Food and Agriculture Organization of the United Nations

FAO WATER REPORTS

45

ISSN 1020-1203

Drought characteristics and management in North Africa and the Near East

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DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska

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Drought characteristics and management in North Africa and the Near East

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2018

ISBN 978-92-5-130683-3

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Foreword

The Near East and North Africa (NENA) region is mostly dry by nature because of its geographic location and climatic conditions. Around three quarters of the region consist of desert that is unwelcoming to life and normal human activities, with average annual precipitation less than 50 mm, and arid climate where average precipitation is less than 150 mm per annum. The rest is of either semi-arid or Mediterranean climates. Sub-humid and humid climatic conditions exist only in patches of specific coastal areas and relatively high mountains on the sides exposed to prevailing winds.

Country parts that are under desert or arid climates are permanently dry; they should be managed as such, under ''dryland management plans' which would be part of national drought management plans.

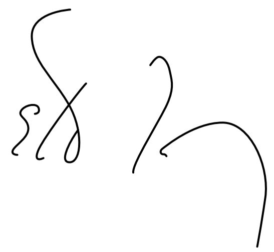
Drought materializes in a reduction of precipitation from the long-term average that extends over a given space scale for a specific period of time and results in impacts on human activities. Drought is a normal phenomenon in NENA region where it is known to have caused the decline of civilizations and ruling dynasties, mass migrations and famines. However, over the past four decades drought episodes in the region have gradually become more widespread and prolonged and more frequent, often with devastating socio-economic and environmental impacts. This gradual shift is likely the consequence of climate change.

Agriculture, including livestock, forestry and fisheries, is particularly vulnerable to drought with severe consequences on food supplies and livelihoods, especially for smallholders and the poor layers of rural societies. It is the first sector to be impacted when drought occurs and also the most impacted of all economic sectors. The provision of emergency response to the affected population, in the form of food, feed and creation of jobs, is the most common approach adopted by governments of the region to deal with drought. While important for alleviating starvation and saving lives, this approach is currently known to have several limitations. A paradigm shift to a more pro-active approach, based on the principles of risk reduction, to build greater societal resilience to drought impacts, is highly needed.

With this concern in mind, the High-level Meeting on National Drought Management Policy (HMNDP), convened by the World Meteorological Organization (WMO), the Food and Agriculture Organization of the United Nations (FAO) and the Secretariat of the United Nations Convention to Combat Desertification (UNCCD), took place in Geneva, in March 2013, gathering over 430 participants from more than 90 countries, including ministers and senior officials, dignitaries, heads of a number of organizations and agencies, scientists and country delegates. The purpose of the meeting was to initiate a dialogue on the need for such a fundamental shift in the way droughts are perceived and managed and to encourage governments to develop and implement national drought management policies consistent with their development objectives. The Meeting issued a declaration that, among other provisions, urged WMO, FAO and UNCCD Secretariat as well as other concerned parties, to assist governments, especially the developing countries, in the development of National Drought Management Policies and their implementation.

The concern about drought impacts is fully embedded into FAO's Strategic Framework which drives the organization's activities. Increasing societal resilience to disasters, especially drought which drastically affects rural livelihoods, is one of the five Strategic Objectives constituting FAO priorities. Within the framework of this Strategic Objective, FAO joined hands with the Robert B. Daugherty Water for Food Institute of the University of Lincoln-Nebraska, for launching a study on drought characterization and management in drought prone regions of the world. Getting a close picture of both drought characteristics and the way it is managed in different regions is essential not only for steering the shift from emergency response to more pro-active policy and long-term planning but also for assessing gaps and vulnerabilities and providing the right support to countries to achieve this shift. The other goal of the studies is to provide background information, first for designing drought risk management planning guidelines that are tailored for the specific characteristic and needs for each region, and second for the preparation of national and regional projects aimed at implementing pro-active drought management plans.

This reports reviews drought and the way it is managed in the NENA region which is highly prone to the phenomenon, on one hand, and is highly vulnerable to it because of weak institutional and policy frameworks, on the other. The report constitutes a good basis to rethink policies and reformulate preparedness and response plans which can strengthen resilience to droughts in the region, taking into account the social, economic and environmental contexts specific to each country. We hope that it will help foster a fundamental shift in the way drought is perceived and managed in the region and we reiterate FAO's continued support to the countries of the region in the development and implementation of drought management policies consistent with their development objectives.



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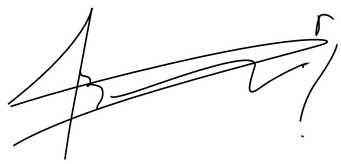

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Acknowledgements

This publication would not have been possible without the contribution and valuable support of several persons. The study of drought characteristics and management in the NENA region was conceptualized and commissioned by Mohamed Bazza, Senior Water Resources Officer, Land and Water Division, FAO, Rome, up to late last year. National reports for member countries of the region were first drafted by Abdellah Ouassou, FAO Consultant, based on data and information available at FAO and other existing literature. The regional report was prepared jointly by Mohamed Bazza and Melvyn Kay, FAO Consultant. Cody Knutson from the National Drought Mitigation Center, on behalf of the Robert B. Daugherty Water for Food Institute, both at the University of Nebraska-Lincoln, reviewed the draft versions and provided input and insightful remarks on the essence and the structure of the report. Melvyn Kay, FAO Consultant, provided professional proofreading and editing. James Morgan, Graphic Designer, FAO, designed the layout and formatted the document, whereas Rica Izquierdo, FAO Consultant, completed the references and, jointly with Corinne Spadaro, Staff Assistant, FAO, aligned the document with FAO publication guidelines.

Thanks and appreciation are extended to all.

Thanks, gratitude and appreciation are hereby expressed to all, including those missed or whose names are not mentioned explicitly.

The study is a contribution to FAO Strategic Programme Five which is aimed at increasing the resilience of livelihoods to disasters. It was conducted in partnership with the Robert B. Daugherty Water for Food Institute of the University of Nebraska-Lincoln, USA.

Executive summary

This report reviews drought management across North Africa and the Near East. It includes Algeria, Bahrain, Egypt, Iraq, Iran, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, UAE, and Yemen, to the extent of data and information availability.

This is an arid/semi-arid region and one of the world's most water-scarce areas where drought is a familiar phenomenon. In almost all the countries the average annual water resource is less than 1 000 m^3/capita (World Bank definition of water scarcity), but some have less than 500 m^3/capita which defines acute water scarcity. The average is only 274 m^3 in North Africa (Algeria, Egypt, Libya, Morocco, Tunisia) and the rises to 1786 m^3 because of high rainfall areas and shared water resources in the Near East (Iraq, Jordan, Lebanon, Palestine, Syria), although this figure hides the extremes across these countries. In the Arabian Peninsula (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, UAE, Yemen), the average annual per capita water resource is only 84 m^3.

In 2013, the average annual rainfall across North Africa was only 96 mm, 414 mm in the Near East, and 85 mm in the Arabian Peninsula. Some countries, such as Libya, Oman, Saudi Arabia, and UEA rely heavily on fossil groundwater; while others, such as Egypt, Iraq, Syria, and Sudan depend on surface water sources, often sharing with other countries. Morocco, Algeria, and Iran rely on a mix of both surface and groundwater. In contrast Bahrain, Kuwait and others in the Arabian Peninsula rely increasingly on desalinated water, treated wastewater, and virtual water in food imports.

The studies which make up this report show that, even without drought, water is limiting both economic and social development in most countries in the region. Indeed, many country reports focus on coping with acute water scarcity rather than drought per se. In general, they report that rainfall and surface water resources are scarce, variable, and unreliable. Both renewable and fossil groundwater resources are being over-exploited at an increasing rate. Water pollution, resulting from urbanisation and poor land practices are reducing the availability of good quality water (FAO, 2008). Drought just adds to the burden that all these countries face.

Although oil supports a number of economies, agriculture is still an important part of the region's GDP and essential for maintaining national food security. It is a dominant consumer of water, up to 90 percent of available water resources in some countries. Although most countries are semi-arid, rainfall is important for producing most of the basic staple food crops and for maintaining the rangelands for livestock which are a major component of many family livelihoods, particularly among nomadic people. This is the sector that suffers most when drought occurs. Irrigation plays a role in producing basic food crops and also cash crops in those countries that have sufficient surface and groundwater resources available. In some countries, such as Egypt, parts of Iraq and Iran, and Saudi Arabia, irrigation is the only realistic option for large scale agricultural production.

Droughts are a regular feature in the region and they have significant social, environmental, and economic impacts where rainfed farming is important. In Iraq, Jordan, Morocco, and Syria, the severe drought in 1998-2001 was considered to be the worst drought in 30 years, particularly. Its impact triggered real concern and raised awareness of the need to develop National Preparedness Plans for Drought Mitigation. In the years that followed, various regional conferences in Tehran (in 2002) and Doha (in 2004) were held through which FAO provided technical assistance to member countries to enhance their capacities to formulate and implement drought mitigation and preparedness strategies, and to develop guidelines and implement action programmes for combating drought with particular emphasis on policies, infrastructure, community participation, and political commitment (FAO, 2005).

For the purposes of this review, the countries are grouped in terms of proximity, climate, and hydrology as follows:

North Africa – Mauritania, Morocco, Algeria, Tunisia, and Libya because of their proximity along the North African coast and Mediterranean climate (Chapter 2)

Egypt and Sudan in the River Nile basin (Chapter 3)

Iraq and Syria in the Tigris and Euphrates basins (Chapter 4)

Iran (Chapter 5)

Jordan, Lebanon, Palestine in the eastern Mediterranean (Chapter 6)

Arabian Peninsula – Saudi Arabia, Kuwait, Bahrain, Qatar, UAE, Oman, and Yemen (Chapter 7)

DROUGHT HISTORY AND IMPACT

All countries of the region are susceptible to drought but severity and particularly impact and vulnerability vary from country to country.

The extent of historical records also varies but they do show that drought is not something new. It has been a problem for many hundreds if not thousands of years. Mauritania describes severe drought in the Sahel region in the 1910s, 1940s and again in 1968 and refers to the 'the great famine' and 'exchanging children for maize'. Severe drought in 2011 resulted in poor harvests, high food prices, and loss of livestock, and in 2013 the worst drought in 15 years contributed to food crisis across the Sahel in West Africa.

In Morocco and Tunisia, tree ring series over the past 1000 years suggest that droughts occur every 20 years or so, on average, and can last 2, 3, and 4 consecutive years. The latest drought in the winter of the 2015-16 growing season affected all Northern Africa causing significant reductions of cereal production in Algeria, Morocco and Tunisia.

Egyptian records reveal the unreliability of Nile flows, with catastrophic droughts dating as far back as 2000BC. The droughts were all influenced by climate conditions far beyond Egypt's national boundaries across nine other countries in eastern Africa which form the Nile basin. Sudan too is influenced by droughts in the Nile basin, but Sudan also relies on rainfall in northern Darfur and recorded 16 severe droughts since 1972 as well as in earlier centuries. Iran has also made significant analysis of droughts over the past 50 years.

In the Eastern Mediterranean region comprising Cyprus, Israel, Jordan, Lebanon, Palestine, Syria, and Turkey, the drought that lingered between 1998 and 2012 was likely the worst of the past nine centuries, according to a recent tree ring data study (NASA[1], 2016).

1 https://www.nasa.gov/feature/goddard/2016/nasa-finds-drought-in-eastern-mediterranean-worst-of-past-900-years

Iraq and Syria both rely on major shared rivers for water but equally there are parts of the country which rely on rainfed farming. Syria, in particular recorded drought every second year during the past 50 years with drought records going back to AD46. The 4-year drought, which started in 2006, has had major consequences with mass migration from the countryside to the cities and is thought to be a significant contributor to the overwhelming problems now facing Syria.

In Lebanon, Jordan, and Palestine, drought has always been a hazard. Tree ring studies in Jordan show extreme events in the 1800s. More recent droughts from 1958 to 1962 decimated Jordan's camel herds and, in 1997, drought led to 30 percent reduction in the sheep flock. In 1999, the Badia grazing lands failed to produce enough biomass and only 40 percent of red meat and milk were harvested. Rainfed wheat and barley production fell by 88 percent and dam water levels reached unprecedented lows. Jordan is the only country in the region that rations water year-round. Palestine recorded droughts dating back to the 5^{th} and 6^{th} centuries with widespread droughts throughout the last century and severe shortages in 2007 and 2008. Water shortages were so acute that rainfed farming has totally collapsed.

In the Arabian Peninsula, although there is some rainfed farming, there is heavy reliance on groundwater for irrigation, some of which is rechargeable but most comes from extensive fossil aquifers which are being over-exploited. Only Saudi Arabia reported historical droughts dating back to the 17^{th} century, most other countries focused on more recent events. Indeed, they focused more on the ever-present water scarcity they face rather than on drought events that, in most cases, added little to the problems being faced and the potential solutions.

Climate change is expected to affect all the countries in similar ways.[2] Changes in rainfall and temperature are expected to reduce river flows and groundwater recharge. Evidence suggests that rainfall patterns have shifted in terms of timing, duration, and intensity – all of which pose challenges to land users, hydro-power corporations, industry, and urban centres.

CAPACITY TO DEAL WITH DROUGHT

The technical, administrative, and financial capacities in the region to deal with drought are poor. Most countries have institutions that coordinate emergency preparedness, response and recovery systems, but they need to be reinforced with real information exchange and cooperation between agencies at the central level, between those at a local level, and with much greater community participation and support. The emergency management agencies and NGOs increasingly emphasise recovery, exit strategies, and mitigation over relief. But lack of funding, preparedness, and coordination remain significant constraints. There is still too much focus on recovering from drought rather than being less susceptible to the effects of drought.

Several countries report on the various organisations that address drought at different levels, although many also criticise their effectiveness in dealing with drought and particularly the lack of coordination among those involved. In Algeria, for example,

[2] "Record or near-record temperatures occurred in parts of the Middle East and northern Africa on a number of occasions from late July to early September [2016]. The highest temperature observed was 54.0 °C at Mitribah (Kuwait) on 21 July which (subject to ratification) will be the highest temperature on record for Asia. Other extremely high temperatures included 53.9 °C at Basra (Iraq) and 53.0 °C at Delhoran (Islamic Republic of Iran – a national record), both on 22 July, while significant high temperatures were also reported in Morocco, Tunisia, Libya and the United Arab Emirates." Quoted from: WMO, 2017. WMO Statement on the State of the Global Climate in 2016. WMO-No. 1189. https://library.wmo.int/opac/doc_num.php?explnum_id=3414

there is no particular structure dedicated to drought and early warning systems are geared to floods and earthquakes. In Iraq, 12 out of 18 Governorates say they have experienced drought but do not have any action plans in place. Iran has a Disaster Task Force that coordinates emergency disaster activities after the event has occurred, but it can be weeks and months between decision making and action on the ground, particularly for remote towns and villages. These are common themes across the region, though several countries indicate their intention to put more responsive structures in place.

Disaster relief usually includes priorities given to ensuring drinking water supplies, providing subsidies for irrigation equipment and well drilling, providing feed to safeguard livestock, restructuring farmer debts, creating jobs in rural areas, and implementing public awareness campaigns. But these actions, though well-meant can have unforeseen consequences. Providing livestock feed, for example, can stop nomads from moving to places that are less stressed causing over-grazing in areas, particularly around the larger conurbations. Aid in this way can also produce a dependency culture which stops people from taking personal and community actions to increase their resilience. Several countries offer 'wish lists' of what needs to be done rather than stating what is actually being done.

Proactive responses to prevent or mitigate drought impacts can be cheaper than providing relief during drought events but this logic does not necessarily translate into action through planning, budg*et al*locations and changes in the behaviour of institutions. Many countries see long-term development of water resources as being proactive in mitigating drought, but poor planning can actually exacerbate the impacts of drought and the missed opportunities to attenuate them.

VULNERABILITY

Agriculture is still an important part of GDP for most countries and apart from maintaining drinking water supplies, this is the most vulnerable economic activity, particularly for farmers whose livelihoods rely on rainfed farming for basic food staples and on livestock grazing on rangeland. Indeed, livestock production is perhaps the most vulnerable of all for nomadic people. Once the range fails to provide biomass, a whole catalogue of events begins to unfold and communities may take years to recover, if at all.

In Morocco, 90 percent of agricultural land is rainfed and agriculture represents 15 percent of GDP, 23 percent of exports, and employs half of the nation's labour force. Farmers face mounting water scarcity, fragile soils, water and wind erosion and land degradation. They have typical extensive production systems which combine subsistence cereals with livestock and in a 'normal' year produce 70 percent of agricultural GDP. Irrigation is less vulnerable to immediate drought but will be vulnerable to longer-term drought as river flows and groundwater recharge are affected. Droughts are also costly. In 1994, agricultural GDP fell by 45 percent and national GDP by 8 percent. Cereal production fell from 9.6 million tons to 1.7 million tons. During the period 1980-85, which coincided with a long drought, energy production fell by 46.

In Egypt, which relies almost entirely on irrigated farming, agriculture provides 14 percent of GDP and provides livelihoods for 55 percent of the population. Worries about drought faded somewhat with the construction of Aswan dam, which stabilised annual flows and power generation. However, droughts well beyond national boundaries render the whole of the Nile valley vulnerable. Of more immediate concern to Egypt is the increasing demand for water in the nine countries at the upper end of the basin as they seek to provide water for growing populations and to mitigate the impact of drought in their own countries.

Yemen is highly vulnerable to drought not only because of the lack of rainfall, basic infrastructure, and institutions to manage water resources but also because of the lack of security and the rule of law that provides stability for people to live peacefully. A special problem is 'qat' production that consumes a significant amount of the nation's limited water, often at the expense of other uses including domestic supply. This problem has outpaced the government's ability to make the changes needed to develop sustainably.

