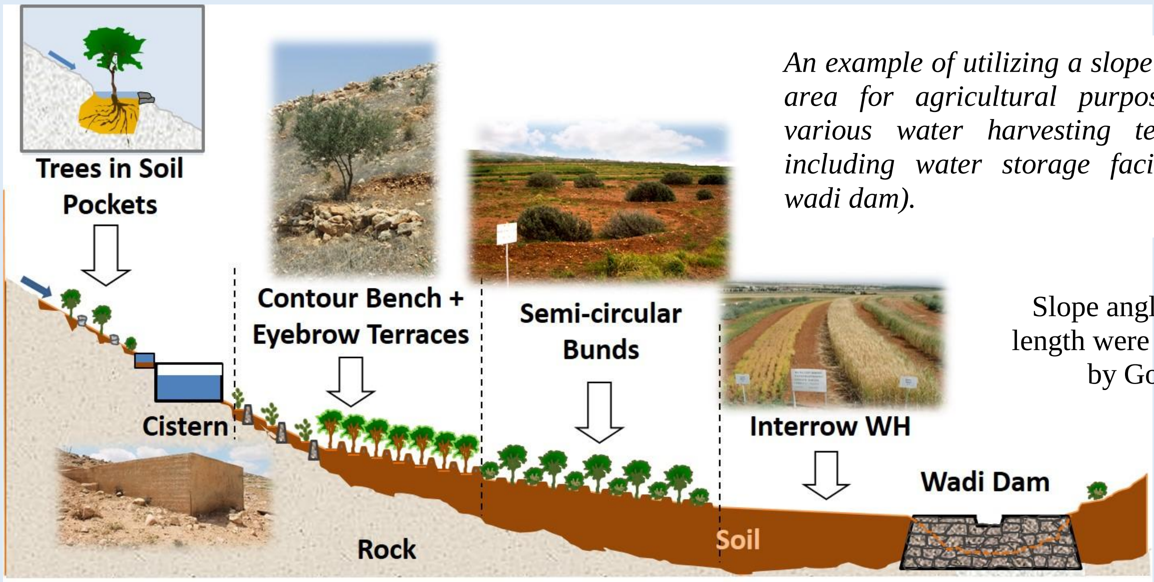
A **good example** offers a project in the West Bank, Palestine, located in Tammun (Tubas Governorate) and Al-Dahriya (Hebron Governorate). The project is a collaboration between the USAID-funded 'Middle East Water & Lifelihood Initiative', the International Center for Agricultural Research in the Dry Areas (ICARDA), Beirut and the Applied Research Institute – Jerusalem Society (ARIJ) in Bethlehem.

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 suitable to determine slope length, slope angle, watershed areas and position of structures serving soil and water conservation and water harvesting.

An example of utilizing a slope for agricultural purposes by employing various Water Harvesting techniques, complemented by water storage in a cistern and behind a wadi dam.

Google Earth image overlaid by slope map and elevation profile



An example of utilizing a slope in a semi-arid area for agricultural purposes employing various water harvesting techniques and including water storage facilities (cistern, wadi dam).

Slope angle and slope length were determined by Google Earth.

Contact: Saher Alkhouri , MSc., Research Associate, (skhouri@arij.org), The Applied Research Institute – Jerusalem Society (ARIJ) , West Bank, Palestine, Website: www.ARIJ.org

Climate Change impacts the application of rainwater harvesting by:
(1) shifting the application belts of RWH methods synchronously to the shifting of the ecological belts, and
(2) altering the application of techniques, the physical structures and the kind and volume of water storage to fit to the altered climatic conditions.

Ad 1: 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, which have been marginally suitable for grazing will turn to become desert (a process, which takes already place since decades due to overgrazing). Areas marginally suitable today for rainfed agriculture will turn to become

grazing areas and so forth. The application zones of the various RWH methods will move with the relevant ecological belt.
Ad 2: On the **technical field**, the **impacts of climate** change have to be met (a) by an increase in catchment area and/or (b) by increasing runoff coefficients on catchment areas, (c) by achieving a higher water use efficiency (e.g. using an efficient water supply system, cultivating crops in greenhouses, keeping other growing conditions (e.g. soil fertility) at high level, covering the soil with plastic or organic mulch etc.), (d) by an increase in storage volume.
Higher rain intensities and more erratic rainfall demand

- a larger catchment-to-cropping-area ratio and
- a strengthening / raising of water harvesting structures (bunds, dams, walls).

For further in-depth studies on water harvesting it is recommended to consult the book Oweis et al. (2012). *Rainwater Harvesting for Agriculture in the Dry Areas*. The papers of Prinz 2014a and 2014b deal particularly with the impacts of climate change on water harvesting.
Within each water harvesting method there are numerous techniques available, fitting to different slope angles, soil depths and other environmental conditions (Mekdaschi Studer et al. 2013).

7 RESPONSE MEASURES: RAINFED FARMING

7.1 Introduction

Most Arab countries' food production is from rainfed areas. Nearly 83 percent 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, where agriculture and/or herding are the main sources of their livelihoods.

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 to achieve new targets of food security if desired investment levels are realized. On-farm results show the huge potential for improving land and water productivity and profitability of smallholder rainfed agriculture.

7.2 Techniques, crops, varieties

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

Table 9: Area of seasonal crops under rainfed cropping in Arab countries (in percent)

Country	2010	2011	Average
Jordan	67	69	68
Tunisia	83	83	83
Algeria	87	88	87.5
Sudan	92	93	92.5
Syria	70	66	68
Somalia	86	86	86
Iraq	35	34	34.5
Lebanon	34	34	34
Libya	89	89	89
Morocco	87	79	83
Mauritania	94	94	94
Yemen	64	52	58
Total	**83**	**82**	**82.5**
Additional Useful Statistics (million ha)			
Seasonal crops irrigated areas	6.99	7.89	7.44
Seasonal crops rainfed areas	35.31	35.63	35.47
Permanent crops irrigated areas	2.69	2.96	2.82
Permanent crops rainfed areas	5.02	5.14	5.08

Source: compiled from FAO data.

Source: Shideed et al., 2013

Source: ACSAD

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

Fig. 21: Not only drought and salinity tolerance, but resistance to various pests and diseases is vitally important for adapted varieties

Facing these problems, several programmes were launched by regional and international organization like ACSAD and ICARDA for developing varieties resistant to various diseases and also drought and salinity tolerant to adapt to climate change, and also to save water. These new varieties are genetically modified seeds that give high yields values, stable productivity, salinity and drought tolerance and disease resistance. The main outlines of these kinds of programmes are:

1- Establishing a genetic bank for all the varieties that showed a 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 of varieties resistant to yellow rust disease; temperature rise encourages the emergence of this disease, also in insects 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, e.g. not to allow insect infestations and (d) alleviating the need for nitrogen, e.g. by cultivating leguminous crops.