DROUGHT MITIGATION PRACTICES

Most drought mitigation is embedded in rural, agricultural, and food security development programmes. The aim is to incorporate drought management through disseminating technologies to combat drought, and support policies and incentives to use land and water resources rationally.

Urban areas and industries are often overlooked as droughts may have less direct effect on people and in less dramatic ways but may have higher costs to the economy, given that much of the value addition is typically carried out in urban areas. The growing integration between agriculture and industry at the national level makes the economies of these countries even more vulnerable to shocks from drought.

In the Arabian Peninsula, the growing demand for water from municipalities and agriculture is the main problem rather than drought. The solution is seen in increasing non-conventional water resources such as desalination and use of treated wastewater. Falaj or Qanats (man-made springs) are also seen as a precious resources that help to mitigate drought, particularly for agriculture. Yemen and other Gulf states also exploit spate irrigation, which relies on controlling flash floods in wadis. These provide security for farmers but equally they are vulnerable to over-exploitation and, in the case of falaj, renewal will depend on the availability of recharge.

ISSUES

Lack of drought management planning and coordination was a constant theme among the country reports as was the need to coordinate drought at the highest levels in government. Some stressed the need for integrated water resources management (IWRM) as a means of building resilience to drought and water scarcity. Morocco and Tunisia referred to the poor relationships among government institutions who failed to provide and exchange information for implementing drought management planning and early warning systems. Also, public interest groups are likely to impede progress in the development of drought plans if they are not included in the process.

In addition, poor institutional and human capacity at all levels and among all stakeholders is constraining drought management. Another issue is that current agricultural policies are leading to increasing land degradation and impoverishment and need to be re-examined in the light of drought mitigation. Tunisia also raised the issue of private sector insurance linked to drought so that the pressure was not always on the State budget.

1. Background

This report reviews drought management across North Africa and the Near East. It includes Algeria, Bahrain, Egypt, Iraq, Iran, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, UAE, and Yemen.

The region is arid or semi-arid and is one of the world's most water-scarce areas where drought is a familiar phenomenon. In most countries the average annual water resource is less than 1000 m^3/capita, which the World Bank uses to define countries which are water scarce. However, some have less than 500 m^3/capita, which defines acute water scarcity. The average is only 274 m^3 in North Africa (Algeria, Egypt, Libya, Morocco, Tunisia) and rises to 1786 m^3 because of high rainfall areas and shared water resources in the Near East (Iraq, Israel, Jordan, Lebanon, Palestine, Syria), although this figure hides extremes across these countries. In the Arabian Peninsula (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, UAE, Yemen), the average annual per capita water resource is only 84 m^3. All of these figures compare to the world average of 5,996 m^3 (FAO AQUASTAT, 2014).

In 2013, the average annual rainfall across North Africa was only 96mm, 414 mm in the Near East, 85 mm in the Arabian Peninsula. Some countries, such as Libya, Oman, Saudi Arabia, and UEA rely on fossil groundwater; while others, such as Egypt, Iraq, Syria, and Sudan depend on surface water sources shared with other countries. Morocco and Algeria rely on a mix of both surface and groundwater. In contrast, Bahrain, Kuwait and others in the Arabian Peninsula rely increasingly on desalinated water, treated wastewater, and virtual water in food imports.

Studies show that water is limiting both economic and social development in most countries in the region. In general, rainfall and surface water resources are scarce, variable, and unreliable. Both renewable and fossil groundwater resources are being over-exploited at an increasing rate. Water pollution, resulting from urbanisation and poor land practices, are reducing the availability of good quality water (FAO, 2008).

Although oil supports a number of economies, agriculture is still an important part of the region's GDP and is essential in maintaining national food security. Rainfall is vital for producing most basic staple food crops and for maintaining the rangelands for livestock, which are a major component of many family livelihoods, particularly among nomadic people. Irrigation plays a role mostly in producing cash crops in those countries where sufficient surface and groundwater are available. In some countries, such as Egypt, parts of Iraq and Iran, and Saudi Arabia, irrigation is the only realistic option for large-scale agricultural production.

Droughts are a regular feature in the region and have significant social, environmental, and economic impacts, particularly in places where there are already pressures on existing water resources. The severe drought in 1998-2001 was considered to be the worst drought in 30 years, particularly in Iraq, Jordan, Morocco, and Syria. Its effect was to trigger real concern and raised awareness of the need to develop National Preparedness Plans for Drought Mitigation. In the years that followed, FAO Regional Conferences for the Near East region that were held in Tehran (2002) and in Doha

(2004) highlighted such a need. This led FAO to provide technical assistance to member countries to enhance their capacities to formulate and implement drought mitigation and preparedness strategies, as well as to develop guidelines and implement action programmes for combating drought with particular emphasis on policies, infrastructure, community participation, and political commitment (FAO, 2005).

For the purposes of this review, the countries are grouped in terms of proximity, climate, and hydrology as follows:

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Arabian Peninsula – Saudi Arabia, Kuwait, Bahrain, Qatar, UAE, Oman, and Yemen (Chapter 7)

2. North Africa

Drought is a regular feature of life in North Africa that comprises Mauritania, Morocco, Algeria, Tunisia, and Libya, which all experience a Mediterranean climate along their coastal strips where most of the populations live. All these countries experience a Mediterranean climate with rainfall along the coast but in the south they all face the arid conditions of the Sahara desert.

2.1 MAURITANIA

2.1.1 Background

Located in the arid Sahel region of West Africa, Mauritania is among the world's least developed food-deficit countries, ranked 155 out of 187 countries on the 2013 UNDP Human Development Index. The country is characterised by vast tracts of desert and scarce water sources. Most inhabitants are nomadic and the poorest people live in rural areas, and do not have easy access to basic necessities and sanitation facilities (WFP, 2013).

The climate is dry with low and erratic annual rainfall ranging from 450 mm in the south to only 50 mm in the north. There are repeated cycles of drought and degradation of natural resources profoundly affecting the productive capacity and livelihoods of many households. The country suffers from a structural deficit with domestic food production meeting only 30 per cent of national needs during years of good production. Food and nutrition security is dependent both on the pastoral situation and fluctuations in world commodity prices (ARC, 2013).

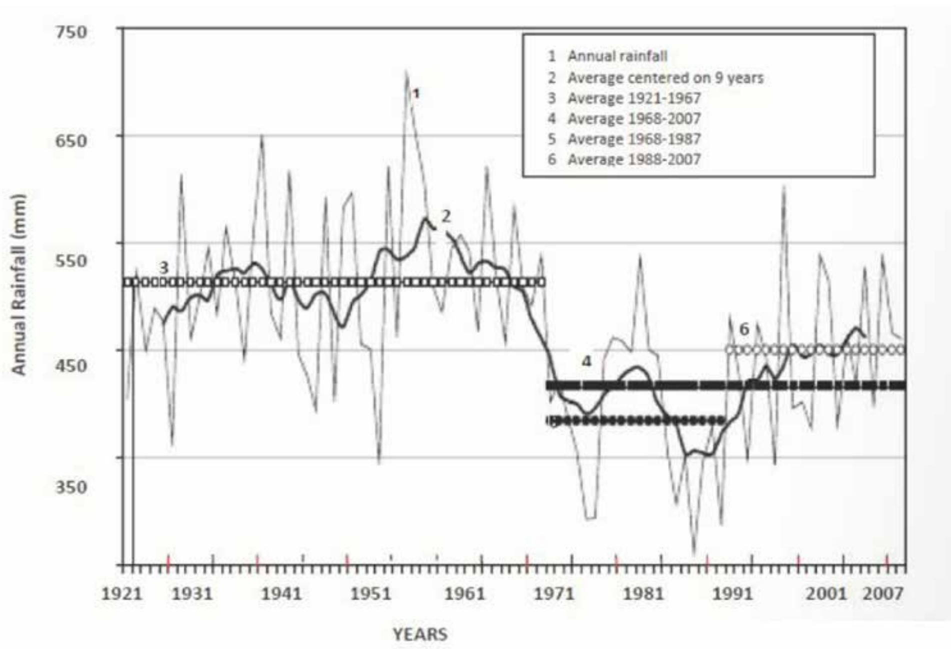
2.1.2 Drought history

During the 20th century, three periods of intense drought affected the Sahel. There were droughts in the 1910s and 1940s and again in 1968. The 1910 drought was severe and extended throughout the Sahel up to 1916. The lowest rainfall occurred in 1913 (Sircoulon, 1976; Vannitsem and Demaree, 1991).

The 1910 drought is remembered as "the greatest famine in history" and as the "sale of children" – children being exchanged for millet. This was the most severe drought recorded in the Sahel since at least 1850 (Nicholson, 1978). Since 1968, the average annual rainfall for nine years fell below the 1921-2007 average (Oser, 2010). Between 1921 and 1967, the average annual rainfall was 514mm and between 1968 and 2007 it was 417mm – a 19 percent decrease (Figure 1). In 1987, an especially severe drought period abated and rainfall increased (Lebel and Ali, 2009).

The meteorological drought of 1968 decreased the vegetation cover and by 1980 it had almost completely disappeared in the town of Nouakchott and its surroundings. Since 1984, dunes have appeared and a state of irreversible degradation seems to have been reached. By 1991, the dunes had extended even with the rainy years at the end of the 20th century (Mainguet *et al.*, 2008).

FIGURE 1
Annual average rainfall in Mauritania



Source: OZER., 2010

According to FAO, the long drought years in the 1970s and 1980s impacted food security. The 150 mm isohyet calculated for 1977-1987 was placed close to the location of the 250 mm isohyet of the 1941-1970 period – in other words, the desert had extended by an area of 150 000 km^2. A steady decrease in rainfall was observed between 1970 and 2000. In direct correlation with the observed reduction of rainfall, the desert has steadily advanced southwards (Barnett *et al.* 2005; Du and Xie, 2008; CRA, 2005).

2.1.3 Impacts of drought

Mauritania, along with other countries in the Sahel, was significantly affected by severe droughts during the 2011 rainy season that resulted in poor harvests, high food prices, and loss of livestock. In January 2012, it was estimated that the food crisis was affecting approximately 700 000 people located mainly in the central and southern regions of Hodh El Chargui, Guidhimaka, Gorgol, Brakna and Assaba (WFP, 2013).

The effects of climate variation, repeated cycles of drought, and degradation of natural resources have exacerbated the vulnerable food security situation. According to the food security monitoring survey (December 2012 –January 2013) between 20 and 30 percent of the population was still suffering from high food insecurity. The current drought – Mauritania's worst in 15 years – has contributed to a food crisis across the Sahel region of West Africa, putting more than 15 million people at risk (WFP, 2013).

Recurrent drought years in the 1970s and 1980s contributed to the sustained migration of people to the towns and cities, 23 percent higher than in 1977 (Arnaud *et al.*, 1998).

2.1.4 Government policy on drought

REACTIVE RESPONSE TYPE

The government is increasingly engaged in humanitarian responses to the recurrent drought and displacement of persons coupled with chronic poverty and vulnerability. The humanitarian community's response plan comes in support of the various programmes. These include (UNOCHA, 2014):

The emergency plan Emel (“Hope” in Arabic) was still ongoing in 2014 and included several components, such as free distribution of food to vulnerable groups, subsidised necessities and food for livestock, creating food security stocks in villages (SPAC), transferring money to where it is most needed, and rehabilitation and construction of water supply infrastructure for communities and livestock.

The existence of the National Agency "Tadamoune", established in 2013, to fight against the legacy of slavery, inclusion, and poverty.

The BREAD plan (Plan of Action for Nutrition Inter-sectoral) is a programme in planning and implementing nutritional activities. The government mobilises the necessary funding for implementing this plan.

The Strategic Framework to fight against poverty and food insecurity, national programmes for education, water, hygiene, sanitation, and health; all of which are essential and complementary inter-sectoral initiatives.

The programme to improve pastoralism and irrigation in the Sahel supported by the World Bank through the Permanent Interstate Committee for drought control in the Sahel.

The Permanent Interstate Committee for drought control in the Sahel (CILSS), which aims to strengthen resilience through emergency actions, prevention, and development.

Revitalising emergency preparedness plans (risk reduction and disaster management) with the support of the mission Capacity for Disaster Reduction Initiative (CADRI).

The designation in 2013 of a humanitarian focal point ranking Advisor to the Minister, Ministry of Economic Affairs and Development (MAED).

All these initiatives contribute not only to meet the urgent needs of people affected in the short-term, but also enhance the resilience strategy for the medium and long-term.

PROACTIVE RESPONSE
(DROUGHT RISK MANAGEMENT POLICIES/PLANS)

Proactive responses to drought are based on the feedback from household food security surveys. These identified vulnerabilities including people experiencing severe acute malnutrition, severe food insecurity, IDPs, and epidemics.

To prepare for droughts in anticipation of crises, village food stocks and seed shops, and money transfer are steps taken to mitigate the adverse effects of shocks on vulnerable populations in the most drought prone areas.

In the 1980s, the government established the Food Security Commission (CSA) to manage food insecurity and emergency response. This structure provides a platform for a complementary partnership with African Risk Capacity (ARC) whereby they could leverage limited resources by providing an additional layer of funds to implement response programmes early enough to protect livelihoods.

In 2012, the ARC Secretariat convened a consultation to introduce an ARC Operations Planning concept to an audience of key stakeholders, followed by a series of workshops and technical training to enhance the government capacity and in-country stakeholders. The Africa Risk View (ARV) software was introduced to determine the risk transfer to ARC and objectively trigger a payout when the drought thresholds are met. An operation plan was prepared that links the existing national intervention mechanisms in order to provide an early response for a potential ARC payout (ARC, 2013).

Individual countries responded to the drought by attempting to invest in government programmes in natural resources, including agriculture, biodiversity conservation, fisheries, forestry, livestock, and water resources. Most countries operate an entire cabinet-level ministry dedicated to each of these sectors.

Bilateral international development assistance, particularly from Canada, France, Germany, Japan, Italy, the Netherlands, Norway, Sweden, and the United States, and multilateral development assistance, particularly from the European Union, the United Nations Development Programme, the World Bank, and the World Food Programme, significantly increased after 1973. International development assistance to the Sahel countries increased from US$500 million in 1970 to US$2.5 billion in 1994 (Naudet 1998). This represents an increase of aid to the Sahel as a fraction of total international development assistance from 2.5 percent in 1970 to 5 percent in 1994. In 1976, the Organisation for Economic Cooperation and Development (OECD) established the Club du Sahel, which raises funding specifically for Sahel countries.

Sahel countries and foreign partners have established a vast network of national and regional institutions to avert ecological disaster such as the tragic deaths in the drought of 1968-1973. Although these institutions have developed a safety net of last resort, they need to make more progress on sustainable natural resource management, biodiversity conservation, and the restoration of ecosystem functions across the Sahel.

EARLY WARNING SYSTEM

In response to the famine and the death of up to 0.25 million people following the Sahel drought of 1968-1973, nine countries (Burkina Faso, Cape Verde, Chad, Guinea-Bissau, Mali, Mauritania, Niger, The Gambia, and Senegal) established a regional organisation, the "Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel" (CILSS) (Permanent Interstate Committee for Drought Control in the Sahel). CILSS operates a scientific research centre "Centre Régionale AGRHYMET", and a socio-economic research centre (Institut du Sahel). These institutions established several new systems that seek to avert future catastrophic impacts of environmental change in the Sahel. The CILSS Secretariat gathers political leaders at periodic meetings to coordinate natural resource management policies.

The "Centre Régionale AGRHYMET" collects and analyses natural resource data and operates an early warning system to provide alerts of potential drought and locust outbreaks. The "Institut du Sahel" conducts a small programme of socio-economic research focused on the Sahel.

2.1.5 Vulnerability to drought

Vulnerabilities include people experiencing acute malnutrition, those in situations of severe food insecurity, IDPs, and epidemics following drought impacts such as loss of crops, loss of livestock, lack of rangeland forage for livestock, and water scarcity including water pollution.

Agricultural and herding practices have always been tenuous in the dry climate. Rainfed and "derrière barrage" cultivation are the main cropping systems and have long been exposed to variability in rainfall. Agricultural production depends on seasonal rainfall.

With less water, animals are at increased risk of disease and death. Dehydration and lack of forage are constant concerns. Animals in stressed conditions are more susceptible to disease. Water sources become increasingly contaminated through overuse, and the convergence of large herds around the watering holes creates easy opportunities for large-scale disease transmission.

For poor communities, the consequences of drought and animal disease can be tragic. In fact, livestock provide a key source of income and food throughout the year, particularly when insufficient rainfall compromises production of staple food crops. In these water-scarce periods, successfully maintaining the herd is critical to a family's survival. As recently as the 1980s, 70 percent of Mauritanians were nomads and subsistence farmers. In the past 30 years, recurrent droughts have forced many of these people to move to the cities. But cities are finding it difficult to cope with the influx. There is high unemployment and a severe lack of social services. Almost half the population, and 75 percent of the country's poor, still depend on agriculture and livestock. These activities generate about 33 percent of the country's GDP. For these reasons, the government has made it a priority to make rural livelihoods more resilient to the impacts of drought and climate variation. Mauritania's 'NAPA, National Adaptation Programme of Action, 2004' identifies drought and desertification and their impacts on land and water resources, and their impact, in turn, on livelihoods and food security as a key issue, highlighting that pastoralism and agriculture are the most vulnerable sectors (UN-WFP, 2013).

The results of the studies carried out in the context of NAPA, have enabled the consulted parties involved to opt for a sectoral and ecosystem approach based on the accurate identification of the sectors and ecosystems most vulnerable to drought and their relationship with the living conditions of the poor in general and the rural community in particular. The main results reveal a significant level of vulnerability such as: significant degradation of arable land; degradation of pasture and loss of livestock; degradation, even disappearance, of forests; high risk of collapse of coastal dune bar; and decreasing water resources (PANA-RIM, 2004).