Improvement of wheat production in the Arab world

ACSAD implemented a project in several Arab countries in aim to improve the wheat production under rainfed and irrigated agriculture to assure the food security. Improved wheat seeds from ACSAD's varieties were cultivated in the participant countries (Saudi Arabia, Algeria, Libya, Morocco, Jordan, Iraq, Yemen, Sudan, Syria and Lebanon) in collaboration with the Islamic Bank for Development (IBD). 22 varieties of soft and hard wheat where developed during the project, 120 tons of these seeds were at ACSAD's research center in Deir Elzour and tested in the participated countries, the total cultivated area was 3461 hectares, the project was accompanied with a capacity building programme for the technical and scientific staffs involved in the project.

Several varieties are adopted by the Arab countries and used actually for wheat culture:

Wheat varieties resistant to yellow rust: soft wheat ACSAD 885, Douma 2 (Syria), Armad (Algeria); soft wheat ACSAD 901, Douma 4 (Syria), Tel Ammarah 2 (Lebanon), Monah (Algeria), ACSAD 901 (Libya, Saudi Arabia); soft wheat ACSAD 1133, Douma 6 (Syria).

Early harvesting varieties: Hard wheat ACSAD 65 (Syria, Jordan, Morocco, Iraq, Tel Ammarah 1 Lebanon); Hard wheat ACSAD 357 Bohouth 107 (Libya, Mauritania); Hard wheat ACSAD 1105 Douma 1 (Syria), Tel Ammarah 3 (Lebanon).

Salinity tolerant varieties: soft wheat ACSAD 899, 969, 59, 901, 1069; hard wheat ACSAD 65, 357; barley ACSAD 176.

Reference: Plant resources department at ACSAD, Final report of the project, www.acsad.org

7.3 Cultivation and production of fruit tree cultivars adapted to drought

Fig. 22: Almonds, pistachios and olives (from top) Source: ACSAD

The Arab world is characterized by various types of fruit trees which 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. The trees of olives, pistachio, almond and figs are of big economic, social and ecological importance, and well known by their adaptation capacity in growing and producing under poor marginal environment, calcareous and sandy lands, where they can contribute in improving the environment, increasing the vegetation cover and fighting desertification. The environmental conditions in the Arab countries are widely variable, therefore it is crucial to study the site condition especially the meteorological conditions before choosing trees species and varieties

The tree species vary in their drought tolerance and differ in their ability to withstand drought (for instance):

- The drought tolerance of almond tree comes from the ability of its root system that penetrates deep in the soil seeking for moisture in addition to its strong growth and the ability of trees in achieving the water balance through dropping part of leaves during severe heat.

- Pistachio can tolerate drought because of the waxy nature of its leaves and thickness of its bark and its ability to produce roots withstand shallowness of soil in addition to its short stem.
- Fig tree is considered more tolerant to drought and water deficit 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, in addition, its cracked bark helps it in adapting to large variations in temperature between summer and winter. Its deep root helps in extracting more soil moisture (Fig. 22).

These trees offer many economical, ecological and social benefits, which can be summarized as follow:

1- Wide adaptability for planting in dry areas of the Arab region
2- The ability for cultivation in poor, marginal, calcareous land and saline soil.
3- Fruits are of high demand in Arabic and international markets.
4- Utilization of the residue of pistachio and olive milling as fertiliser or animal feed and also as a source of bio-energy.
5- Offering job opportunities in cultivation processes and fabrication
6- Contribution in assuring food security in the Arab region.

7.4 Conservation Agriculture (CA)

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 aims at improved livelihoods of farmers through the application of the three CA principles (FAO 2011a):

- **Minimal soil disturbance**: ploughing operations are not practiced in CA. Moisture loss and soil compaction that follows tillage are avoided, infiltration and percolation of water through the soil increase, 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% of the soil surface, but never less than 30% . Direct sowing is done through the soil cover.
- **Crop rotation:** Deep rooting **c**ereal - legume combinations are preferred.

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

In North Africa, no-tillage systems have been promoted particularly in Morocco and Tunisia. In Morocco 4000 ha of no-tillage have been reported, in Tunisia 8000 ha in 2008 (FAO, 2011b). In West Asia, so far only in Syria there has been a significant adoption over some 18,000 ha, while Lebanon and Jordan are supporting pilot activities in CA. (FAO 2011 b).

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

- Low biomass production in drylands limits soil cover.
- There is acute competition between animal fodder needs and soil cover in the dry season.

Fig. 23: Tractor-mounted direct seeder sowing wheat into rice residues in Egypt Source: FAO 2008

- As CA is normally based on use of machinery (Fig. 23), small farmers have to rent machinery (direct seeders) from owners. One limiting factor for further spread of CA is the unavailability of low cost CA equipment. 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. In Egypt experiments in the Nile delta on irrigated rice-berseem-wheat cropping systems were carried out (FAO2008).

7.5 Soil and water conservation (SWC)

There are always strong links between measures for soil conservation and measures for water conservation and in most cases, these 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 minimise the runoff losses and to increase the available soil moisture for crop growth, which is of utmost importance when dealing with climate change adaptation in agriculture through maximising the benefits of rainwater.

We distinguish between agricultural/biological and mechanical measures.
Agricultural / biological methods include:

- **Improving crop husbandry**: Refers e.g. to right timing for sowing and harvesting
- **Improving crop selection**: Preferable are short-cycle crops (e.g. millets), crops with deep root systems being low in water demand and crops with drought dormancy (e.g. *Sorghum*).
- **Contour cropping / farming**: *Contour farming* orients crop furrows following the contour lines of the farmed area. Furrows run on contour, which reduces runoff. Contour farming was practiced by the ancient Phoenicians, and is effective for slopes between two and ten percent. Contour plowing can increase crop yields from 10 to 50 percent, partially as a result from greater soil retention.
- **Improving infiltration and water storage capacity of soil**: As mentioned under 'Conservation Agriculture', *organic mulching*, applying farm yard manure and mineral fertilizer, conservation tillage or no-tillage (or ploughing-in of organic matter), the removal of hard pans in the soil and a legume-rich crop rotation help increasing organic matter content of soil. Rainwater infiltration and water retention in the soil matrix are accordingly improved.
- **Reducing evaporation from soil surfaces**: *Surface mulching* with organic material is (a) providing protective cover of soil surface, (b) reducing evaporation, (c) impeding weed growth and (d) improving infiltration. It may also beneficially reduce soil temperature. Possible disadvantages of organic mulches are e.g. (a) problems of pest, disease, or nitrogen lock-up, (b) the lack of implements which can plant or drill through the mulch, (c) organic mulches are liable to be rapidly degraded in high temperature. Plastic mulches reduce evaporation, too, and protect against heavy rains.
- **Lowering evapotranspiration losses of plants**: This can be achieved by (a) shading the crop with shade trees ('agroforestry'), (b) by cultivating crops in greenhouses or plastic tunnels, or (c) by reducing wind speed. The latter can be achieved by shelterbelts (lines of trees perpendicular to the direction of prevailing winds) and other types of windbreaks. Wind may also cause mechanical damage to crops. Some useful tall species are tamarisk *Casuarina equisetifolia*, and *Eucalyptus camaldulensis*. Drawbacks: A windbreak may also rob crops of light, water and nutrients. Additionally, *Casuarina* and *Eucalyptus* have got allelopathic properties. Thus, the advantages of a windbreak must be weighed against the disadvantages in any particular environment. Windbreaks can also be constructed of dead organic or plastic materials (Fig. 24). Future higher wind velocities have to be taken into account when planning windbreaks.