The effects of drought on the country's economy can be measured through the evolution of the most vulnerable sectors and sub-sectors (agriculture, livestock farming, forestry) but also the pressure on water resources both for human needs, as well as for cattle and irrigation. The rural areas are home to 45 percent of the country's total population and 56 percent of the active population. They include more than 75 percent of the poor and they generate only 26 percent of GDP.

Both agriculture and livestock farming have declined because of their almost complete dependence on uncertain climatic conditions. Each element of climatic stress has had a considerable impact on communities' sources of subsistence and their environment. For instance, the considerable drop in rainfall has resulted in the loss of livestock, a loss that is greater among animals that are moved around (extensive breeding), the massive rural exodus among livestock herders and their cessation of a nomadic lifestyle, and the drop in agricultural production (particularly rainfed agriculture) and the massive migration of farmers to urban areas. Thus, if the situation does not improve (a positive change in rainfall and/or implementation of mitigation or adaptation measures), livestock farming, representing about 67 percent of the rural sector GDP and 12 percent of the country's GDP, will continue to decline (PANA-RIM, 2004).

2.1.6 Practices to alleviate drought impacts

Over thousands of years, pastoralists and farmers have developed adaptation strategies to cope with variations in the weather. These principally focus on moving to areas which were less hot and dry and not overpopulated, and developing and protecting water resources. In recent years, agricultural diversification, temporary migration and employment have been added as coping strategies.

None of these strategies are as robust as they used to be as a result of climate variation. Drought has further exposed unprotected soil, raised temperatures, and dried out wells, and compromised land management practices that were least marginally sustainable. Since 1968, the plant growth period has decreased by 20 to 30 days. Barnett *et al.* (2005) estimated that since 1970 some 150 000 km^2 of Mauritania has turned to desert, with populations constantly retreating from areas becoming uninhabitable. As a result, there has been a reduction of livestock and livestock movements and so they tend to stay around large agglomerations. Animal diseases are on the rise and animal deaths are more common.

Degradation continues to be exacerbated by recurrent droughts, thus contributing to the expansion of the desert and reduction of cultivable area. As a result, more people are farming and herding on smaller pieces of land, there is increased competition between cropping and livestock, and farmers are increasingly using marginal soils that are sensitive to erosion. Wide scale lack of livestock movements is reflected in the proliferation of villages along the main paved roads, and among and within villages there is a widening disparity of wealth favouring those with the means to acquire land and livestock. This further impoverishes crop and livestock farmers who sell to them during shocks. In short, traditional pastoralists are abandoning their nomadic lifestyle, selling their livestock, and becoming destitute.

The average agricultural income is below the poverty threshold. Due to their sedentary nature, livestock and agriculture are vulnerable to the availability of pasture land. Although nomads have traditional access to these resources, there is competition and tension with other users. As a result, incomes are meagre, forcing people to sell their animals at prices that don't allow them to purchase productive capital. Some cope by finding additional sources of income, often cutting trees for charcoal production. When all else fails, they migrate to the cities.

The overall effect on rural incomes and rural food security can be devastating. According to FAO, domestic food production has declined over the past 40 years and this led to reduced income for rural populations. Poor rural households allocate up to 80 percent of their income to food; many have had to cut back on other expenses such as health and education, and have been forced to sell their assets and reduce their consumption of meat and dairy products. Acute malnutrition in children aged 6–59 months is 12.5 percent nationwide – well above the World Health Organisation threshold. Choric malnutrition affects as much as a third of the population in the centre of the country, and in the south-east where projects are targeted.

2.1.7 Previous and current adaptation practices

In the face of renewed drought in the 1970s and 1980s, people devised new strategies regarding the use of natural resources. For instance, livestock farmers adopted mobility as a strategic response and this has made possible the development of grazing land and areas without water, and the seeding of pastures over a very wide area.

Mobility has enabled nomadic people to adapt their production to harsh eco-climatic conditions and to develop a whole system for managing natural resources based on consensus and pastoral solidarity. In fact, the mechanisms for access to resources adopted by livestock herders are based on the principle of the Islamic 'Fiqh' through community of pastoral resources, consensus, and shared responsibility.

Among poor households, livestock farming is a source of income, a means of capitalisation and a form of insurance. These different aspects are all the more important if they are situated in a context of poor and uncertain agricultural production. Traditional solidarity enables poverty to be dealt with through mechanisms driven by a religious and traditional ethics.

When lack of feed and health of their livestock are compromised by drought, many pastoralists resort to a process known as destocking by selling a significant portion of the herd to maintain the health of the remaining animals. This can help to reduce disease and dedicate scarce food and water resources to the livestock they retain. However, destocking periods mean reduced profits as increased supply drives animal prices down.

Among the new adaptation strategies for pastoralists is the development of livestock farming close to a permanent tent or a house; this is frequently used with goats raised for their adaptive capacity with limited food requirement, a few camels, and cows. But lately, a significant new trend has been observed, which is to partition the grazing area in an effort to achieve food self-sufficiency and the need to settle in one spot. In addition, the phenomenon of settlement, a consequence of drought, has accelerated the development of lands for agricultural use and an urgent search for a new economic space.

Local people (farmers and herders) have traditionally adapted to arid conditions by promoting the natural regeneration of trees and shrubs. Natural regeneration is a practice in which farmers and herders set aside entire parcels of land or select small trees in agricultural fields and pastures, protect the trees, prune them to promote rapid growth, and raise them to maturity. The practice requires no special inputs and encourages the propagation of well-known, multiple-use trees.

Traditional livestock herding practices also reduce the risk of overgrazing, and land degradation (Breman and De Wit 1983, Hein 2006). Traditional herders generally kept stocking rates low and moved herds when forage became low. They avoided concentrating livestock for extended periods in the same location. These practices contributed to the development of a nomadic way of life for many herding ethnic groups.

With regard to agriculture, farmers have adopted adaptation measures focusing on crops better adapted to drought, a shortening of the vegetative lifecycle in the rainfed system, the use of fast maturing crops, and of watershed crops in catchments areas of dams and wetlands. The development of irrigated agriculture, the diversification of crops focusing on market gardening, and crops grown under glass, the intensification of agriculture, and the development of drip and spray irrigation are other strategies recently developed in response to climate change.

In the forestry sector, traditional methods of meeting the basic wood requirements among communities living in the vicinity of the forests and the new country policy promoting improved furnaces and renewable sources of energy, the use of gas, and participatory management of natural resources are some of the main features of the new national strategy for adaptation to climate change.

Concerning water, local communities have developed rudimentary devices in an effort to adapt to the new context of water scarcity. Surface water is managed and stored in large domestic canaries, rudimentary water storage pools, and dykes. Sea flooding can slow down fast flowing surface waters near the coast.

Underground water, wells (ogglats) have been dug in areas where there is shallow groundwater. In some places, there are deeper traditional wells with walls supported by branches.

2.1.8 Risk prevention and management mechanisms

See Appendix 1.

2.1.9 References

See Annex

2.2 MOROCCO

2.2.1 Background

Morocco has a population of nearly 34 million people. The climate is marked by sharp differences in temperatures between the Mediterranean and the desert. The country faces problems of development and sustainable management of scarce resources. There are wide geographical disparities and unpredictable weather conditions. Natural resources are under pressure from population growth, improving living conditions, and economic growth. The demand for water includes potable water (6 percent), industrial use (4 percent), and agriculture (90 percent) (Mandi and Ouassani, 2013).

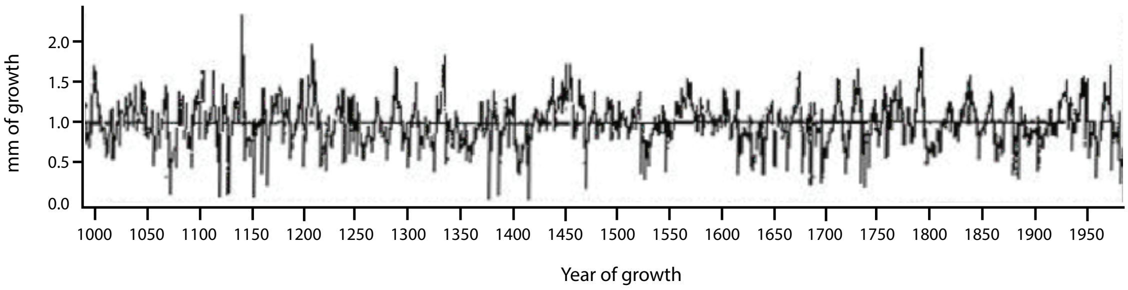
2.2.2 Drought history

Preliminary analysis of longer tree-rings series over 1000 years suggest that Morocco has experienced periods of intense drought in the past. Tree ring analysis suggests that drought occurred every 20 years (Chbouki, 1992) (Figure 2). The long-term drought frequency determined by tree-ring techniques is summarised in Table 1.

Tree ring studies in Morocco (Stockton *et al.*, 1988; Chbouki, 1992) suggest that the long drought episode of 1980-85 which triggered these studies did not represent a trend toward greater aridity as similar dry periods had occurred during the preceding 1000 years.

FIGURE 2

Col Sad tree-ring series (Cedrus atlantica) illustrating the rhythmic variability and the magnitude of drought



Source: Chbouki, 1992.

During the 20th century, Morocco experienced several droughts of different durations and intensities with more than 10 major dry periods which extended over the entire country. Ouassou *et al.* (2005) identified 12 dry periods from 1895 to 2003. Dry periods were 1904-05; 1917-20; 1930-35; 1944-45; 1948-50; 1960-61; 1974-75; 1981-84; 1986-87; 1991-93; 1994-1995 and 1999-2003 (Table 2). Some droughts persisted for up to 6 years (1930-1935 and 1980-1985). More recent droughts and their impact are listed in Table 3.

The agricultural seasons of 1944-45, 1982-83, 1994-95 and 1999-00 were among the driest years experienced with 1994-95 as the driest this last century (Table 4).

TABLE 1

Number of droughts occurring in north central Morocco 1000-1984 based on Col Sad tree-ring series

Drought Length	Number of occurrences	Time interval between occurrences (years)
1 to 6 years	89	11.0
2 to 6 years	35	28.5
3 to 6 years	9	113.7
4 to 6 years	6	182.0
5 to 6 years	4	303.3
6 years	3	455.0

Source: Adapted from Chbouki (1992) by Amesiane and Ouassou (2000)

TABLE 2

Morocco recent droughts statistics, 1985-2003

Drought Length	Number of occurrences	Time interval between occurrences (years)
1 year	1986-87	2
2 year	1991-93	4
2 year	1994-1995	1
4 year	1999-2003	4

Source: Adapted from DMN 2006 by Ouassou (2014)

The most recent drought episode in Morocco was in 2015-16, with rainfall for the period September 2015 to April 2016 15 %-40 % below average at most locations; consequently the total wheat harvest was 65 % below that of the previous growing season (WMO, 2017.

Between 1978 and 1994 average annual rainfall (between October and April) decreased by 30 percent compared to the period 1917 to 1961 (Agoumi and Debbarh, 2006). Over the last 45 years, the trend in rainfall shows significant decrease in quantity and in total annual number of rainy days, especially during the February-March-April period that is critical for cereal production (Driouech, 2006).

Water storage in dams is generally for multiple purposes including drinking water, irrigation, and hydropower. Without this storage the water supply to main cities and agricultural perimeters would have been disrupted.

TABLE 3
Main droughts recorded from 1900 onwards

Years	Drought impact	Years	Drought impact
2006-07	700 000 people affected. Grain production reached only half of the normal year's levels	1959	Souss, Anti-Atlas
2004-05	Reduced economic growth rate from 3.5 to 1.3% for 2005	1957	Generalised with exception of Eastern and extreme North
2000-01	The country imported about 5 million tons of wheat in 2001 (compared to 2.4 million tons in normal years)	1953	Eastern, north Atlantic coast and Haous
1999-00	275 000 people affected. Economic Damages: USD 900 million	1952	Coast and South plains
1998-99	Reduced incomes due to drought caused GDP to fall by 1.5 percent in 1999	1951	Agadir & Essaouira region
1996-97	Reduced incomes due to drought caused GDP to fall by 2.3 percent in 1997	1950	Souss & Gharb
1994-95	General; Reduced incomes due to drought caused GDP to fall by 7.6 percent in 1995. Cereal production fell from 9.5 million tons in 1994 to 1.6 million tons in 1995.	1949	Souss & North coastal plains
1993	General	1948	Atlantic coast & Anti-Atlas
1992	General with the exception of Ouarsasate area	1945	General with important rainfall deficits
1990	Gharb, Sais, Eastern and High Atlas	1944	North littoral plains
1988	North of Middle Atlas	1942	Eastern and North littoral plains
1989	North of Middle Atlas	1937	Eastern and North littoral plains
1987	General with the exception of Oriental and Sais	1935	Pains & Atlantic coasts
1986	Eastern, extreme North, Essaouira and Ouarsasate	1933	Gharb, Haous & Souss
1985	North of Morocco with the exception of Atlas coast	1931	General
1984	General with the exception of North Atlas coast	1930	Plains et South Atlantic coast
1983	General	1927	Coast and South Atlantic plains
1982	General with the exception of Middle Atlas and Anti-Atlas	1926	Plains et North Atlantic coast & Haous
1981	General	1925	South Atlantic coast
1975	General with the exception of the East and Midelt region	1919	South Atlantic coast
1967	Sais, Gharb and North Atlas coast	1918	South Atlantic coast
1966	General with the exception of Middle Atlas and Anti-Atlas	1916	South Atlantic coast
1964	High and Anti-Atlas regions	1910	South Atlantic coast
1961	High Atlas, Anti -Atlas, Eastern and south Atlas coast	1905	Atlantic coasts

Source: (M.A.E.E, 1997 ; RMSI, 2012)

TABLE 4
Comparison of drought episodes 1944-45, 1982-83, 1994-95, and 1999-00

Region	Afourer-Tadla	Agadir	Marrakech	Casablanca	Meknès	Tanger	Oujda	Agricultural season	Average deviation
Annual rainfall (mm)	-	119	139	261	293	420	139	1944-45	
Deviation from mean (%)	-	-52	-43	-43	-53	-44	-60	-	- 49
Annual total (mm)	193	89	101	273	419	536	151	1982-83	
Deviation from mean (%)	-41	-64	-59	-41	-33	-29	-57	-	- 46
Annual total (mm)	185	121	259	149	285	360	232	1994-95	
Deviation from mean (%)	-44	-51	9	-64	-50	-51	-28	-	- 40
Annual total (mm)	170	118	185	264	317	603	146	1999-2000	
Deviation from mean (%)	-48	-53	-23	-32	-44	-18	-53	-	- 39

2.2.3 Government policy and institutions

Ministries dealing with water management including agriculture, water and environment, forestry, interior, health, energy and mines, and finance, are also concerned with drought management. Overall coordination of drought management issues is the responsibility of the Permanent Inter-ministerial Council for Rural Development (PICRD), which has the ability to officially declare the onset of drought. The technical secretariat of this Council is under the Ministry of Agriculture and Rural Development, which heads the periodic meetings of the Inter-ministerial Technical Commission once a drought episode is declared.

CONSULTATIVE INSTITUTIONS AND BODIES

Institutions include:

The National advisory board represented by the Superior Council for Water and Climate (SCWC)

The National Council for Environment (NCE)

The Permanent Inter-ministerial Council for Rural Development (PICRD) created in 1999 following the severe drought episodes

The National Meteorology Office

The National Drought Observatory (NDO) created in 2001 and attached to the General Secretary of Ministry of Agriculture and Rural Development and based at the Institut Agronomique et Vétérinaire Hassan II (IAVHII)

The General Council for Agricultural Development (GCAD).

The PICRD and the NDO have advisory roles to their respective ministry on a continuous basis while the others structures have much less frequent consultative role on drought issues.

WATER RESOURCES MANAGEMENT

The main institutional stakeholders in the water sector are represented by the key ministerial departments including water and environment, agriculture, local authorities (Ministry of interior), health, energy and mines, and finance departments. NGOs such as water user associations and natural resources/environment protection associations are also actively operating in the country in response to civil society's needs. The overall coordination is the role of the Directorate General of Hydraulics (DGH, State Secretary for Water) with a strong involvement of the Water and Ag-Engineering Administration (AGR, Ministry of Agriculture). Decisions related to water resources management are implemented by the Public Offices and Agencies which operate under the supervision of their respective ministries: ONEP for drinking water, ORMVA for irrigation, and ONE for hydropower.

NATIONAL EXECUTIVE INSTITUTIONS

The Executive institutions in charge of advising the various line agencies and ministries issue recommendations and approve plans. These institutions include the Ministry of Water (State Secretary for Water, within MTAWE); Ministry of Environment (State Secretary for Environment within MTAWE); Ministry of Agriculture and Rural Development; Ministry of Interior; Ministry of Health; and the Ministry of Energy and Mines.

The Inter-ministerial Technical Commission (ITC) is the basis of the executive board at the national level. It includes ministry representatives of Agriculture (MADR), Forestry (HCFWFD), Water (DGH, ONEP), Energy (ONE), Interior (MI), Health (MH), Finance and Credits (MF, CNCA). The ITC meets weekly to report to the Permanent Inter-Ministerial Council for Rural Development which, based on the Commission report and the information provided by the advisory bodies, may declare drought and drought affected regions. If drought is declared nationwide, then the National Drought Mitigation Plan is set for execution. This is basically the reactive relief dimension of the plan that has to be implemented and supervised at the national, regional/provincial and local levels.

REGIONAL AND LOCAL INSTITUTIONS

The Regional River Basin Agencies contribute to drought management and adjust water allocation according to available resources. Their effective implementation is, however, yet to be initiated through the Local Authorities, ORMVA, the Regional Environment Councils, and the water users associations (AUEA).