Fig 24 a-f: Agricultural/biological methods of Soil and Water Conservation (SWC): a) Contour farming (agroforestry), b) Organic mulch soil cover, c) Farm Yard Manure, d) Conservation tillage (in Tunisia), e) Greenhouse production of tomatoes (Tunisia), f) Windbreak made of dry date palm leaves (Photos: Prinz)

Mechanical/engineering methods include:

- **Minimizing runoff losses** by construction of

- **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 runoff. 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 runoff and promote water retention in the field.
- **Terraces**: *Terracing* is the practice of creating either level or slightly inclined strips in a hillside area. Different types (e.g. bench terraces, conservation terraces, graded terraces etc.) serve different purposes

- **Reducing or slowing down overland flow in valleys and in wadis:**
  - Stone lines, following contour, perpendicular to water flow in broad valleys
  - Checkdams, preventing the widening and deepening of a narrow wadi, and assisting in filling it up with sediments. They reduce the velocity of runoff in the wadi (Fig. 25).
- **Dealing with excess water**: "Grassed water ways" channel and dissipate runoff through surface friction, impeding surface runoff 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.

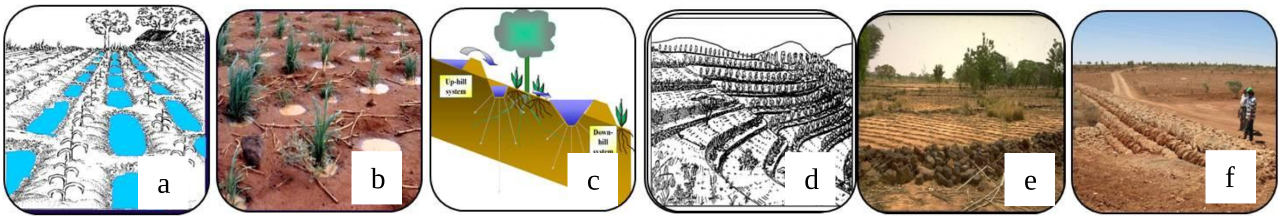


Fig. 25a-f: Mechanical/engineering methods of Soil and Water Conservation (SWC): a) Tied ridges, b) Zay (pit) system, c) Fanya Juu/Fanya Chini system (Ditch-Ridge System), d) Conservation Terraces, e) Stone lines in a wide valley; Zay technique is applied inbetween the lines, f) Checkdam in a wadi (NE Libya)
Sources: For a-c) and e-f: Prinz; for d): Hurni 1986

The above mentioned methods and techniques are core elements of IWRM and future water management has to pay even more attention to them than today as effective climate change adaptation measures.
Since long it is known, that conser-vation measures must have visible short-term benefits to the farmer to be accepted / implemented (Hudson, 1987).

7.6 Supplemental Irrigation (SI)

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 (Oweis and Hachum 2012). 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 available, 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 northern and western Syria (where annual rainfall is greater than 300 millimeters) has increased from 74,000 hectares (in 1980) to 418,000 hectares (in 2000), an increase of 470 percent. SI caused rainwater productivity in northwest Syria to increase from 0.84 kilograms of grain per cubic meter to 2.14 kilograms per cubic meter. Similarly, for biomass water productivity, the obtained mean value was 3.9 kilograms per cubic meter for deficit SI. In Syria, average wheat yields under rainfed conditions are only 1.5 t/ha and this is one of the highest in the region. With SI, the average grain yield was up to 3 t/ha. In 1996, over 40 percent of rainfed areas were under SI and over half of the 4 million tons national production was attributed to this practice. Supplemental irrigation does not only increase yield but also stabilizes farmer's production.

The irrigation water is in most cases applied by sprinkler irrigation. Preconditions for Supplemental Irrigation 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.

8 RESPONSE MEASURES: IRRIGATED FARMING

8.1 Water productivity and Water Use Efficiency (WUE)

At present and even more under future climate change conditions, irrigated agriculture will take place under water scarcity. 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 is useful to identify the sources of water loss, to compare different irrigation systems and the best irrigation scheduling strategy, and to analyze the water saving performance of irrigation systems and respective management.

The term 'Water Use Efficiency' (WUE) 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^3. In agronomy often a wider definitions is applied, defining WUE as the yield of useful biomass (e.g. grain) produced by a crop to the volume of water applied to the rootzone 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).

8.2 Irrigation methods and management

Traditional surface irrigation prevails in irrigated agriculture because it is low-cost, easily implemented and doesn't need skilled labor or advanced techniques. Modern Irrigation Systems comprise modern irrigation techniques (sprinkler and localized) in addition to 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 is consisting of pipes instead of open canals, in such a way to deliver water into the furrows by means of gated pipes or siphons, in this case 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 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 irrigation to farmers and to the farming system (Fig. 26).

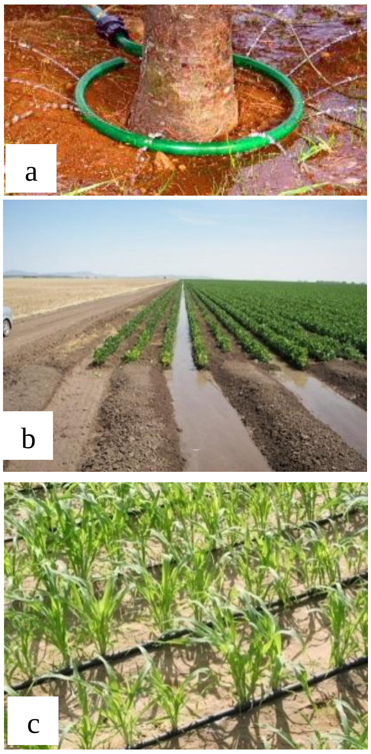


Fig. 26: Irrigation methods: a) microsprinkler for tree irrigation, b) Furrow irrigation, c) Drip irrigation Source: ACSAD

For the traditional irrigation and considering that the total efficiency of water uses, expressing the relation between plant consumption from water for physiological processes and water withdrawal from the source, is not more than 50%. At scheme level, overall efficiency (storage and conveyance efficiencies) does not exceed 40%. At farm level, water use efficiency, which includes distribution uniformity and application efficiency of the irrigation method, could vary from 50% with surface irrigation techniques, to 70% with sprinkler irrigation, to 85% with drip irrigation. As mentioned, irrigation efficiency is related to its components, if it is possible to achieve canal conveyance and delivery efficiency 80-95%, this figure will decline to 40-50% or less under surface irrigation which has several negative features (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 (e.g. in oases), a high water table level and soil salinity.

Fig.27: Incrustations in a water pipe Source: ACSAD

Drip irrigation, in general, might be the one to be recommended for irrigation in arid and semi-arid regions like 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, making the water waste high. Under drip irrigation, such waste doesn't exist since water application is localized near the plant's stem. Water quality is of primary importance in the design, operation and maintenance programmeme of sprinkler and drip 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 could reach the drippers, using sand and screen filtrations (Fig 27).

All plants need water to grow and produce good yields. 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 had 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, e.g. decrease plant population, apply less fertilizer, adopt flexible planting dates, and select shorter-season varieties.

Fig.28: Measuring soil moisture with tensiometers Source: ACSAD

The goal of an effective scheduling programmeme is to supply the plants with sufficient water while minimizing loss to deep percolation or runoff. 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, aquaterr probe, tensiometers, electrical resistance blocks and the hand feel method (Fig. 28).

8.3 Deficit irrigation

To achieve a high Water Use Efficiency (WUE) under water scarcity conditions, an irrigation strategy called 'Deficit Irrigation' is applied. Basis of this strategy is the knowledge on the sensitivity of the various growth phases of a crop to water stress and the impact of this water stress on yield level. In 'Deficit irrigation', plants receive full irrigation during drought-sensitive growth stages and outside these periods, often the vegetative stages and the late ripening period, lower than usual quantities of water. Deficit irrigation allows to reduce 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) Knowledge of the farmers on the sensitive phases of each of the crops cultivated, asking for a well functioning agricultural extension service (Kirda and Kanber, 1999), (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, also in Arab countries, are interested in purchasing **'organic', healthy food.** On request of the Saudi Arabian Ministry of Agriculture, GIZ, Germany, 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 for organic food. Within a mere 8 years, the project has turned organic agriculture in the **Kingdom of Saudi Arabia** into a success story. The four **objectives** are: (a) Increase agricultural productivity and the number of small organic farms, (b) Production of healthy food, (c) Conservation of natural resources and (d) Reduction of irrigation water consumption in agriculture which is crucial in any climate change adaptation mesure.

Numerous measures in awareness raising among farmers and the public, in organic production, research, training, marketing, certification, legislation, policy development etc. were initiated and a National Organic Action Plan (NOAP) has been developed. Saudi Arabia is the first country within the Gulf and MENA-Region with a national organic agriculture support policy. Up to mid-2014 more than 100 Saudi organic farms have been certified and new farmers are continually converting their production systems to organic. These farms are located all over Saudi Arabia, but most of them are located around Jeddah, Riyadh and Dammam, where demand is highest.

The successful Saudi Arabian example (in its full dimension) can be copied by other (oil) rich countries only (e.g the Gulf States). 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.

Link: http://www.saudi-organic.org.sa/

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

9 RESPONSE MEASURES: FORESTRY AND AGROFORESTRY

9.1. *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 also 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 (e.g. through mangrove stands) (Fig. 29). Forests themselves are sensitive to climate and other changes in their environment.

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, 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.

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 of field missions and training workshops, (b) publishing of brochures to raise awareness, (c) implementing measures, (d) establishing a 'community of practice' at MENA level for exchange of lessons learned. Collaborating countries are Algeria, Lebanon, Morocco, Tunisia, Turkey (and Syria).

Barouk Cedar Park, Lebanon

Contact: R. Alexander Kastl , German Agency for International Cooperation (GIZ) Morocco, Reinhard.Kastl@giz.de, http://www.giz-cpmf.org

Link: http://www.giz-cpmf.org/thematic-issues/climate-change-adaptation/forest-ecosystem-based-adaptation/

Climate change policies must therefore (a) encourage forest protection (see Case Study 'Capacity Development'), (b) promote afforestation activities including maintenance (using a wide variety of tree species), (c) install forest fire management systems, (d) strengthen extension and awareness on forest and climate change issues, (d) amend institutional and legal structures to facilitate adaptation and mitigation actions (FAO 2011d; FAO 2013b).

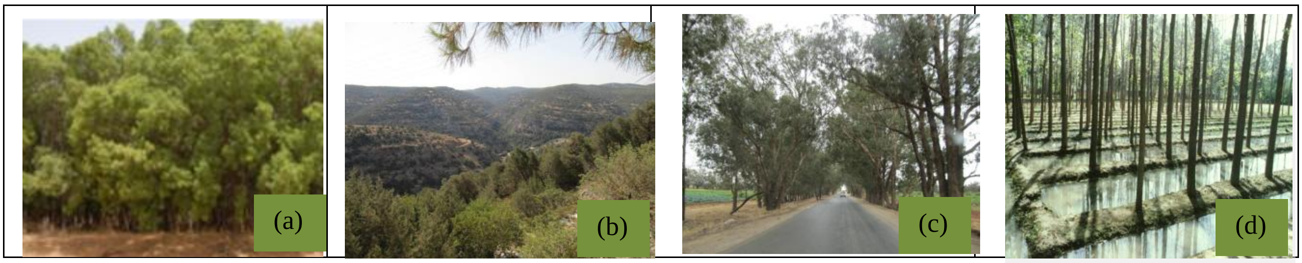


Fig. 29: Examples of forest functions: (a) Productive forest, (b) al-Jabal al-Akhḍar, Libya, rich in biodiversity, (c) Alley with shade trees (NW Libya), (d) Trees cultivated for biomass production growing on untreated wastewater
Sources of photos: (a) UNEP, (b) + (c) Prinz, (d) FAO

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; more sustainable production of wood fuels,
- Trying to harmonize the needs of local population with forest conservation,
- Protection of biodiversity of standing forests and planting species tolerant to CC impacts,
- Enhancing the resilience of forests through appropriate forest structure and composition,
- Implementing forest management practices which reduce vulnerability to extreme events such as storms and fires and establishing fire brigades and corridors to help species migrate.

Case Study: Tree Cropping in Arid Areas for Mitigation and Adaptation to Climate Change

Trees always paid a significant role in Arab agriculture - just to mention the olive tree (*Olea europaea*) and the date palm (*Phoenix dactylifera*). Since long, different tree species have been selected to meet the local needs.