REGIONAL AND LOCAL SETTING FOR DROUGHT MANAGEMENT

The Regional Drought Committee is headed by the Wali of the economic region, who normally supervises more than one province in the region, while the province is headed by a governor. The Regional Drought Committee is responsible for all decisions pertaining to the National Drought Mitigation Plan related measures and actions to be implemented in the region. This committee includes representatives of key ministries (ONEP, ORMVA, DPA) and elected members of the rural and urban collectivities of the region, in addition to active NGOs. The coordinating role and the composition of the Provincial Technical Committee at the province level are similar to those of the regional drought committee at the region level. At the local level, a number of Local Drought Committees/Specialised Drought Committees representing ministry line agencies and NGOs are responsible for detailed examination of the content of the proposed measures. At the different levels of implementation of the National Drought Mitigation Plan, political pressure groups and elected members of the local communities become actively involved.

CURRENT STATUS OF WATER MANAGEMENT REFORMS

The role of the State in water resources management is outlined as follows:

Water mobilisation. The State, through the DGH, is in charge of all infrastructure related to water mobilisation, except for small dams and wells.

Irrigation water allocation. The State is in charge of all large-scale irrigation. Many projects of medium and small-scale irrigation dimension have also been realised and/or planned. The Administration through regional structures of Ministry of Agriculture (ORMVA) directly manages large-scale irrigation systems, although involvement and active participation of water users associations (AUEA) are growing.

Water distribution. The State is involved in production, through ONEP; and in distribution through ONEP and the "régies", which are also in charge of the drinkable water programmes for rural areas.

Water pricing. For the "régies", the prices are set by a commission headed by the Prime Minister that defines pricing structures and levels to all water users. For the ORMVA, prices are set by a decree involving three ministers.

Water allocation. The State is in charge of realising the master plans of water resources for the main hydrological basin. At this level, demands by sectors are estimated and resources are allocated. The master plans are presented to the SCWC to be amended or approved. These plans are the basis of water allocation between ONEP (for potable water) and irrigation.

Conflicts resolution. Through the courts or the administration, the State mediates conflicts over water use. Usually, these conflicts relate to the management of dams and are settled through the arbitration of the "Direction Régionale de l'Hydraulique, DRH" (Regional Hydraulic Directorate), which has become the regional river basin agencies.

Registration of water rights. The State is in charge of registration of water rights although this function is still in its infancy. There is no uniform registration of agreement, concession or of the different water rights that are supported by the law. The basin agencies will have to put a registry in place in order to unify this treatment.

RECENT EVOLUTION

The State plays a major role in water resources management and these multiple interventions have a huge cost to the State budget and have forced the government to reconsider its options. It was estimated that the overall budget accounts for more than 90 percent of total investment cost for irrigation. The cost of current policies explains the shift in favour of more involvement of the private sector and a change in cost-sharing between the State and the water users' beneficiaries.

REACTIVE DROUGHT MANAGEMENT

Because of the severe droughts that dominated much of the country during the 1980s, the government adopted a reactive action plan to mitigate the drought effects in the form of relief operations which initially focused on drinking water and livestock relief. However, the more dramatic subsequent development of the droughts and the growing awareness from the scientific community and civil society led the policy-makers to adopt a more pro-active approach. As a result, the National Programme for Drought Mitigation has two clear orientations:

An operationally oriented short-term reactive programme with relief operations as the main focus, and

A structurally oriented drought planning programme focusing on the long-term pro-active approach to drought mitigation.

It is now strongly believed at the political level that any national drought management strategy should address these two conflicting/complementary approaches of the long-term drought management policy.

When a drought occurs nationwide, the policy so far applied consists of setting up a relief programme. Funds are made available to alleviate the consequences of drought and to assist rural populations in solving the problems associated with, (i) drinking water, (ii) livestock protection and feed subsidised, (iii) job creation, and (iv) agricultural credit debt relief. This is typically a crisis-management approach whose cost is significant in terms of public money, time, and human resources. In the 1999 drought year, a total of MDH3.18 billion (approximately US$318 million) was allocated to the national drought relief programme, including MDH332 million for drinking water, MDH300 million for the livestock, MDH1.91 billion to create job opportunities in rural areas, and the remaining covered the agricultural credit sub-programme.

Simplification of administrative procedures was proposed to speed up the execution of proposed drought mitigation activities. The procedures were simplified to include (i) definition of programme of activities to be undertaken to alleviate the drought impacts, (ii) visa and signing of the programme, and (iii) spending and payment regulations.

PROACTIVE DROUGHT MANAGEMENT

Following the severe drought episodes of the 1980s, and the increasing awareness among decision-makers and the public, the government set up strategic drought planning in order to move away from the prevailing crisis drought management. In 1995, preliminary guidelines for a new approach to drought based on risk management principles provided a more proactive drought management approach. The process is outlined in Figure 3.

However, there are still weaknesses to overcome, the most important being, (i) poor institutional coordination, (ii) lack of availability of data and of clear mechanisms for circulating information, and (iii) lack of internal financial resources to meet the recurrent cost of the proposed activities for institutional capacity building.

THE NATIONAL DROUGHT OBSERVATORY

In 2001, the National Drought Observatory was created within the Ministry of Agriculture and Rural Development, located on the campus of Institut Agronomique et Vétérinaire Hassan II (IAV Hassan II), as a means of building institutional capacity to cope with drought, and also as a coordinating structure and link between the scientific community working on various drought issues and the decision-makers in charge of the drought mitigation activities.

The Observatory is managed by the Ministry of Agriculture and Rural Development, through a central management unit located at IAV Hassan II. In addition to the involvement of the central administration of the Ministry, its regional structures are also involved in the proposed operational activities during implementation. The Observatory is still trying to permanently involve and develop links with the Royal Centre for Remote Sensing, and the other ministerial structures and institutions, basically the National Meteorology Office, the Hydrology Administration (Water Department), the Department of Environment, the Department of Forestry, and the Ministry of Higher Education and Scientific Research through university centres. Other national partners may join the network as activities around drought management develop. At the international level, the National Drought Observatory is supported by the US National Drought Mitigation Centre, University of Nebraska-Lincoln, and by the United States Department of Agriculture.

METEOROLOGICAL DROUGHT, WEATHER FORECASTS, AND DROUGHT EARLY WARNING

Morocco has some 40 complete weather stations (synoptic stations) operated by the National Meteorology Office. The Met Office has full-time meteorologists who monitor rainfall patterns and weather forecasts in relation to drought events, using different models.

A series of triggers are used by Ministry of Agriculture for monitoring crop stage and the state of livestock and pasture, by Ministry of Water (as State Secretary) for available water management, and by Ministry of Communication for public awareness about development of the drought situation.

Three models are run on a monthly basis to help forecast drought trends. These are for developing short-term forecasts: radar coverage and numerical weather prediction; and long-term forecasts:

Project Al Moubarak (NOA, based on statistical model)

Project El Masifa (based on both dynamical and statistical models)

Arpège-Climat dynamical model from "Météo-France" (El khatri and El Hairech, 2014).

The Meteorology Office publishes a monthly newsletter on drought trends. All these features are considered as strengthening the organisation whose expertise is recognised by WMO and bilateral collaborative agreements particularly with France, Italy, and the USA. The National Directorate of Meteorology uses long-term weather forecast simulation models for a more proactive approach to meteorological drought management.

AGRICULTURAL DROUGHT – CROP PRODUCTION AND LIVESTOCK

The reactive response to agricultural drought includes drought triggers, ministries involved to produce a national drought plan of action, the components of that plan and its implementation. Actions are of two kinds. A first series of measures concerns the financing of agricultural activities affected by the drought, including a system of farmer insurance for cereal production failure. A second series of measures concerns seed supplies, the objective being to increase seed availability for the next agricultural season. The Crop Production Directorate collects information mainly through its regional structures. Every week during the drought period, a campaign document is prepared summarising main events observed by province particularly on cereal growth. This information, in addition to that provided by the Meteorological Office, is used to monitor the drought process during the growing season. Monitoring of dysfunction of market prices for basic commodities and agricultural inputs, along with pricing policies and subsidies during drought period is the responsibility of the Programming and Economic Affairs Directorate. Lack of a continuous recording system and of quantitative assessment of drought development in different regions on a real-time basis may be considered as the main weakness within the Ministry of Agriculture and Rural Development. Coordinating mechanisms for water management issues with the newly established Secretary of State for Water have yet to be reshaped.

The Livestock Directorate receives information from Agriculture Provincial Directorates (rainfed areas) and from Agricultural Development Offices (irrigated areas) about the state of cattle feed supply, prices for animals and for feed, state of watering points for livestock, grazing land availability, and herd sanitary states. Also, this Directorate closely monitors the animal feeding balance and the imports of animals and animal products, which are communicated by sanitary services control at the country border. The livestock numbers surveillance system allows control of herd reduction during drought and helps to maintain a minimal population for reproduction. Collected information is analysed by the services of this Directorate to elaborate necessary scenarios for decision-makers regarding livestock safeguard and protection. A weekly report is produced on drought impact and severity on animal production. The main objective is to fill part of the fodder deficit to enable herders to overcome their financial incapacity to face important feed purchases to protect their herds. Under drought conditions, activation of the livestock safeguard plan is considered to be operational enough but independent evaluation of its impacts in different regions of the country is still to be carried out.

HYDROLOGICAL DROUGHT AND WATER MANAGEMENT

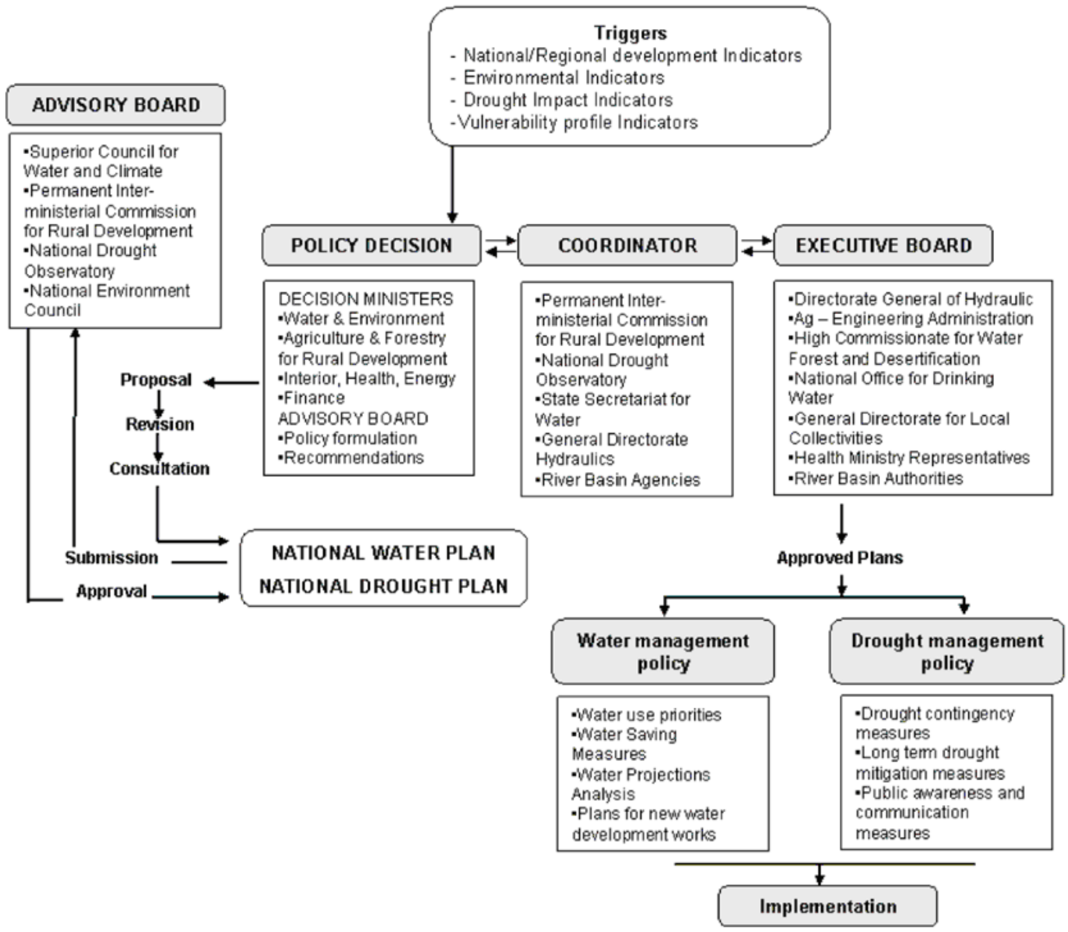
The General Hydraulic Directorate has the responsibility of surface and groundwater resources mobilisation and evaluates with the relevant structures of the agricultural sector (mainly the Administration du Genie Rural) and other users, the water needs throughout the drought period. The evaluation is regularly made in joint meetings on the basis of indicators concerning the average rainfall deficit across the country, the amount of water stored in dams and the situation of the main groundwater tables. The outcome is a number of scenarios for water allocation by sectors (irrigation water, domestic, industrial). Estimates are proposed to activate the water supply programme.

Responsibility for implementing the proposed measures is shared with other ministry departments and institutions, mainly the Ministry of Agriculture and National Office for Drinking Water. The newly promulgated participation of the regional water basin agencies to decentralise decisions and to consider specific needs at the regional/local levels is an important element of equity. The participatory approach to decision-making with regard to water allocation under drought conditions is certainly a strengthening factor of the system. However, conflicting views between the hydraulics and agriculture decision-makers may alter the decision process with sometimes negative impacts on irrigated agriculture. This is particularly true when the level of stored water in the dams is low enough to have the right water allocation compromise between irrigation and other users.

SOCIO-ECONOMIC DROUGHT

One of the major impacts of drought is the considerable loss of agricultural seasonal jobs and the risks of rural migration to urban areas. In order to maintain populations in rural zones, the government has included job creation activities in drought planning, such as constructing country roads, operating land improvements, and irrigation management operations.

FIGURE 3
Proactive responses in agricultural and hydrological drought



Source: Ouassou et al., 2007

2.2.4 Vulnerability to drought

AGRICULTURE AND LIVESTOCK SECTOR

Agriculture is an important part of the Moroccan economy and is most vulnerable to drought. This sector currently represents 15 percent of Gross Domestic Product (GDP), 23 percent of exports, and employs close to half of the labour force. People living in rural areas remain economically vulnerable (World Bank, 2010). Farmers face mounting water scarcity, fragile soils, water and wind erosion, and land degradation. Rainfed agriculture concerns about 90 percent of agricultural land and includes mainly small traditional farms (70 percent are less than 5 hectares) in extensive production systems dominated by subsistence cereal, combined with food legume crops and livestock, and produce in "normal" rainfall conditions, about 70 percent of agricultural GDP.

Despite low productivity and disappointing progress in the adoption of new technologies, rainfed agriculture plays a critical role because it is the primary source of employment for 75 percent of the rural population and it produces the bulk of the country's basic food supplies of cereals, pulses, and oilseeds (Kydd and Thoyer, 1992). Cereal production is the most important agricultural activity. However, climatic conditions fluctuate widely from year to year and severe droughts often occur at any time during the growing season. As a consequence, the agricultural production and welfare of rural populations, which represent half of the country's total population, may be dramatically affected. Rainfed areas produce over 75 percent of cereals and food legumes, about 70 percent of the production of oil (30 percent olive oil and 40 percent of other vegetable oil), 25 percent of milk and cultivated forage, 18 percent of vegetables, and 15 percent of sugar. In addition, the rangelands cover 13 million hectares that provide more than one third of the total livestock feed needs and 70 percent of total meat production.

Droughts are extremely costly. The 1994-1995 drought caused agricultural GDP to fall by 45 percent and GDP to fall by nearly 8 percent. Small holders are particularly vulnerable to climate variation. Commercial farmers have technical know-how and financial resources to cope with adverse climate conditions, but small farmers have no buffer (Mokssit and El Khatri, 2001).

Drought decreased cereal production from 9.6 million tons in 1994 to 1.7 million in 1995; it reduced rural employment by 60 percent and led to a reduction of 50 percent in agricultural added value, as compared to average of 1989-1994. There are large variations of drought impact between regions depending on their vulnerability. In 1999 drought had profound effects in Tadla, the central region, where mean annual rainfall was reduced by 22 to 35 percent. Livestock had a feed deficit of 25 million feed units or 25 000 tons of grain barley equivalent. In a normal year, cereals provide 1 560 000 working days, which were reduced to 240 000 days in 1999. Job opportunities were reduced by 85 percent. Food legumes and forage crops were a total loss (Ouassou *et al*., 2007).

WATER SECTOR

Annual water resources per capita are estimated at 700 m^3, which is well below UNDP's scarcity criterion of 1000 m^3. By 2025, per capita water resources are expected to be below the absolute threshold of 500 m^3 (El Badraoui and Berdai, 2011).

The drinkable water supply of urban areas was assured in an almost-normal way during the periods of drought with the exception of Marrakech where 27 percent limit was implemented in 1983; Tétouan where 36 percent limitation was implemented in April 1995; and Tangier where close to 50 percent limitation was implemented during 1993 and 1995.

The rural development strategy has mainly focused on improving the modern irrigation sector which consumes, on average, 85 percent of available water resources. The whole irrigated area contributes 45 percent of the agricultural GDP and produces 75 percent of the agricultural exports. During the periods 1980-85, 1991-1992 and 1994-95, the water supply for irrigation from dams was only 30-35 percent of the demand.

SOCIO-ECONOMIC IMPACTS OF RECENT DROUGHTS

Drought has considerable negative impacts on the economy and people in terms of crop production losses, reduction in GDP, and loss in livelihoods. In 1997, drought reduced incomes causing GDP to fall by 2.3 percent and, in 1999, reduced incomes causing GDP to fall by 1.5 percent. In 2000, 275 000 people were affected by drought and economic damage was estimated to be US$900 million.