Under climate change conditions **carbon sequestration** becomes an important parameter: Goal is a high growth rate (biomass gain) by marginal water input in quantity and quality. Various trials have shown, that Eucalypt species (e.g. *E. camaldulensis, E. gomphocephala, E. grandis, E. occidentalis*) have a great potential, when water quantities of 50 to 80% 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 Kebili area, Tunisia, large volumes of drainage water from oases are available for afforestation works

In **Tunisia, the Institut des Regions Arides (IRA)** in cooperation with the **German agency GIZ** 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) preferred whenever possible.

Link: http://www.ira.agrinet.tn

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

9.2 *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 ICRAF's website: http://worldagroforestry.org/).

Table 10: Various types of agroforestry systems and relevant climate change adaptation (CCA) in Arab countries

	**Un- irrigated agroforestry, combining field crops and trees** Forest trees often planted in perpendicular belts around agricultural fields. Eucalypts are excluded. Forest trees perform different functions e.g wind protection, soil conservation, 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 (Scene in NE Libya)*
	**Irrigated agroforestry, combining field crops and trees (Market production)** Strips with fruit trees (e.g. 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: NE Libya)*
	**Agroforestry system combining trees and bushes with domestic animals** The tree / bush species used are *Pistacia atlantica*, olive trees, almond, hawthorn**, tamarisk and others. This system can be established (a) in the form of belts and perpen-dicular 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:NE 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 (NW Libya)*
	**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. *Photo: Prinz (Location: River Nile island, Egypt)*

*CCA = Climate Change Adaptation; **hawthorn = Crataegus sp

.10 LIVESTOCK MANAGEMENT

10.1 Introduction

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 1037 million poultry and birds.

Fig. 30 : Ewes and lambs Source: ACSAD

The majority (89.83, 73.29, 91.22 and 60.58 % of the groups mentioned) is kept in 10 African member countries of the Arab League.
Livestock producers 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.
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 could be produced with a smaller number of animals (Fig. 30).

10.2 Livestock and water

In this framework, ACSAD has established an applied programme for improving and care of sheep and goats (small ruminants) in the Arab countries which represent the main part of Arabian animal wealth. Within this programme, numerous measures are implemented in many Arab sheep and goat stations which could lead to optimal use of animal resources in the participating Arab countries.
Water forms about (75%) 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.
The ambient temperatures which is surrounding the animals, affect the amount of water consumed by them (Table 11). The following table presents the relationship between ambient temperature and consumed water by dairy cows.

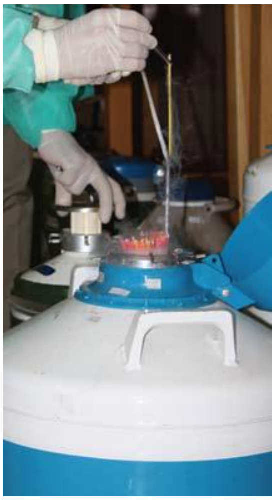
Table 11: Relationship between ambient temperature and consumed water by dairy cows

Ambient temperature (°C)	Live weight (Kg)	Daily milk production (Kg)	Fat content in milk (%)	water requirements (liter / cow)
+4.5	529.8	14.58	4.4	56.5
+10	540.6	17.87	4.4	90
+15.6	540.6	17.05	4.3	94.5
+21.1	542.0	16.82	4.2	99
+26.7	539.7	15.55	4.1	94.5
+32.2	544.8	11.61	4.2	85.5

Source: ACSAD

But the amount of water that an animal drinks varies also depending on the method of delivery. A cow which gets water from an individual automatic trough drinks 48.14 liters water a day, while a similar cow which get water from a common trough twice a day drinks only 28.14 liters water. The same trend was registered by sheep.

10.3 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 these 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 goats breed which is distinguished in high milk production and twining rate (Fig. 31).

These methods contribute to an accelerating of the genetic improvement programmes of some promising breeds in the Arab countries. In order to raise the productivity of herds and reduce the numbers required to bred leading to relieve the pressure on the pasture and feed demand and rationing water spent on breeding herds and irrigation of forage crop.

10.4 Livestock management

Fig. 31: Milk analysis at a laboratory
Source. ACSAD

Herd management or livestock management could be broken down into various topics; for each of these topics there are multiple methods to manage. These and how each of the represent procedure is optimal managed build the fundaments of this session of the guide, what will be clarify in this session as follow:

10.5 Feed management (animal nutrition)

Feeding strategies in arid and semi-arid areas vary according to such factors as production system, animal species, household income, social categories, and distance to the city center (transportation cost).
In all production systems there are many diseases which have a negative influence either on animal health or on animal productivity. Therefore it is very important to control animal diseases specially the epidemiologic disease. An Optimal Herd health management includes the string implementation of vaccination programmes and repeated anti parasites treatment.

10.6 Management of mating season (animal reproduction)

It is essential for the provision of replacement animals through the regular production of newborns. Successful reproduction is also necessary for milk production. More efficient reproduction can be achieved when breeding takes place in the physiologic optimal time, which could be exactly determined through simple methods. A modern bio-technique measure could be easily implemented when the optimal mating time is determined; it's the artificial insemination (AI), which used to accelerate 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's 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 by the use of AI.

10.7 Optimal raising of newborns

Another part related to the reproduction process is the rearing of newborn and young animals which build the major financial source for the herd. Generally, the choice of an animal breed depends primary on the adaption tolerance which means that 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, when introduced to local conditions, will often produce even less than local animals. Therefore local breeds which 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. Here's again the use of artificial insemination will bring the biggest benefit.

11 PASTURE MANAGEMENT AND FODDER PRODUCTION

11.1 Overview

Herders and workers in agriculture and grazing showed throughout history in the Arab countries the ability to adapt to climate variability. It is likely to be able to adapt to climate change successfully if they receive the requested support and assistance and have the rights of land-use. People has taken

Fig.32: Inspection of pasture land
Source: ACSAD

over the centuries several measures to cope effectively with the climate changes, **such as the seasonal movement of livestock, mixed agriculture based on integrated crop-livestock, and water harvesting.** These capabilities must be taken into account by the researchers and policy-makers at the investigation and development of technologies for adaptation to climate change and future strategies.
However, the current rate of climate changes is greater than the ability of livestock producers to adapt to these changes. The governments in the Arab countries have to invest in research, development and creation of legislation and policies that in one hand encourage those who follow sustainable methods of production and on the other hand discourage those who practice unsustainable methods of production. When we learn about plant species environment and plant communities in the pastoral land, we can plan agricultural technology properly to improve rangeland and organize its exploitation in a scientific and rational manner (Fig. 32).

11.2 Rainwater Harvesting in pasture management

Rain is the most important factor that determines the vegetation type and its productivity. Not only annual rainfall, but also rainfall intensity and its spatio-temporal distribution and the relative humidity of the atmosphere play a role in the development of the vegetation cover. By collecting and concentrating rainfall the production of hay can be increased. Rainwater harvesting is one of the most important techniques for several reasons:

- Help in the development of natural pastures,
- Accelerate the rehabilitation of the natural vegetation,
- Contribute to increasing the availability of soil moisture for plants for relatively long period,
- Contribute to raising the efficiency of the production of forage and pasture,
- Provide natural feed for the animals,
- Provide water storages for animals drinking water needs.
- Fight desertification in arid and semi 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 tractor. Per day 10 to 15 hectares can be covered; the costs are in the range of 100 US$ per hectare. This might be economical, if large areas are to be covered (Oweis et al. 2012).

11.3 Pasture rehabilitation

The Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) developed and implemented several pasture rehabilitation projects in different Arab countries like: UAE, Algeria, Oman, Saudi Arabia.
Rehabilitation of pastures could be done in two ways:
Natural rehabilitation: the natural method in rehabilitating pastures consists of several points:

a. Prevent grazing or postpone it for a certain period of time until the pasture regains its productivity.
b. 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.
c. Prevent grazing during certain seasons during which the excellent species are sensitive to grazing.
d. Restrict grazing of animals which 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 which proliferated at the expense of high-yielding species.
e. Construct small fences across the pasture to allow plants within it to release seeds to neighboring parts where free grazing is allowed.

11.4 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 / or seeding. Good pastoral shrubs species are deteriorated not only by overgrazing but also by wooding, this kind of plants need 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 the biodiversity.

Rehabilitation of degraded area in North Kordofan state – Sudan

The over exploitation of natural resources in Sudan led to land degradation and desertification acceleration, this phenomenon has taken environmental, economic and social dimensions, which required degraded land rehabilitation to secure food production. In this domain the implementation of this case study was carried out in cooperation between ACSAD and the ministry of agriculture and forestry in Sudan. The rehabilitated area is located in north Kordofan State. 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 generating for 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 of vegetation cover and rangelands productivity, also it was noticed that the ecosystem in the area moving towards stability, which indicts the success of the implementation activities and technologies.

The area before and after rehabilitation.

Sources: ACSAD – Land and water use department- desertification monitoring and combat program

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

Fig. 33: Atriplex and Salsola are most widely used plant genera for artificial pasture rehabilitation Source: ACSAD

11.5 Fodder production

Fig. 34: Commercial production of Opuntia in Palestine (West Bank)
Source: Prinz

Fodder production: A large number of annual or perennial herbaceous crops, but also 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 ones which are planted solely for fodder production or which serve also other purposes, such as shelterbelts, sand dune fixation or soil erosion control (e.g. *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 (Fig.34).

11.6 Feed sources

Agricultural residues are considered as one of the most important feed sources in arid and semi-arid regions upon which the breeders rely to feed their animals in the Arab World, 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 which are accompanied by a severe shortage of fodder, pasture and water, impacted negatively the availability of animal feed in these areas, making it necessary to search for forage alternatives at economically acceptable costs. The solution was to use agricultural wastes and by-products on a large scale after improving their nutritional value and using some simple techniques which, as well, help the breeders to adapt to these climate changes and ensure that they continue the productive process in the breeding and care of ruminants.

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

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

Fig. 35: Various techniques to improve the nutritional value of agricultural residues
Source: ACSAD

This action is characterized as one of the basic tools in the adaptation with the climate changes, Moreover, the choice of this application in improving the nutritional value of the waste agricultural by-products has the advantage of being available in large quantities in the arid and semi-arid areas.
The implementation of this procedure requires securing some of the necessary supplies to ensure the success of this procedure, where the theoretical and practical training for technicians and livestock breeders to invest all the resulting agricultural wastes in areas of their presence, then securing some equipments to chop and mix the agricultural residues and preparing them to be formed into integrated feed or filler feed (straw and hay) of improved nutritional value. Also the dry wastes should be collected and shredded in their production areas (agriculture crop areas) or areas where the wet residues of the agricultural processing industry are available (sugar factories or canneries).

FISHERIES & AQUACULTURE*12.1 Overview*

Marine waters border the Arab countries on all sides: the Arabian Gulf on the east, the Atlantic Ocean on the west, the Mediterranean Sea on the north, and the Indian Ocean on the south. In addition to these, 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, marsh lands, swamps, reservoirs, and natural and man-made lakes, are estimated to cover about 1.5 million km^2 (Fig. 36).

Fig.36: Aquaculture contributes to food security and income generation Source: http://www.abc.net.au/

The major states where these are available are Egypt, Sudan, Iraq and Syria. 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 River Nile. In Sudan, the main inland fisheries are in the Blue and White Niles in addition to the main stem of the River Nile. 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 Syria, Lebanon, Jordan, and Mauritania. Most of the inland fisheries in the Arab states are characterized by subsistence fishing to meet immediate food supply needs of populations living in the vicinity of the water bodies.
The fish production (including aquaculture) was estimated in the Arab region by 4.3 million tons in 2013 (2.6% of the total world production). 33.9% of it came from Egypt, most of it from aquaculture. It still a big challenge to develop fish cropping in both sea and inland aquaculture. Egypt is the first country in aquaculture with one million tons per year, followed by Saudi Arabia and Oman with thousands of tons (Table 12).
In Egypt aquaculture accounts for about 65 percent of all fish produced in the country. Of these about 85 percent are obtained from semi-intensive culture technology employed in brackish water. About 10 percent come from cage culture in fresh water and about 5 percent from rice-fish culture (FAO 2010b).
The Arab Organization of Agriculture Development (AOAD) is preparing a strategy for the Arab countries to develop the aquaculture to increase its portion of the fish husbandry from 25.7% to reach 50%.
Whereas (renewable and non-renewable) good quality water (< 1.5 dS/m) become scarcer year by year, there are large volumes of brackish groundwater of different salinity levels available, which can be utilized best for aquaculture, if suitable fish species or other types (e.g. shrimps, prawns etc.) are selected.