In 2000-2001, 5 million tons of wheat where imported compared to 2.4 million tons in normal years. In 2004-2005, drought reduced economic growth rate from 3.5 to 1.3 percent. In 2007, some 700 000 people were affected, and wheat production fell by 76 percent compared to 2006. In 2011, total cereal harvest was less than 3.2 million tons, a sharp drop from 8 million tons in previous years. Therefore, the country faced a large import bill (FAO, 2010b; Fox News, 2012; Schilling, 2012; World Bank, 2010).

ENERGY PRODUCTION

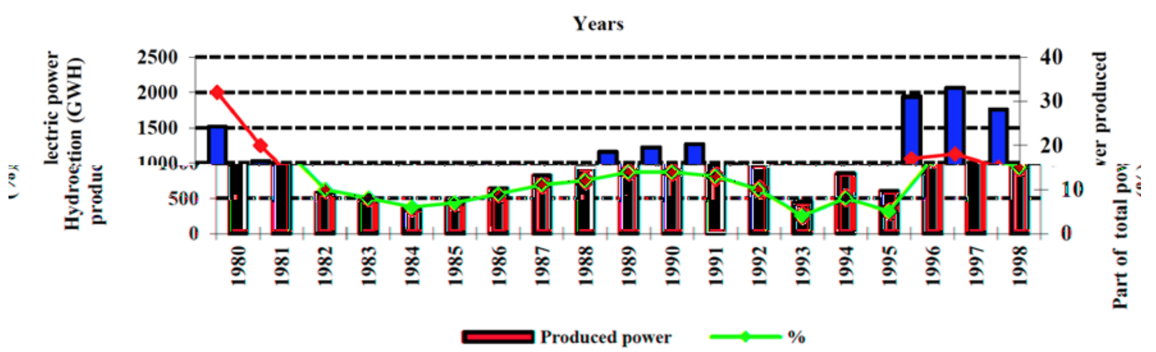
During 1980-1985 annual hydropower production was 740 GWH, which was 46 percent below average. Between 1991and 1995, drought resulted in a 42 percent fall below average (Figure 4).

2.2.5 Practices to alleviate drought impacts

MEASURES AND PRACTICES FROM GOVERNMENT AND OTHER SUPPORTING INSTITUTIONS

Water resource measures: Maximising dam storage. There are more than 140 dams and a total of 150 dams are expected to be complete by 2030 – with a total storage of

FIGURE 4
Impact of drought on hydropower production



1.7 billion m^3. There is also a programme of small dams being planned, 1000 by 2030. Other practices being introduced include water conservation and management, water harvesting, improving aquifer recharge, and strengthening the control and penalties for over-use of groundwater.

Other measures include water transfers between several basins, desalination (up to 400 million m^3/year), waste water reuse (300 million m^3/year), and improved water distribution efficiency by 2020.

Water metering and price scaling is also being introduced to enable better water use rationing.

Agriculture adaptation practices: Better use of water in agriculture getting more crop per drop. These types of activities included growing drought-tolerant crops, improved varieties tolerant to stress, and certified seeds; direct seeding; change in seeding dates and/or seeding density; supplemental irrigation; good agronomic practices (soil preparation, weeding, etc).

Other practices include: introduce index-based weather insurance schemes; drought monitoring and early warning; scale up financial and technical assistance (drought relief and management plan); enhance the value of traditional knowledge in drought management; strengthen regional and international cooperation; dry farming techniques; crop and plot diversification; income source diversification off the farm.

The average potential annual water savings by improving irrigation is expected to be 2.4 billion m^3; conversion to modern irrigation techniques a potential saving of 2 billion m^3 if 40 000 hectares per year are upgraded.

Crops adaptation practices: Change cropping to barley instead of wheat because barley ripens faster avoiding late water deficit (Kuhn *et al*., 2010); chickpea or lentils planted late when there is rainfall delay, to make best use of available water from late rains in the season (Lybbert *et al*., 2009). Use of fallow to accumulate water and fertiliser in the soil. Stockpiling grain and cereal straw in good years as buffer for dry season (Skees *et al*., 2001).

Rangeland livestock – short term: store fodder and animal feed; reduce flock size and animals in distress to feed remaining flock; sell young lambs first then if needed reproductive ewes; shift animal and peoples' diets to lower price/lower quality inputs.

Rangeland livestock – long-term: monitor and forecast livestock and feed and rangeland forage availability; adjust legal and institutional framework; complement with purchased animal feed; loan and credit schemes between private contractors; collect grass/hay during the rainy season and store; re-organise transhumance schemes, with mechanised transport; shift flock composition towards goats; develop shrub and bush planting; improve management and use of community forests.

For more measures to alleviate drought impacts, see Appendix 2.

2.2.6 Measures to build resilience to drought

To increase resilience against climate variation, agricultural policies should focus on soil and water conservation actions, rangeland vegetation, and balanced groundwater usage. Strategies to reduce risk to drought implemented were:

In 1995, established the water law, with emphasis on integrated water resources management through better water use efficiency, resource allocation practices, and protection of water quality

In 2001, created a National Drought Observatory (NDO)

Adopted a weather-insurance approach in cereal production (Stoppa and Hess, 2003)

Development of solar energy – preservation of forest and watershed ecosystems

Integrated Watershed Management by the Regional River Basin Agencies and HCEFLCD

Replacement of firewood in semi-arid rangelands by developing saving wood stoves and solar power plants and home apparatus.

2.2.7 Issues

Incomplete survey of used wells and incomplete use of metering for controlling agriculture irrigation

Privatisation of land used as rangeland impeding livestock movement and destroying natural Alfa ecosystem

Resistance of different government institutions to provide and exchange information needed for implementing drought management plan and early warning system.

2.2.8 References

See Annex.

2.3 ALGERIA

2.3.1 Background

Algeria has limited natural resources, erratic and unevenly distributed. With the exception of fossil water in the Sahara, natural water resources are mainly located in the north of the country. Some 90 percent of the population live along the North African coast on 13 percent of the country's land area. This is the wettest area with average annual rainfall ranging from 400-1000mm and surface water resources are most important. South towards the Saharan Atlas the rainfall is between 100 and 400 mm and groundwater resources are most important. These are the high cereal plains and pre-Saharan steppe pastures. This is where drought impacts are greatest. Beyond to the South, the arid Sahara desert occupies the remaining 87 percent of the land area.

Some 90 percent of the total surface water (estimated at 12.4 billion m^3 annually) occurs in the coastal area. The remaining 10 percent is divided between the Highlands and the Saharan basins.

Irrigation consumes 62 percent of the water resources. The demand for drinking water, which has increased significantly since the 1970s, accounts for 35 percent of the total demand. The share of the water for industry is only 3 percent (Mosas and Ghosn, 2014).

2.3.2 Drought history

Substantial and sustained dry conditions occurred in the 1540s, the 1860s, the 1870s, the 1920s, and the 1940s; and four times in the last five centuries there are six-year periods where every consecutive year was below the long-term mean: 1548–1553, 1737–1742, 1770–1775, and 1876-1881. Drought events from 1456 are summarised in Table 5.

The most recent drought (1999–2002) in Algeria and Tunisia appears to be the worst since at least the middle of the 15th century and is potentially due to the possible link to anthropogenic climate change (Hoerling and Kumar, 2003; Seager *et al*., 2007).

Throughout the 19th century (1850-1950), North Africa, while predominantly rural periodically experiences "black" years (or periods), related to climatic events (droughts), agricultural crop failure, shortage, or sometimes even famines, and health problems (various epidemics). The significant decrease in the Algerian population from 1861 to 1872 was often attributed to these various calamities that hit the country every ten years (Tabutin *et al*., 2001).

The 1876-1881 drought events are the worst in the early record. Historical sources also point to drought, famine, cholera, and plagues of locust (Taithe, 2006), and in particular to a persistent drought at Belesma (Batna) that caused massive damage to the cedar forests (Boudy, 1955).

From 1945 to 1947, Algeria experienced a terrible drought. In the South of Oran, in the region of Ain Sefra, official sources reported about 3 000 people died of starvation in a population of 80 000, and 900 000 sheep were lost, almost 90 percent of the livestock perished. Twenty years later, in early 1966, Algeria experienced the lowest rainfall since 1945, and this caused poor crop germination and production loss (Kassoul and Maougal, 2006).

Several dry periods were observed in the north between 1922 and 1992: 1910-1920, 1939-1948; and 1973-1992. These were characterised by famine, wildfires, and major social disruption. The 1973-1992 period was particularly dry with adverse impacts on water resources with lower inflows into dam storage, falls in groundwater levels, and shallow wells and springs running dry (Meklati, 2009) (Table 6).

Poor rainfall in 2001 and the winter season of 2002 meant that critical shortages occurred in drinking water to large urban centres, particularly in Wilaya of Algiers. All the dams supplying Algiers were in what is called "dead band", a decline not seen since the dams came into use (Kettab *et al*., 2004).

Matari and Douguédroit (1999) noted that the 1940s drought was mainly due to poor spring rains and in the 1980s it was due to poor winter rains. More recent droughts mainly delayed planting and germination which affects plant growth and crop production for arable and livestock farmers.

2.3.3 Impacts of drought

The intense and persistent drought observed in Algeria during the last 30 years and characterised by a rainfall deficit estimated to be 30 percent of the average annual rainfall has had a negative impact on river flow regimes causing serious consequences for all socio-economic activities of the country.

TABLE 5
Drought history in Algeria and Tunisia 1456–2002

Period/year	Events	Duration/ interval	Observations
1456	1 drought event	1 year	The driest single years over -1456-2002
1548-1553		6 years periods	
1502-2008	94 dry events	1 rare event of 4 years	With a mean occurrence interval of 5.4 years
17th century	15 events among 23	1 year	Highest number of dry events
	4 drought events	2-year	Highest number
1737-1742		6 years periods	
1765-1768	1 drought event	4 years	
1770-1775	1 drought event	6 years periods	
1867	1 drought event	1 year	
1876-1881	1 drought event	6 years periods	Worst sustained (drought, famine, cholera, plagues of locust, damage to cedar forests)
1877-1879	1 drought event	3 years	Dieback of one third of the cedar trees
1879-1907	63 dry events	1 year	The maximum interval between drought events was 28 years
	12 dry periods	2 years	
	1 event (1877-1879)	3 years	
	1 event (1765-1768)	4 years	
1890	1 drought event		Data from Oran station
1910-1920	Period of drought		Similar to droughts in Sahel
1922	1 drought event		
1937	1 drought event		Severe and generalised
1939 à 1948	Period of drought		Time of particularly severe dry conditions
1945-47	1 drought event	3 years	‘year of hunger’ described by Albert Camus, 3000 death south Oran
1947, 51, 66,1976			Dieback of Cedrus atlantica
1961	1 drought event		Severe and generalised
1970	1 drought event		Severe and generalised
1973 à 1992			Gradient rainfall deficit from 17 percent in the East toward 33 percent in the West of the country
1977-1978	1 drought event	2 years	Second severe drought period preceding dieback of Cedrus atlantica
1978	1 drought event	1 year	The driest observed year (138.4 mm)
1975-1998	Period of drought		Gradient rainfall deficit from 11 percent in the East toward 20 percent in the West of the country
1981-84	Period of drought	4 year	
1988, 1989, 1990; 1993, 1994, 1995.	2 drought events	3 years	
1997	1 drought event	1 year	The driest reconstructed (148.6 mm)
1999–2002	1 drought event	4 years	The longest period of consecutive drought years for AD 1456–2002
2000, 2001, 2002	1 drought event	3 year	2002 the driest single year 1456-2002; water shortage in major urban centres, such as Algiers and Oran
20th century	20 drought events		Worst period from 1502 in terms of severity and frequency (13 out of 20 dry took place in 2nd half of the century)
before 20th century	drought years		Drought occurs between 12 and 16 times per century
in the 20th century	drought years		Drought occurs 9 times per century

TABLE 6
Inflows in by hydrographic regions during a whole and a dry period

Hydrographic regions	Inflows(Hm^3/year) Whole Period	Inflows (Hm3/year) Dry Period	Reduction rate (%)
Oranie Chott-Chergui	385	265	31%
Cheliff – Sahres	1650	1155	30%
Algérois-Hodna -Soummam	4290	2634	39%
Constantinois -Seybouse -Mellegue	4985	4137	17%
Sahara	620	440	29%
TOTAL	**11930**	**8631**	**28%**

Source: (UNDP, 2009)

Water resources are essential for food production. In 2007, of the 150 000 hectares to be irrigated, only 43 000 hectares were actually irrigated due to drought. There was a reallocation of irrigation water to the drinking water supply of the population especially in the west of the country (UNDP, 2009).

CHANGES AFFECTING GROUNDWATER

Reduced rainfall due to drought established since the early 1970s resulted in a steady decline of groundwater reserves of major aquifers in the north. In many plains of the country, the level of the water table has dropped at an alarming rate to more than 30 m at l'Arbaa, nappe de la Mitidja (Algeria, 2000). The worsening of droughts coupled with the overexploitation of groundwater has resulted in the mineralisation of unsaturated zones of deep aquifers in semi-arid regions such as the highlands of Oran and the high western plains. Groundwater accounts for 80 percent of water use in the northern region; it can sometimes exceed 90 percent in some areas (UNDP, 2009).

2.3.4 Government policy on drought

REACTIVE RESPONSE FOR WATER SUPPLY AND AGRICULTURE

Drought management was and continues to be crisis management by committees and composed mainly of National Agency for Water Resources (ANRH), the National Agency for Dams and Transfers (ANBT), central and decentralised structures of hydraulics and water distribution companies. These committees had, during the 2002 drought, the task, firstly, to collect real-time data on inflows to dams and the condition of water supply; and secondly, to propose an emergency plan (launching campaigns for extra drilling, water rationing or cutting programmes for human drinking-AEP and irrigation). The management of drinking water in the city of Algiers, induced by three years of drought, was organised by delivering water by tankers in the most-affected areas, by drilling 40 wells, by making interconnection of the Abdelkader Education Project (AEP) network of the city with three dams located more than 100 km to the west of the capital, and by installing several water desalination stations. This response to the shortage always seems to be the rule, since the water agencies do not have yet any operational information system.

In the event of a disaster (drought, locust invasion), the state has implemented a range of insurance schemes and special funds to compensate farmers and ranchers. When drought is declared, the government supports the pastoral economy to ensure water availability by drilling additional wells and supply feed for livestock at subsidised prices. However, this support has a negative effect, "while providing feed grain in times of drought, animal density is sustained, at the same time it should be reduced to allow the vegetation to recover"(FAO, 1998). This was also highlighted by the Ministry of the Environment (ME, 2000) which criticised overgrazing and rangeland degradation. The actions of the High Commissioner for Development of the Steppe (HCDS), set up in 1983, were limited to rehabilitating degraded rangelands through deferred grazing and plantations of Atriplex, and rehabilitating thousands of hectares by planting pastoral crops (Nedjraoui Bedrani, 2008; Khelil, 1997). The assistance provided by the government to the pastoralists helped to keep the herd in the steppes but the overloading accelerated its destruction and this eventually led to bankruptcy among some breeders.

Agricultural drought (and socioeconomic) is followed locally by the Wilaya Directions of Agriculture (Ministry of Agriculture) through observing the impact of drought on the cereal crop. Local radio stations are used by agricultural services, chambers, and associations, to alert growers and herders of pending risks.

The National Agricultural and Rural Development Programme (PNDAR) is encouraging the use of appropriate irrigation technology in the dry regions. The private sector has invested primarily in the production and installation of irrigation systems "drip" and micro irrigation. In the oasis, the PNDAR financed, at the request of local communities, the rehabilitation of traditional irrigation systems (foggaras).

DROUGHT RISK MANAGEMENT POLICIES/PLANS

There is no particular structure in Algeria specifically dedicated to drought, and the early warning system in place is dedicated to natural disasters mainly for floods and earthquakes. All actions during drought events are reactive responses. The drought onset is triggered in rainfed areas from the conditions of wheat field observations in different regions (wilaya).

The regulatory and organisational arrangements exist for establishing drought monitoring, but currently the infrastructure is oriented to major disasters in particular floods and earthquakes. This includes:

A national agency for the prevention and the management of major risk in the Ministry of Environment to assist in the areas of programming, mobilisation and deployment of national and international media

A National Delegation to the major risks with the mission of planning and coordinating under the Head of the Government

A National Centre for alert and decision support at the Interior Ministry, responsible for collecting, disseminating, and exploiting real-time information and data from early warning networks of all kinds and in particular the first network installed after the floods in 2001 in Algiers by the services of the National Meteorological Office with the assistance of the World Bank

The launch of the first Algerian microsatellite "ALSAT 1" by the ASAL November 2002 is part of a global and international programme for the prevention and management of natural disasters (Disaster Monitoring Constellation) called "DMC" (Sitoun, 2006).

In times of crisis after a long drought, the municipality is committed to emergency measures prescribed by the ORSEC Plan, while the distribution programme is established by the Drinking Water management company. The mobilisation programme established by the Ministry of Water Resources and implemented by the National Agency of Dams or Water Department of the Wilaya concerns the exploitation of groundwater resources.

However, there are some proactive actions particularly in the water sector, written into the National Water Policy for future implementation (Box 1).

For monitoring and early warning systems:

- Early warning systems rely on the evaluation of surface water by the ANRH over 160 hydrometric stations.

BOX 1

The national water policy objectives

These will be achieved by:

- Securing drinking water supply of the population
- Improving food security rate by maintaining and expanding irrigated areas.