Table 12: Fish production (inland fish eries and aquaculture) in Arab countries 2011 – 2013

Country	2011		2012		2013			% of total production
	Fishing	Cultivation	Fishing	Cultivation	Fishing	Cultivation	Both	
Egypt	375.4	986.8	354.2	1017.7	434.9	1017.7	1452.6	33.9
Morocco	956.7	0.3	1164.5	0.4	1169.4	0.4	1169.8	27.3
Mauritania	644.3	-	644.3	-	646.7	-	646.7	15.1
Oman	158.6	0.2	191.6	0.2	195.5	0.2	195.6	4.6
Yemen	146.3	14.3	146.1	13.6	146.1	11.8	157.8	3.7
Tunisia	110.5	4.3	112.5	4.3	112.8	4.4	117.2	2.7

Algeria	93.4	1.8	101.8	1.8	100.4	1.8	102.2	2.4
Saudi Arabia	59.4	16.1	64.0	26.1	66.0	26.4	92.3	2.2
Other Arab countries	292.8	27.3	306.2	36.1	312.5	36.6	349.1	8.1
Arab region	2837.3	1051.0	3085.1	1100.1	3183.2	1100.1	4283.3	100.0
World	90500	62700	90800	74400	90500	70500	161000	

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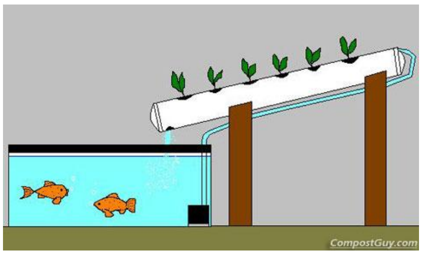
12.2 Climate Change impacts and adaptation

Fisheries and aquaculture are threatened by changes in temperature and, in freshwater ecosystems, precipitation. Storms may become more frequent and extreme, imperiling 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. 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 box '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 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 defenses 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).

Case Study: Aquaponics – An Integrated Aqua-Agriculture System



Aquaponics system
Source: CompostGuy.com

Food production in urban environments becomes more and more important. One interesting solution is the introduction of **'Aquaponics'**, which combines conventional **aqua-culture** (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.

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.

Aquaponics application in Gaza

In cooperation with FAO, **aquaponic food production units** where 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/ag/agp/greenercities/pdf/GGCLAC/FAO-Gaza-aquaponics.pdf

Hint: www.fao.org/fileadmin/templates/FCIT/PDF/Fact_sheet_on_aquaponics_Final.pdf

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13 SCREENING OF ADAPTATION MEASURES

An outcome of this tutorial is evaluation and prioritizing the proposed adaptation measures, this evaluation should be criteria based. Methods and tools should be carefully selected with respect, mainly to their relation with IWRM and also to the required data, area of application and constraints of application (Tables 13 & 14). However, it has to be kept in mind, that the prioritization of measures is always location-specific. A measure of top priority in one location can be of inferior meaning in another location. Therefore, a sound problem analysis, followed by a resource analysis, are always the first steps for any prioritization of measures.

13.1 Screening criteria

Table 13: Screening criteria

No.	Criteria	Description	Rate
I	Does it promote Integrated Water Resources Management?	This is clearly a priority, and can be considered to be a mandatory criterion in almost all cases.	Completely =3 Moderately =2 Indirectly=1
II	Is there an evidence of application	From evaluator point of view and experience	Yes=2 No=1
III	How widely is it used in arid areas	From evaluator point of view and experience	Very widely=3 Widely=2 Relatively=1
IV	Does it consider relevant social, environmental and economic issues and impact analysis	This is also fundamental – because adaptation must be in line with and promote sustainable development.	Completely=3 Moderately=2 Not relevant=1
V	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.	Completely=3 Moderately=2 Not relevant=1
VI	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.	Completely =3 Moderately =2 Indirectly=1
Total			**(from 6 to 17)** **17**

1. Screening of adaptation measures

In table 14, all the adaptation measures and fields are listed with the rating scale according to the described criteria (table 13), evaluation could be made by the user of this tutorial according to the above criteria and rating for any procedure in table 14.

Table 14: Screening of adaptation measures

Adaptation mesure	**Criteria**						**Total Rate**
	I	**II**	**III**	**IV**	**V**	**VI**	
Avoiding surface water contamination							
Avoiding groundwater contamination							
Avoiding canal water contamination (Canals are often used for solid waste dumping)							
Lower losses in conveyance & distribution canals							
Leakages in canals and pipes							

In-situ moisture conservation							
'Soil & Water Conservation' measures							
'Water Harvesting' (Microcatchments, Macrocatchments, Floodwater harvesting)							
Evaporation losses from soil surfaces							
Cultivation in 'Protected Environments'							
Change of sowing dates, sowing depth							
Better plant nutrition							
Use of less water demanding, well adapted crops & varieties; crop diversification							
Combination of cropping with animal husbandry							
'Conservation Agriculture'							
Establishment of Early Warning Systems							
Drought monitoring							
Education in water management, Soil & Water Conservation, water harvesting etc.							

The final evaluation will in three level according for the total rate of the procedure as follow:

13-17: Highly prioritized adaptation measure

9-13: Moderately prioritized adaptation measure

6-9: Relatively prioritized adaptation measure

V ADAPTATION MEASURES IMPLEMENTATION MATRIX

1 Stakeholders and their role in water management

Successful implementation of feasible options for Water Management (WM) related to climate change adaptation depends on how different stakeholders play their roles. There are many stakeholders (national, regional and international organizations) dealing with various elements of climate change adaptation. 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 framework, coordinate related WM interventions, implement various national programmes and projects, regulate activities of other stakeholders, farmers, capacity building, technical backstopping and extension services.

Additionally, various NGOs operate at national or regional levels that 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 WM 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. Fig. 37 shows the different stakeholders and their areas of implication.

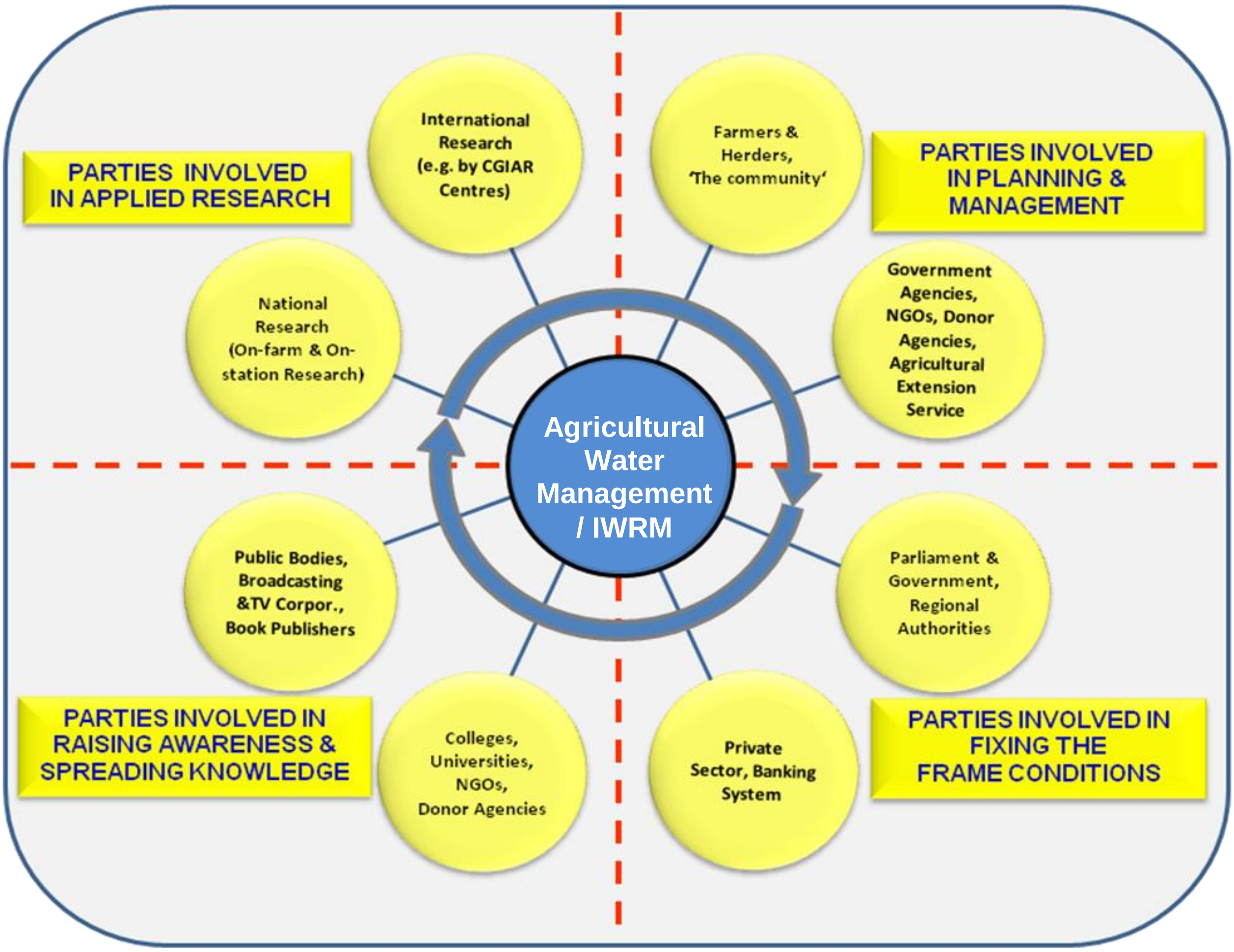

Fig. 37: Stakeholders involved in Agricultural Water Management (IWRM) in Arab region

Source: Prinz 2014a, adapted

2 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 are e.g.

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

These services might be supplied by the State directly or indirectly (e.g. by the Meteorological Service, by an Agricultural Extension Service, by agricultural research stations), by newspapers, radio and television stations, by marketing organizations, by commerce & industry, by cooperatives or NGOs.

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

(1) The adaptive capacity of many small farms will be limited to changing varieties, improving their animals or constructing rainwater cisterns. On 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.

(2) The adaptive capacity of medium-sized farms is much better, when the 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 flood problems may cause problems, which farmers cannot overcome without support by Government or NGOs.

(3) The adaptive capacity of large farm is doubtless the best and normally they do have access to all relevant information, to loans and state support. State support is needed in securing water supply (water storage), preventing floods, improving infrastructure, establishing cadastre service, getting agric. research results etc.

So collective irrigation and agriculture projects are of high adaptive capacity compared with small ones, this experience is widely applied in the Arab countries in North Africa like Morocco and Tunisia, and recently launched in middle-east Arab countries like Syria.

VI. AREAS FOR ACTION: SUGGESTIONS FOR FOLLOW-UP

1 NATIONAL POLICY LEVEL

Adaptation is successful if it reduces the vulnerability of poor countries and poor people to existing climate variability, while also building in the potential to anticipate and react to further changes in climate in the future. The evidence from past experience 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 demonstrate that development and adaptation to climate risks can be strongly complementary. Strategies for disaster risk reduction, water resource management and food security should all feature highly 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 also be provided to enable communities to plan for adaptation strategies. Community development projects implemented in the villages integrated 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 adaptive capacity in vulnerable local communities, which already need to adapt to climate change. 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 climate change adaptation measures into the design and implementation of national development plans, poverty reduction strategies and sectorial 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).

3 REGIONAL POLICY LEVEL

The successful integration of climate change adaptation 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 & 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,, d) plan and implement concrete adaptation measures, (Fig. 38).

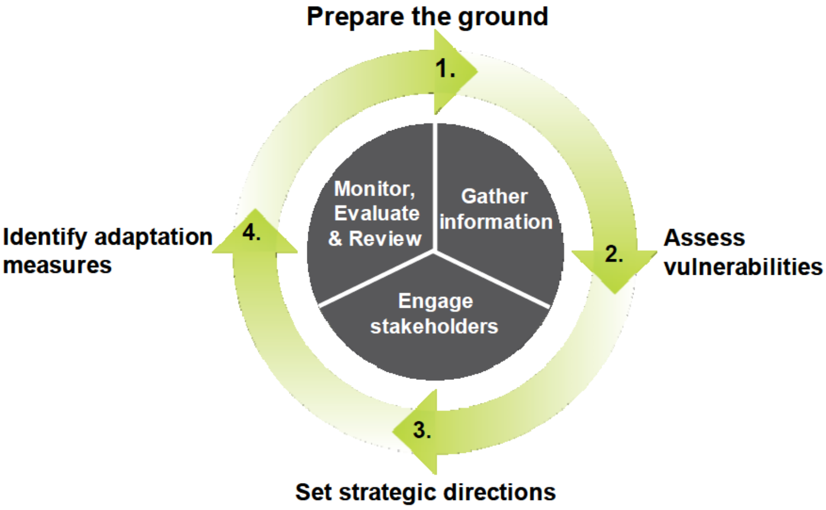

Fig. 38: A schematic diagram of regional adaptation strategy to climate change (Ribeiro et *al*., 2009)

It could be mentioned here, at the Arab 'Regional Policy Level':

The Arab Regional Strategy for Water Security, the section on rural water security / Irrigation. This strategy was drafted by the Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD), and was adopted in 2010 and functioned as a framework for joint action between 2010–2030. This strategy and its action plan were adopted by the Arab Ministerial Water Council (AMWC). One of the strategy’s objectives is to promote “cooperation among Arab states for the management of shared water resources”. This target has been further defined in an “Arab Countries Cross Continental Process” at the 6th World Water Forum. Its aims are stated as follows:

1) by 2020 the signing of permanent agreements on shared water resources in the Arab region according to the “Convention on Shared Groundwater Resources in the Arab Region” and international water law and
2. by 2025 reinforcing the establishment of permanent agreements between riparian Arab countries and neighbouring countries on ground and surface water resources on reasonable and equitable basis and according to international water law and historic agreements." (ACCWaM 2011).

The Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and SocioEconomic Vulnerability in the Arab Region (RICCAR). This initiative 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 Arab Ministerial Water Council (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 'Arab Knowledge Hub for Climate and Water' is one of the activities of RICCAR (ACCWaM 2011).

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