To ensure the mobilisation of necessary water resources, the water sector is planning, within the 2009-2014 programme priorities:

a) To transfer part of the coastal zone dam water to the area of the Tell Atlas, in which the excess will then be transferred to the Highlands. The deficit of the coastal area should then be compensated by desalination of sea water and the water saving. The remaining deficit of the Highlands will be compensated by the possible transfer from the Sahara's water (Albian aquifer). Similarly, it is envisaged to re-use treated wastewater in irrigation and in industry

b) To build new sea water desalination. Sixteen major project units are the goal for 2025 with 942 Hm3 volumes to be desalted

c) To implement 75 project dams with overall capacity of 6 billion m3 as the target for 2025. Thirteen dams with 1.4 billion m3 capacity have been built

d) Inter-regional water transfers by three major transfers to mobilise an additional annual volume of 940 Million m3 to bring the total volume to 4 billion m3 in 2010

e) Annual groundwater transfer from Ain Salah to Tamanrasset over a distance of 700 Km of 50 million m3 volume in 2009

f) Rehabilitation of water systems would be i) through better management of irrigation water in agriculture and the use of modern irrigation techniques that would reduce 20 to 30 percent of the demands; and ii) through the leak rate reduction from 40 percent to 30 percent by a supply networks rehabilitation programme for drinking water (AEP)

g) Wastewater Treatment plants are under construction with an annual capacity of 400 million m3 by 2025 with a goal of annual wastewater treatment and reuse of 1.2 billion m3.

- Improved and modernised monitoring networks by installing ten automatic climate stations in Algiers province, a satellite receiving system, and weather radar to measure rainfall in Dar El Beida station.
- Planning Tools: regularly developing and updating Regional Master Plans for integrated management and a National Water Plan. The master plan of water infrastructure adopted by the Council of Ministers and incorporated in the National Development Plan of the Territory (SNAT).
- Forecasting and management: Forecasting models for inflows and flood simulation models of water table and quality.

INSTITUTIONS INVOLVED IN DROUGHT MANAGEMENT

There are five regions managed by basin agencies through watershed committees established in 1996 and consisting of representatives of the administration, elected representatives of the local communities, and users. In 1996, the Superior Water Council chaired by the Minister of Hydraulics was established. This board includes all water using sectors. Other coordination structures, such as the National Committee of Waterborne Diseases and the National Coordinating Committee of Operating Agency in irrigated areas have also been put in place. The water potential of these basins shows some spatial disparity; the areas where water is in short supply are the most sensitive to drought and desertification are located to the west of the country. Institutions involved are:

- Ministry of Agriculture and rural development
- Ministry of Water Resources (MRE) is the central authority responsible for the development and implementation of the National Water Policy and has local decentralised relay with the Wilaya's Water Resources Directorates (DREW). Under the supervision of MRE:
    - o National Agency of Water Resources (ANRH) is responsible for reviewing and assessing water resources and irrigated land
    - o National Agency for Dams and Transfers (ANBT) is responsible for mobilising and transferring water resources to the places of use
    - o Water Algerian mission (ADE) manages all the business of updating drinking and industrial water including the implementation of annual and multi-year investment programs
    - o National Sanitation Office (ONA), manages and develops of urban sanitation infrastructure
    - o National Irrigation and Drainage Board (ONID) responsible for managing the irrigation areas that the State and local authorities concede it; In this context, the Board is also tasked to implement strategies to rationalise the use of water for irrigation
    - o National Advisory Council on Water, created by decree in 2008, is the new framework for institutional coordination on various aspects of water policy
    - o The Regulatory Authority of Water Public Services created by decree in 2008 has the prerogative to evaluate water and sanitation services provided to users, control costs and rates
    - o The River Basin Agencies (ABH) created in 1996 at the regional level with Basin Committees mark the transition from a compartmentalised sectoral management to a concerted management at the watershed regions

- o The General Directorate of Forestry. The national focal point of the UNCCD. Implementation of the National Reforestation Plan (NRP)
- o The High Commission for Development of the Steppe HCDS, Integrated development policy steppe and pastoral areas
- o The National Office of Meteorology ONM - prediction, and models on weather and climate measurements, periodic bulletins
- o The National Monitoring Centre - collecting, disseminating and exploiting real-time information and data of all kinds of early warning systems
- o The National Observatory for Environment and Sustainable Development (ONEDD) created by executive decree in April 2003. It is responsible for managing networks of observations and measurements of pollution and monitoring of natural environments, to collect from national institutions and specialised agencies data related to the environment and sustainable development
- o The Centre for Scientific and Technical Research on Arid Regions CRSTRA – Desertification and Management of Arid and Semi-arid Lands
- o The Algerian Space Agency (ASAL) – knowledge and rational management of the country's natural resources
- o The National Centre for Space Techniques (CNTS) – analysis of satellite images, maps of vegetation index, monitoring of forest fires, forest maps
- o National Irrigation and Drainage Board (ONID) is responsible for managing the irrigation areas that the state and local authorities concede it; in this context, the Board also tasked to implement strategies to rationalise the use of water for irrigation
- o The regulatory authority of public water services created by decree in 2008 to assess the powers of water and sanitation services provided to users, control costs and rates.

2.3.5 Vulnerability to drought

There is strong competition for water among the major water users in addition to imbalances in the availability of resources between regions, which makes distribution and trade-offs difficult. Domestic water use has increased significantly in volume and proportion from 16 percent of the total in 1975, to 35 percent today. During the same period, the share of agricultural water fell from 80 percent to 62 percent (Mosas and Ghosn, 2013).

AGRICULTURE SECTOR

According to Seitoun (2006), agriculture is the sector most exposed to weather and therefore the most sensitive to drought. The sector's contribution to GDP is US$8 billion, and employs 1.2 million people (20 percent) of the active population. Agricultural production is poorly documented except for wheat yields, which suffer from rainfall deficiencies. In 2001-2002, cereal yields were influenced by insufficient rainfall, which extended over three years. Cereal production decreased by 27 percent with a total production of 1.9 million tons, followed by industrial tomatoes (-10 percent), olives (-4 percent) and olive oil (-14 percent).

RANGELAND AND LIVESTOCK

The steppe regions cover 32 million hectares, 20 million hectares of steppe rangelands, and 12 million hectares of pre-Saharan route. These are the most sensitive ecosystems to drought and desertification (Nedjraoui *et al*., 2009).

Algerian steppes are marked by great rainfall variability. In addition, recent decades have seen a marked decrease in annual rainfall, sometimes with several consecutive years of persistent drought. The rainfall reduction is about 18 to 27 percent, and the dry season has increased by two months over the past century (Nédjraoui et Bédrani, 2008). The loss of rangeland livestock production decreased for Steppes Alfa from 70-140 UF/hectares in 1978 to 18-74 UF/hectares in 1993; and the steppes White Artemisia from 70-190 UF/hectares in 1978 to 22-120 UF/hectares in 1993 (Nedjraoui *et al*., 2009). In some regions, repeated droughts in recent years and rangeland degradation have driven the reduction in traditional habitats of most small pastoralists and agro-pastoralists who now experience rapid impoverishment. Many have now moved to the cities and surrounding towns, often in very precarious conditions, given the low efficiency of job creation policies in urban areas (Nedjraoui and Bédrani, 2008).

FORESTS

Forest areas were not spared; they also have suffered significant dieback following successive droughts between 1947 and 2002, and in the drought years, 1980, 1989, 1990, 1993, 1994, 1995, 2000, 2001, and 2002 (Lakhdari, 2010).

2.3.6 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

To reduce the water consumption in agriculture, the ministries of water resources and agriculture are trying to convert traditional agricultural irrigation to water-saving irrigation systems. They started to provide free water-saving equipment up to €2600/hectare to farmers who expressed demand for improvement. In 2000, the surface irrigated areas represented 85 to 90 percent. By 2008, this had fallen to 63 percent, while the area with modern irrigation equipment reached 20 percent for sprinkler and 17 percent for drip irrigation.

Since the early 2000s, the government has placed water shortages as a priority on the political agenda and substantial resources have been made to mobilise new conventional and non-conventional water resources. The new water policy was thus structured around two strategic axes:

- The development of water infrastructure: dams, transfers, sea water desalination plants, sewage treatment plants
- The institutional reform of the water sector which aims to promote better management of the resource.

The relative lack of financial resources has so far constrained the missions of the River Basin Agencies (ABH). However, with the creation in 2011 of the National Agency for Integrated Water Resource Management (ANGIRE), massive investments have been made that resulted in an increase in the numbers of dams, increased the use of desalination of sea water, and the reuse of wastewater. In 2011, a large-scale project was launched to transfer water some 750km from Albian of Ain-Salah (North of Tamanrasset wilaya) to the town of Tamanrasset.

However, in spite of these investments Algeria is expected to have a water deficit of 1 billion m^3 from 2025 onwards. Rationalisation of the use of agricultural water is needed. The strategy is to secure and reduce agricultural water volatility, improve the efficiency of water distribution systems, and convert surface irrigation to drip irrigation (Mosas and Ghosn, 2013).

2.3.7 Measures to build resilience to drought

See appendix 3.

2.3.8 Issues

Despite the organisational and regulatory measures drought remains a serious hazard. A host structure (ONM) for early warning for drought and floods officially exists but it does not give the required attention to drought, although it appears explicitly in periodic bulletins. Furthermore, there is no independent body specialising in monitoring and analysis of drought. Crisis management always seems to be the rule.

2.3.9 References

See Annex.

2.4 TUNISIA

2.4.1 Background

Agriculture is the largest water user accounting for 83 percent of annual consumption, with an irrigable area of nearly 400 000 hectares. Agriculture employs 16 percent of the workforce. In 2013, the population in 2013 was 10.9 million with 33.5 percent in rural areas (World Bank, 2014). Annual water availability per capita is low at only 450 m^3 (SEMIDE, 2008).

Rainfall is characterised by its scarcity and spatial and temporal variability. The annual average rainfall varies from 1500 mm in the north to 100 mm in the south. Temperatures are high and this leads to high evaporation from water resources and farmlands (Mougou *et al.*, 2002).

2.4.2 Drought history

Drought episodes have been traced back to the 8th century. Records indicate that during the period 1907–97 alone, 23 dry years were observed.

The drought analysis conducted by Touchan *et al.* (2008) based on multi-century tree-ring records generated a well-validated reconstruction for the period 1456-2002 (547 years). The longest period of consecutive drought years over this period is estimated to be 4 years. This occurred during 1999-2002 and is the worst since the middle of the 15th century (Hoerling and Kumar, 2003; Seager *et al.*, 2007). Single drought years typically occur between 12 and 16 times each century, although the number rose to

19 in the 20th century. The driest single years were 1867 and 2002. Substantial and sustained dry conditions occurred in the 1540s, the 1860s, the 1870s, the 1920s, and the 1940s. Four times in the last five centuries there were 6-year periods where every consecutive year was below the long-term mean: 1548-1553, 1737-1742, 1770-1775, and 1876-1881.

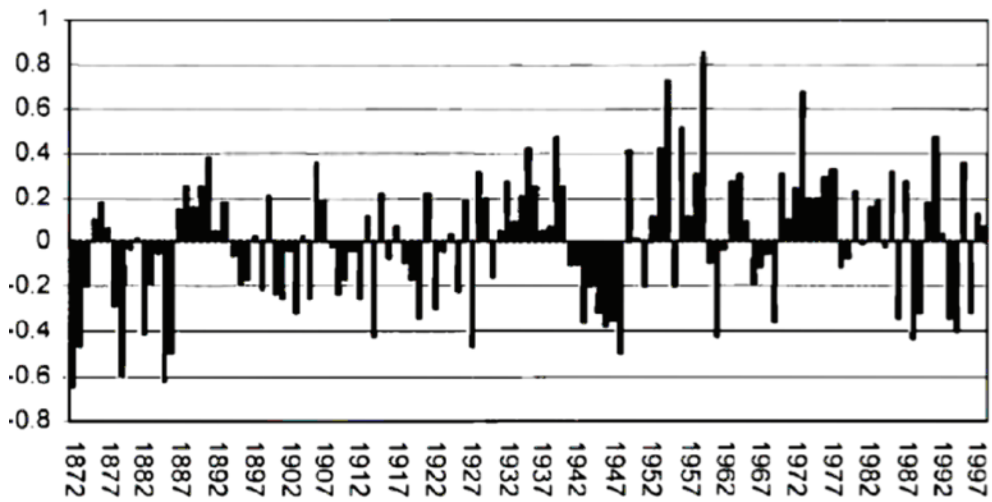
Many studies show that the frequency of one dry year is high for all the country. The frequency of two consecutive dry years and more is relatively low in the north, moderate in the centre and more frequent in the south. Drought periods could affect one or several regions or could be generalised; their duration could be from one month or season to one year or more.

During the 20th century, Tunisia has experienced several major droughts that were often multi-year and had large spatial dimensions (Hénia, 2001) (Figure 5).

The 1950s and 1970s stand out as dry years. The periods of the 1920s, 1940s, 1960s and 1980s showed multi-year droughts, high spatial extension, and a significant rainfall deficit. Droughts in 1940s are the most severe of the century. Some stations had four successive years (1944-1945 to 1947-1948) while others reported 6-8 successive dry years. Droughts in the 1960s lasted from 1961 to 1969. During the 1980s, low rainfall years are more frequent; however, at the end of the decade, a severe drought year was 1987-1988, with rainfall deficit affecting the whole country, apart from the extreme southeast. This deficit was 20 to 50 percent of the average annual rainfall in the north-west and over 60 percent for much of the centre and southwest (OSS, 2008).

Tunisia experienced a severe drought in 1893 (Cordies, 1947). This phenomenon was repeated three times in the years/period 1930-1940, 1989-1990, and 2000-2008 (Ben Salem, 2011). The latest drought to hit the country was in 2015-16 (USDA, 2016).

FIGURE 5
Differences related to the average rainfalls in Manouba Tunis (1872-1998



Source: Albergel, 2001

2.4.3 Impacts of drought

IMPACT OF METEOROLOGICAL DROUGHT

The impacts of drought in the northwest (the wettest region), known as the 'water tower of Tunisia', result primarily in lower stocks of water in dams, draining sources for rural drinking water, increasing salinity in water retentions, and decreased production of grains and forages. Central and south-east regions have a more modest and irregular average annual rainfall, 100 to 400mm. The effects of drought are often much more pronounced than in other regions. The extreme southwest is arid. It is therefore less sensitive to drought. Precipitation analysis of Siliana Station for the period 1966-2006, highlighted 13 dry periods with a maximum duration of four years, for a rainfall deficit of 527 mm and a maximum rainfall of 180 mm. The overall trend of water inflow values decreases for the period 1966-2006, with marked increase in 2003 (Bergaoui et Louati, 2010).

IMPACT OF HYDROLOGICAL DROUGHT

During the dry years, the variation of water flows, rainfall, and evaporation at the level of the great Tunisian dams in the north (Sidi Salem dam) and central (Sidi Saad dam) regions caused a significant decline in surface runoff. The maximum flow deficit was 69 percent during 1996-97 in the north, 89 percent during 1993-94 in the centre and 95 percent during 1993-94 in the south (Hénia and Bensarti, 2006).

The regional rainfall variations affected water levels in the reservoirs. During the 2000s drought period, the total water resources in the reservoirs fell to less than 50 percent of dam capacity (Louati *et al.*, 2007). The rainfall deficit during the drought period 1993-1995 varied from 33 percent to 56 percent. The 1993-1994 and 1994-1995 droughts can be described as severe hydrological droughts. Inflows to dams were very low in 8 of the 18 dams in use during these periods (DGBGTH (1996).

During the 3-year drought from 1999 to 2002, Tunisia was affected regionally, seasonally and annually:

In 1999-2000, the autumn was normal but the winter and spring were dry in the central and southern regions. The water deficit reached 80 percent. Drought was seasonal and moderate in the north and severe in the south and central regions.

In 2000-2001, drought spread across the country, but the northern region was not affected.

In 2001-2002, the whole country was dry. The drought was severe and spread across the country during the autumn and the winter. The spring was moderate in the north, central, and the south-west. A severe drought occurred in the south-east region (Louati *et al.*, 2007)

IMPACT ON CEREAL PRODUCTION

More than 97 percent of the total cereal area is grown under rainfed conditions and are highly vulnerable to the frequent droughts (Slama *et al.*, 2005). Production fluctuates from year to year in line with rainfall. During the dry years 1987-88, 1993-94 and 1996-97, cereal production was poor compared to the average for the period (Abou-Hadid 2006). For the growing season 2015-16, Tunisia's total cereal production was officially announced at 1.3 million MT, decreasing by 43 % compared to the previous season (USDA, 2016).

IMPACT ON LIVESTOCK PRODUCTION

The price of fodder, especially hay and straw, increases during years of drought, particularly when it extends to two and sometimes even three successive years (Khaldi, 2008). The price of feed unit of forage and straw can, in dry years, cost 5 to 8 times that of barley feed (subsidised) (CNEA, 2005). Recourse to the use of hay in the sheep forage calendar occurs only during critical periods (Brahmi *et al*., 2010).

IMPACT ON POPULATION LIVELIHOOD, HOUSEHOLD INCOME AND RURAL POVERTY

Both rural and urban water supplies during 1999–2001 were significantly affected. Water rationing was the general rule in most large cities. Further, recurrent droughts have resulted in serious economic and social problems. The 1999-2001 drought caused a significant agricultural trade imbalance, disrupted the rural economy, increased migration to urban areas, and exacerbated rural poverty.

The most vulnerable and seriously affected social groups were dryland farmers (including cereal producers), olive and fruit growers, and sheep herders. As a consequence of three successive dry years, many herders and farmers found it necessary to purchase supplementary animal feed, water, and other agricultural inputs, leading to increasing debt.

IMPACT ON THE ENVIRONMENT

The long periods of drought caused significant damage to the environment and to the region's biological diversity, including both animal and plant species.

Degradation of natural resources is especially serious in low rainfall areas that represent over 70 percent of the total rangelands. For the nomadic population, their incomes depend directly on the rangelands' quality and quantity. Large numbers of farmers and herders have migrated from their villages to search for water and livestock feed. This phenomenon requires immediate attention to prevent major population displacements and further environmental degradation.

2.4.4 Government policy on drought

Government policy on drought, once drought has been declared, is to take the following actions:

Give priority to drinking water; allow well digging; and support irrigation equipment purchase

Import and subsidise well drilling products

Stop debt repayments; rescheduling farmers' credits; restructure farmers' bank debt; provide supplementary feeds to safeguard livestock with the predominance given to feeding concentrates

Restrict certain summer crops; control land grazing

Create job activities in the rural areas

Implement public awareness campaigns.

REACTIVE RESPONSE TYPE

The response of the State to drought impacts is a crisis reaction. Due to the frequent drought years, a national drought emergency programme was developed, starting in 1988, allocating a special budget to implement the drought relief programme and strategies to help small farmers and livestock-breeders.

The items included (Ben Salem *et al*, 2007):

Provision of sufficient amounts of feeds (authorising livestock access to protected rangelands and increased areas for irrigated crops)

Provision of supplementary feeds (import concentrate feeds like barley, Lucerne pellets, and bran)

Distribution of feed resources (barley and bran) and transportation of bulky roughages (e.g., oat hay and cereal straws)

Subsidising the prices of sorghum seeds and barley and subsidising the transport of bulky roughages

Exoneration of some imported seeds from custom taxes

Donation of barley (free of charge) to smallholders

Control of livestock health (subsidised vaccination, etc.) and complementary decisions (e.g., authorising female slaughtering of low producing animals).

2.4.5 Drought risk management policies/plans

Despite the important structures and programmes to alleviate the effects of drought set up by the State, the approaches are still more reactive than proactive. The existing system deserves to be strengthened and improved (Ben Boubaker, 2006). The State decided to develop a mitigation programme in zones suffering from water scarcity to guarantee their provision with water in the summer season; encourage farmers to get credits from the special agriculture development fund to purchase water tanks and pumps for crops irrigation; and make people aware of the necessity of appropriate use of water and avoid waste.

EARLY WARNING SYSTEM

Tunisia does not have a well-functioning drought monitoring system that would allow it to take timely action to mitigate the effects of drought. Even though the meteorological network is adequate and well-equipped, it is poorly prepared to function effectively as a drought early warning system because of inadequate analytical tools required for drought monitoring, unsuitable information products, and insufficient data sharing (De Pauw, 2005).

However, for the Maghreb region, a network for the development of drought early warning systems (SMAS) was established between Morocco, Algeria, and Tunisia is coordinated by the Observatory of the Sahara and the Sahel (OSS). Its plan of action was launched and some activities have started.

INSTITUTIONS INVOLVED IN DROUGHT MANAGEMENT

The principal organisation involved in water mobilisation, management, and planning, and drought management is the Ministry of Agriculture (MAERH), especially the Bureau of Water Planning and Hydraulic Equilibrium (BPEH) and the central directorates and the regional services (Departments).. The Ministry of Agriculture (MAERH) makes the decision of drought onset and the transmission of the mitigation plan to the National Commission, which is charged to supervise the execution of all operations related to the three drought management phases: (i) before drought preparedness; (ii) during drought management; and (iii) after the end of drought phase. This process is implemented in strong collaboration with the regional and specialised committees. The MAERH promulgates several decisions related to different drought committees and the operations programme for drought mitigation. The Tunisian Central Bank (BCT, Banque Centrale de Tunisie) delivers a circular establishing the easing of credit facilities for farmers. Special decisions are also taken in order to exempt imports from customs duties (Louati *et al*., 2007).

In order to reduce the effects of drought impacts that occurred during 1987-1989 and 1993-1995, a drought management plan was developed with three successive phases:

Drought announcement: Referring to rainfall, hydrologic and agricultural indicators observed in the different regions affected by drought and transmitted to MAERH who then makes a drought announcement and establishes a circumstance memorandum

Warning: This announcement, emitted as a warning note, is transmitted to the MAERH Minister, who proposes a schedule of operations plan to the National Commission, which is composed by decision-makers and beneficiaries

Action implementation: The National Commission is in charge of the supervision and the execution of all the operations and the supervision of all operations when the drought is over (Louati *et al*., 2007).

In order to ensure efficient drought management, three types of committees are established:

Drought National Commission (DNC) which includes representatives of MAERH, ministries of Interior, Economic Development, Finances, Commerce, Transport, and Public Health. Their main mission is to coordinate the execution of the drought mitigation operation programme.

Drought Regional Commissions (DRC) established in each one of the 24 Tunisian Governorates with members belonging to the Regional Departments of all Ministries involved in drought mitigation. It informs the national authorities about the necessary measures to take for their regions

Drought Specialised Commissions (DSC) is responsible for the preparation of the drought indicators observed in each field. They propose an operation planning and scenarios for mitigation of the eventual drought events. The DSC(s) is composed of Water Resources Management Committee, Livestock Safeguard Committee, Cereal Sector Management Committee, and Arboriculture Sector Committee.

The actual water information system is characterised by highly diversified but complementary water resources information and stakeholders' data. Nevertheless, these diversities constrain water data and information exchange, and consequently hamper the efficient use of the recorded information. To avoid this weakness, the Tunisian government decided to establish a Unified Water Resources National Information System called"SINEAU" (Louati *et al*, 2007).

The drought management system was adopted when drought events occurred during 1987-1989, 1993-1995 and 2000-2002. In 1999, the first guideline on drought management was published entitled "Guide Pratique de la Gestion de la Sécheresse en Tunisie" (Louati *et al.*, 1999).

According to the published studies the weaknesses in the system include:

No independent body or unit responsible for drought management

No standard management approach

No regional sharing on drought information

No drought projection

Finance comes only from the State because there are no private sector insurance schemes

Little widespread drought evaluation studies

Poor relations among the different institutions that provide information and data about water.

The latter may be resolved by the establishment of the Unified Water Resources National Information System in the near future (Louati *et al*, 2007).

2.4.6 Vulnerability to drought

VULNERABLE SECTORS OF THE ECONOMY

Water and agriculture are the two main vulnerable sectors (Bachta, 2008; Louati Gargouri, 2010). The long period of drought affects availability of food and water quantity and quality.

Drought affects the agricultural sector as over 97 percent of the total cereal area is grown under rainfed conditions (Slama *et al.*, 2005). Agriculture also sustains the livelihoods of 33 percent of the rural population (16 percent of total population).

VULNERABLE GROUPS OF THE SOCIETY

The most vulnerable and seriously affected social groups are dryland small farmers (including cereal producers), olive and fruit growers, and sheep herders. Farmers' and herders' communities suffer severe loss of income through the loss of harvests, partial loss of flocks, low animal production yields, and weak market prices.

2.4.7 Practices to alleviate drought impacts

The Tunisian population has gained rich experience in water resource management from ancient hydraulic works (Roman, medieval, etc.), the wealth of traditional techniques for the collection, storage, and transfer of water, and the importance of modern hydraulic infrastructure.

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

The government implemented and encouraged actions to alleviate drought impacts (Ben Salem *et al*, 2007):

Use of treated used water in crop production

Intensification of fodder crops by subsidising the seeds mainly during the difficult seasons

Use of the various agro-industrial by-products such as feed blocks

Valorisation of straws by urea treatment

Forest, water and soil conservation, and rangeland improvement.

The government is also involved in improving runoff farming, and rehabilitation and improvement of water infrastructure for conventional sources of water. These interventions include:

Rehabilitation of runoff farming: In 1990, the Government started implementing a project to rehabilitate the Meskat and Jessour systems to stabilise the water balance. Up to 1984, Meskats covered 300 000 hectares planted with 100 000 olive trees; Jessours covered 400 000 hectares (Tobbi, 1994)

Water development: It is estimated that about 29 billion m^3 of rainfall is lost through evaporation and to the sea and to salty lakes. Consequently, in 1990, the government implemented the National Strategy for Surface Runoff Development, which targeted building 21 dams, 203 small earth dams, 1000 ponds, 2000 works to recharge the water table and 2000 works to distribute water for irrigation (EUWI, 2007)

Rehabilitation and development of small hydraulic infrastructure with average capacity about 100 000 m^3 (Chérif *et al.*, 1995), and 29 large dams

Artificial recharging of shallow and deep aquifers

Soil and water conservation implemented from 1991 to the 2002 (Strategy of Soil and Water Conservation) (EUWI, 2007). This project managed 1 million hectares, maintained and rehabilitated 440 000 hectares in watersheds and cereal producing regions.

Non-conventional sources of water include:

Desalination: The construction by Tunisia's National Society for Water Exploitation and Distribution (ZONEDE) of 10 desalination plants in the south to process brackish water with a total daily capacity of 36,200 m^3.

Water reuse/recycling: Treated wastewater has been used since 1965 to irrigate citrus orchards and olive trees of the Soukra irrigation covering an area of 600 hectares (Bahri, 2008). Until 2002, there were 60 water treatment plants reclaiming 150 million m^3/year, managed by the Organisation of Non-aligned States (ONAS). The amount of recycled water in 2020 is expected to be approximately 18 percent of the available groundwater resources and could be used to replace groundwater currently used for irrigation in areas where excessive groundwater mining is causing salt water intrusion in coastal aquifers (Kamisoulis *et al*, 2004).

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

The following farmer strategies were developed to increase water use efficiency:

Modify irrigation practices and systems, use buried stone pocket in the "Jessours" for localised irrigation, and underground irrigation of fruit trees

Change crops, use intercropping and mulching (Frigui, 2010).

In a survey, the strategy adopted by Nabeul farmers with large state farms and orchards was to over-irrigate early in the season, supplement from groundwater having higher salt concentration, and adopt deficit irrigation in summer (Masmoudi, 2010)

In the Medenine with small private properties using shallow wells, the practice was to develop intercropping with drip irrigation, shift to winter production of vegetables, and manage with very saline water from shallow wells (3-7 dS/m).

Local pastoral communities have developed several strategies to mitigate drought impacts. Organising the herd's mobility is the main issue. The local community-based organisations played a key role in identifying the suitable humid areas for their transhumance; it may also order a decrease in the flock size in the face of feed scarcity; and has also been of great importance in organising the temporal and spatial harvest campaigns for hay, Stipa tenacissima ("Gueddim").

The conservation and storage of any excess production, of either weeds or farm by-products, in the good years is also used to mitigate the following severe dry years. However, with the changes in ways of conducting livestock and the environment of sheep production due to increase in drought frequency, the privatisation of rangelands, the disappearance of the old community based organisations, and particularly the appearance of Governmental subsidies for complementary animal feeding since the 1980s, the vulnerability to drought has increased. The latter policy has probably led to the loss of much local indigenous know-how and to an increase in the dependence of the agro-pastoral communities on the feed resources market, particularly of barley.

For governments, the response to drought is seen as a contingency. In regards to drought management strategy, it is only since the drought of 1987-1988 that a response strategy and mitigating actions have been gradually implemented. This strategy is not integrated structurally in the livestock development policy. Moreover, the same objectives of this strategy (preservation of the herd, preservation of livelihoods, not to undermine the recovery capacity of livestock growth after the drought) do not take into consideration the impact on natural resource management and the different categories of farmers and the adoption of technical innovations.

The strategy helped to avoid large fluctuations in herd size, but it resulted in increased imports of barley and animal feed. Budgetary expenses related to these subsidies reached the sum of US$18.7 million or 21 percent of the total expenditure of the General Compensation Fund (CGC) in 1981 (Chouchen, 1989). These economic contingency measures are supported by more structural measures aimed at improving the feed balance. At another level, the authorities are conducting a long-term policy of improving pastoral resources, largely implemented by the services of the OEP (Office of Livestock and Pasture) involved in pastoral plantations and improving rangeland in private land and by the Forest Department officials involved more on the collective and state land (CNEA, 2003). The other observation concerns the deepening pressure on rangeland and the difficulty of ensuring sound management that respects the resilience of these rangelands (Elloumi, 2006).

2.4.8 Measures to build resilience to drought

Even though great strides were made to build resilience there are still many challenges to overcome in developing effective drought monitoring. Some of the most pressing challenges include:

Enhancing data quality and collection network densities

Reducing the cost and increasing the sharing of data

Making early warning information more accurate and user friendly

Integrating physical and social drought indicators into systematic and comprehensive monitoring and early warning systems

Providing support to create and maintain systems.

See Appendix 4 for detailed measures.

2.4.9 Issues

The absence of private sector insurance linked to drought means that the State budget must support all drought measures.

Until 2003, the drought mitigation plan was based on simple note-taking and observation findings. More thorough evaluation of past events is needed to inform future drought planning.

The poor relations among the many different institutions that provide information and data about water and water use is not helpful in drought planning. This should be resolved by the establishment of the Unified Water Resources National Information System “Système d’Information National des Resources en eau (SINEAU)” in the near future.

2.4.10 References

See Annex.

2.5 LIBYA

2.5.1 Background

Libya is among the most arid countries in the world. In 2004, the population was 5.88 million with an estimated growth rate of 2.4 percent. The population is unevenly distributed, with more than two-thirds living in the densely settled coastal areas (FRD, 2005). More than 90 percent of the country is exposed to severe arid climatic conditions of the Sahara. Only the northern most part along the coast of the Mediterranean Sea offers a more favourable climate.

The Libyan economy is mainly dependent on oil which accounts for more than 70 percent of GDP. Other sectors continue to contribute a relatively low share of GDP. Agriculture contributes only 2.7 percent and accounts for 6 percent of the workforce, employing more workers than the oil industry (Abuhadra, 2014). Almost all the cultivable land (about 2.2 million hectares) lies in the Jif€ah Plain in the northwest and the Benghazi Plain in the northeast (Abuhadra, 2014). Permanent pastures account for 13.3 million hectares (FAO, 2010).

Total agricultural land is estimated at 15.4 million hectares composed primarily of pastures, which cover 13.3 million ha. The remaining 2.1 million hectares consist of 1.8 million hectares in arable land and some fruit trees. The area developed for irrigation is about 470 000 hectares but only 240 000 hectares are currently irrigated (FAO, 2010). The rangelands are located in rainfed areas, mainly along the coast where annual rainfall is 50 and 300 mm (FAO-AQUASTAT, 2006; FAO-WFP, 2011)

The main source of water, for both domestic use and for agriculture, is fossil groundwater pumped from deep aquifers in the south to supply water to the populated north. This supply system is known as the ‘the great man-made river’.

Most of the rainfall occurs during the winter between October and March. Sometimes intense storms cause flash flooding in the wadis. Several dams were constructed in the Jabal Nafusah piedmont zone to retain surface water. Open surface evaporation in the western part of the coast was assessed as 3,700 mm/year (El Gseli, 2013).

2.5.2 Drought history

Libya’s surface water resources are prone to drought in much the same way as other countries across North Africa. Groundwater is less prone to drought as this is fossil water dating back many thousands of years. Nevertheless, this is not renewable and so it needs careful management.

The average annual rainfall for 1945-2010 in the eastern region was 350 mm; 254 mm in the western region; 168 mm in the central region; and 22 mm in the Sahara region (an average of 72 mm for north Sahara and 2 mm for south Sahara) (Ageena, 2013). Normalised annual rainfall is shown in in Table 7 and dry years and the drought duration are shown in Table 8.

Rainfall is often erratic and a pronounced drought may extend over two seasons, such as in 1945 in western costal area where an unprecedentedly severe drought caused the loss of thousands of head of cattle. This was followed by 3 to 8-year long dry periods in the 1950s and 1960s. Documentation on the impacts of these long periods of drought that mainly affected the north western costal area is not available (World Bank, 1989).

2.5.3 Impacts of drought

The impact of drought across the country is limited by the dependency on oil for GDP and on fossil water resources for domestic and agricultural use.

Some surface water resources are used in the north and this region is susceptible to drought. Libya, like many Mediterranean countries, has experienced several drought events and water deficits (Abufayeda and El-Ghuelb, 2001). This will likely increase in the future in response to low rainfall and rapid population growth, aggravated by the annual rate of evaporation which is about 1,700 mm near the sea and 6 000 mm in the central and southern regions (LGPC, 2003) resulting in the increase in water requirements for domestic, industrial, and agricultural purposes.

In the 1970s and 1980s, agricultural self-sufficiency was considered a national priority, but this is no longer the case. Libya currently imports nearly 80 percent of its food requirements. Animal husbandry is still a significant activity but relies heavily on imported animal feed (FRD, 2005). The country relies heavily on imports in order to meet its food demands; Libya does not currently face a problem of food insecurity even in dry years (EPRI, 2011).

Cereals occupy 76 percent of the cultivated arable land, almost all under irrigation, and this produces 16 percent of national needs, the rest is imported. So drought does not impact on food security since all staple food is either produced under irrigation or imported. In addition, the staple food is also cheap and heavily subsidised and so it is within everyone's reach. The main food products including wheat flour, semolina, pasta, rice, vegetable oil, sugar and tea are subsidised. The level of subsidy reaches 95 percent for wheat flour supplied to the bakers and 90 percent for wheat flour for direct use; 90 percent for the semolina, and 85 percent for pasta.

Drought will impact vegetation on the rangeland areas. However, even though the government subsidise livestock feed and support 1/3 of the price of purchase

TABLE 7
Mean and spatial variability of rainfall with dry years 1945-2010

Coastal region	Mean annual precipitation (1945-2010) mm /year	Normalised annual precipitation anomalies and values corresponding to the limits of			1945-2010
		(< percentile 0.10) Very Dry years (%)	(percentile 0.25) Dry years	Dry and Very Dry years (%)	All years less than normal
Western -coastal region (A)	253.7	7 (11%)	10 (15%)	17 (26%)	33 (51%)
Central-coastal region (B)	168.1	2 (3%)	4 (6%)	6 (9%)	17 (26%)
Eastern-coastal region (C)	350.8	7 (11%)	4 (6%)	11 (17%)	26 (40%)
North Sahara region (D)	71.7	3 (5%)	15 (23%)	18 (28%)	28 (43%)
South Sahara region (E)	2.2	0	27 (41%)	27 (41%)	36 (55%)

Source: Ouassou adopted from Ageena (2013)

TABLE 8
Mean and spatial variability of rainfall with dry years 1945-2010

A	a	1945	1947	1950	1951	1952	1953	1954	1957	1958	1959	1963	1964	1965	1966	1967	1968	1969	1970	1977	1980	1982	1983	1985	1987	1988	1990	1992	1996	2000	2002	2004	2007	2010
	b	1	1	5					3			8								1	1	2		1	2		1	1	1	1	1	1	1	1
B	a		1947	1948		1952		1954	1957	1958	1959						1968	1969	1970							1988		1992	1993	2000			2009	2010
	b		2			1		1	3								3									1		2		1			2	
C	a				1950	1951		1955	1956	1958		1960	1963	1964	1970	1972	1973	1975	1980	1982	1985	1987	1989	1990	1992	1993	1999	2000	2002	2006	2007	2008	2009	2010
	b				2			2		1		1	2		1	2		1	1	1	1	1	2		2		2		1	5				

A: Western; B: Central; and C: Eastern coastal regions;

a: Dry years (light green) & very dry years (dark green); b: Number of successive dry years

Source: Ouassou adapted from Ageena (2013)

(Elfagehia, 2014), most of the raw material is imported to secure feed for livestock in case the rangeland fails during droughts.

2.5.4 Institutions involved in drought management

The main institutions involved in management, policies, and legislation related to water use in agriculture and urban settlements are:

The General Water Authority (GWA) (Water Resources, Dams, Irrigation, Drainage and Soils)

The Secretariat of Agriculture and Animal Wealth (irrigated agriculture, Agricultural Research Centre)

The Great Manmade River Water Utilisation Authority (water transported for agricultural from the desert)

The Secretariat of Municipalities (water supply to urban settlements)

The General Environmental Authority

The Libyan Meteorological Department

Local Companies for Water and Waste Water

National Company for Desalination under the Secretariat of Electricity, Water and Gas

National Company for Water and Waste Water

Other Libyan institutions: Industrial Research Centre, Academic of High Study, and Al-Fatah University.

2.5.5 Vulnerability to drought

Almost 90 percent of the population resides along the northern coast where most of the economic activities take place. About 88 percent of the population is urban, mostly concentrated in the four main cities of Tripoli, Benghasi, Misrata, and Bayda; the remainder lives in oases in different parts of the country (Abuhadra, 2014; Elgseli, 2013)

In spite of relatively better climatic conditions in the northern coastal region compared to the desert, effective agricultural production is entirely dependent on irrigation. As there are no perennial water courses in Libya, the only feasible water resource is groundwater. Groundwater thus represents a vital natural resource and its economic and social importance for the country is enormous, and covers almost all the public, agricultural and industrial water demands (El-Tantawi, 2005). However, the consistently high annual growth rate of 2.2 percent (2007) with the rapid increase of economic activity in the last 30 years increased the coastal groundwater demand.

Generally, water supply in the cities is not well recorded and managed, and most is lost to the system as leakage from the distribution network and overuse by households, which are not metered and no fees are charged. Tripoli, for example, uses 650l/capita/day, most of which is lost as leakage from the distribution network and overuse by households (FAO, 2009). The underdeveloped water distribution system and the large number of individual wells used for intensive irrigated farming that have developed rapidly since the 1960s using shallow groundwater along the coast (some have been abandoned because of water shortages and poor quality water), have caused coastal groundwater extractions to be in excess of replenishment resulting in the decline of groundwater levels (FAO-AQUASTAT, 2008).

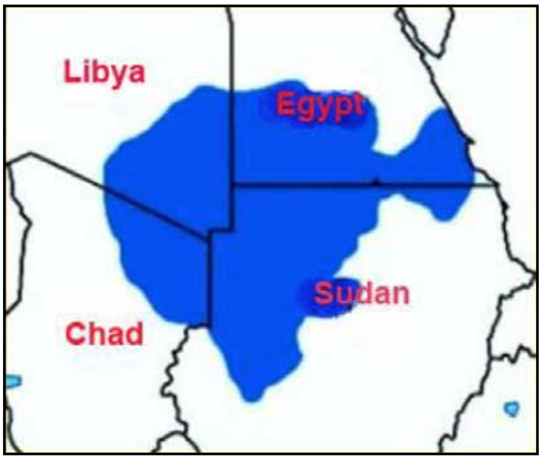
Most renewable water resources, which are predominantly groundwater, exist along the coast where rainfall is more abundant. However, all of the renewable resources are modest in comparison to withdrawals that total 4,268 million m^3, agriculture being the greatest consumer at about 83 percent, 14 percent for municipal use, and 3 percent for industrial use. More than 30 percent of the present municipal water demand is supplied by the great man-made river project (GMRP). Water use however, is still below the World Bank water poverty limit of 1 000 m^3/capita/year (FAO-AQUASTAT, 2000).

Nearly all of Libya's water resources come from fossil groundwater from five basins (regional aquifer systems) in the arid zones. This supplies 80 percent of the total water consumption (Alghariani, 2007). It provides 97 percent of the water consumed for agricultural purposes (Bindra *et al.*, 2003).

Fossil water comes from the Nubian Sandstone Aquifer, one of the most notable fossil water reserves. The great man-made river project, identified as one of the largest water-engineering projects in the world, was designed to reduce the water deficit and increase the area of productive agricultural land by transporting 2,300 million m^3 of fossil water from the south to the north of the country to manage the water scarcity (FAO-AQUASTAT, 2006). The work started in the 1980s. The project, which still has an estimated 25 years to run, was designed in five phases; the third phase was achieved in 2009. When finished, it will eventually combine to form an integrated system.

Demand management does not yet form part of national water policy. At present, no water fees are imposed on users of water for irrigation purposes, and highly subsidised energy for private farmers does nothing to encourage efficiency and increase productivity of water. Rather the focus is on supplying more water and since 1983,

FIGURE 6
The transboundary Nubian Sandstone Aquifer System (NSAS)



Source: Growing Blue, 2011.

the government has pumped large quantities of water from the fossil water reserves using the GMR to meet the growing, but inefficient, demand for more water (Wheida and Verhoeven, 2007).

Libya withdraws water from the Kufra sub-basin (Figure 6), in the Nubian Sandstone Aquifer System (NSAS), which is shared with Egypt, Chad and Sudan. Large withdrawals has led to reduced water levels causing naturally flowing springs and desert lakes linked to oases to dry up. In Egypt alone, water levels have declined by nearly 60m (IAEA, 2013; Growing Blue, 2011). It is unclear how long this can continue.

Libyan officials have concluded that the GMRP does not provide a total solution to the country's water needs and that more water sources will be required. There are plans to build 11 new desalination plants (The Economist Intelligence Unit, 2008).

While initiatives were launched to expand the water supply, water scarcity is increasing. With increased groundwater pollution in addition to the intrusion of seawater, a large proportion of households do not rely on public taps as the main source of drinking water. Overall, access to safe water has deteriorated: 41 percent in 2007 compared to 91 percent in1995 (UNICEF, 2010).

2.5.6 PRACTICES TO ALLEVIATE DROUGHT IMPACTS

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

Limited water resources and desertification are the main climatic issues. The government chooses to alleviate the water shortages needed for irrigation and urban zones by carrying out several actions mainly to enhance supply:

Increasing output from GMRP which transports fossil water from the Libyan South

Diverting GMRP water from irrigation to domestic water supply

Limited reliance on desalination plants for some industrial purposes

Constructing dams in the Jabal Nafusah piedmont zone to retain storm water.

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

A large Libyan population is not served by tap water and sewage. Most households have their own well and reservoir with diverse uses including livestock. Most potable water for drinking is purchased from special water purification shops in bottles or delivered by truck.

2.5.7 Measures to build resilience to drought

See Appendix 5 for details.

To build resilience Libya needs to:

Review agricultural water policies in order to minimise some local deficits in water resources and

Try to avoid deterioration in water quality in the coastal areas.

2.5.8 Issues

An integrated water management plan is needed to build resilience to drought and water scarcity. Households still need to have reliable potable water networks and sewerage, and farmers need to have incentives to use water-saving equipment.

The sewerage network is not well developed and so there is no means to recover wastage or to recycle effluent for other purposes, such as agriculture. Urban waste water is the main source of groundwater pollution.

There is lack of a clear national water policy/strategy that defines the overall long-term priorities and objectives; a lack of a high level body with full authority, and means to coordinate the planning process.

2.5.9 References

See Annex.

3. Egypt and Sudan

3.1 EGYPT

3.1.1 Background

Egypt has seen a rapid population growth from 40 million in 1978 to 84 million in 2012 – (56.5 percent live in rural areas and 43.5 percent in towns and cities – 25 percent of the urban population live in Cairo). Most dwellings and the cultivated land is confined to a narrow strip of land following the main course of the River Nile, which is only 3.5 percent of the country's land area (Nour El-Din, 2013).

Arable land is 2.9 million ha, or 85 percent of the total cultivated area, and permanent crops occupy the remaining 0.5 million hectares (FAO-Aquastat, 2009). Summer temperatures are extremely high, reaching 38 °C to 43 °C with extremes of 49 °C in the southern and western deserts. The northern areas on the Mediterranean coast are much cooler, with 32 °C maximum. Rainfall is very low, irregular, and unpredictable. Average annual rainfall ranges from 200 mm in the northern coastal region to almost zero in the south. The national average is 51 mm (Kundell, 2007).

It is the Nile River which provides more than 95 percent of Egypt water demands. Agriculture depends on this water as over 99 percent of cropping is irrigated and employs 35 percent of the country's labour force (FAO, 2010).

3.1.2 Drought history

Since ancient times, Egypt has relied mostly on the River Nile for water. This is the main source of water as rainfall is low and groundwater is limited. Nile water is used for agriculture, municipal and industry, navigation, hydropower generation, and fisheries.

Nile water does not originate in Egypt, rather is comes from humid Ethiopian and East African highlands. The effects of climate variability, principally rainfall variability in the Ethiopian highlands and Lake Victoria, are shown to have caused significant inter-annual and inter-decadal variability in Nile flows with major implications for water resources in Egypt.

Annual variations in Nile flood discharges made agriculture possible, thus forming the backbone of Egyptian civilization. In the past, this predictable annual rhythm depended on the capricious variations in Nile flood discharges. But farmers could hardly anticipate the long-term vagaries of Nile floods, and as a result, Egyptian civilizations suffered at times from catastrophically high or low Nile flood discharges (Fekri, 2005).

In 2200 BC, there was a catastrophic reduction in the Nile floods over two or three decades. People were unable to grow food and began to starve to death and were forced into committing atrocities, such as eating their own children. This was so severe that famine gripped the country and paralysed the political institutions. The Egyptian sage, Ipuwer, gives a graphic description of the horrendous events of that time and aftermath of the drought which destroyed the Egyptian Old Kingdom around 2200 BC (Fekri, 2011). Every year the level of the Nile began to rise in the summer, covering the floodplain. But when it failed to rise enough or when it rose too much (Baines, 1974), it caused hardship even during the most prosperous periods.

Droughts have always had far-reaching effects causing failure of crops, decreasing natural vegetation, and depleting water supplies. Livestock and wildlife, as well as people die of thirst and famine, and large land areas often suffer damage from dust storms.

Pollen and charcoal evidence recorded two large droughts: one some 5 000 to 5 500 years ago and another around 3000 years ago (Bernhardt, 2012).

In 1970 the High Aswan Dam was constructed to control the annual flows and to protect the region against droughts and floods. In1991, Abu-Seid and Abdel-Dayem noted that Egypt had come out of a prolonged period of low flows lasting from around 1978-1987, unprecedented in the historical record dating back to 1870. In 1988, Egypt was very close to a major water shortage. The high flow year in 1988 was thought at the time to indicate an end to the drought period and the beginning of a cycle of high flow.

Nile flows are explained by events in the catchments of the Blue Nile (Ethiopian highlands) and Lake Victoria (East Africa, the main component of the White Nile system). The long period of low flows during the 1970s and 1980s coincided with drought in the Horn of Africa (Hurst*et al*., 1966; Abu-Seid and Biswas, 1991; and Conway and Hulme, 1993).

Nine countries feed water into the Nile River upstream of Egypt. The annual flows come from rainfall Central Africa (Lake Victoria -White Nile) and melting snow and rains from the mountains of Equatorial Africa (Blue Nile) in the Ethiopian highlands. Ethiopia's Blue Nile accounts for more than 80 percent of the Nile's water (Oestigaard, 2012).

The Nile flows are currently divided between Sudan and Egypt according to the 1959 Nile Waters Agreement with 55.5k m^3 for Egypt, 18.5 km^3 for Sudan, and 10 km^3 for evaporation from the Aswan High Dam (AHD) (Table 9). These figures are based on a fixed mean annual flow of 84 km^3 from 1900 to 1959, the recent low decade-mean (1981–1990), and a high decade-mean (1881–1890). They highlight also the significant historical variability of Egypt's water supply, primarily due to rainfall fluctuations over the Ethiopian highlands (Conway and Hulme, 1996).

TABLE 9
Allocation of water according to the 1959 Nile Waters Agreement

	Volume historical variability (km^3)		
	1881–1890	1900–1959	1981–1990
Egypt	75.0	55.5	49.9
Sudan	25.0	18.5	16.6
AHD reservoir evaporation	10.0	10.0	10.0
Mean flow (km^3)	110.0	84.0	76.5

Source: Adapted from Conway (2005)

While the Aswan High Dam reservoir enabled Egypt to successfully mitigate the effects of the large drought in the 1980s, any event of greater severity may well overwhelm this capacity (Gasser and Abdou, 1989). For example, the very low discharge levels of 1888 and 1889 caused serious economic and political difficulties, as some 100 000 hectares in Upper Egypt did not receive any irrigation water (Vorgelegt *et al.*, 2012).

In last 30 years, 10 droughts events with marked water flow deficit were recorded in Egypt after one month lag from their onset in the East African countries: 1972, 1979, 1982, 1983, 1984, 1986,1987, 1990, 2002, and 2010 (Table 10; Figure 7).

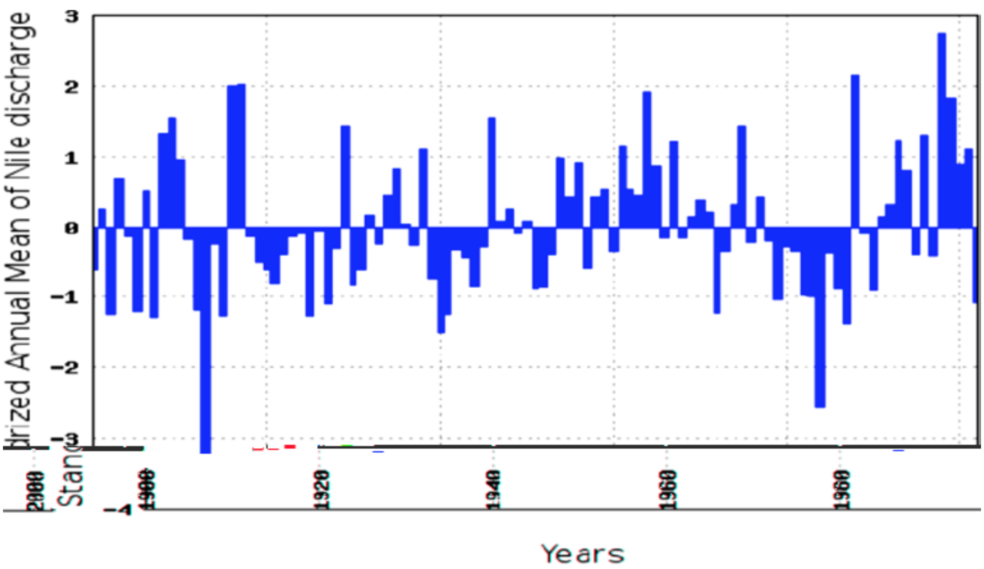
In the past 20 years, Ethiopia has experienced several recurring droughts followed by food shortages and famines. Some 85 percent of Nile flows originate in the Ethiopian Highland and for this reason, Egypt is always concerned about climate variation and drought events in the Horn of Africa. More recent concerns are the developments in Ethiopia that demand water, which will impact further on water availability downstream for both Sudan and Egypt.

TABLE 10
Observed variability in the Nile Flow over the period 1973-1989

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Flow	83	90	102	80	92	86	69	82	85	69	72	53	82	73	68	115	81
Km^3	average	average	high	average	average	average	low	average	average	low	low	low	average	low	low	high	average

Source: Adapted from Elfatih (1996)

FIGURE 7
Inter-annual variability of Nile River total discharge (101 years) 1900-2002



Source: Elfatih (1996).

3.1.3 Government policy on drought

Agriculture can only be developed through irrigation. However, the quality of Nile water and other surface waters (drainage systems) is deteriorating due to anthropogenic pressure. This explains the strategies and policies of the State, which are primarily oriented to the management and protection of the resource.

REACTIVE RESPONSE TYPE

The 1980s drought period and its apparent effects on the Nile flow, which reached its second lowest point in 1984, had its effects on Nile water resources management in Egypt, and involved institutional level reactive adaptations (Conway, 2005).

When drought conditions are severe, it triggers a political action that results in the issue of an intervention bill that allocates funds from the national budget to compensate up to 50 percent of assessed damages. It is followed by detailed analysis of drought impacts. Commissions are set up within municipalities in order to give final assessment and priorities for compensation. The whole process can take more than one year. In addition to direct financial compensations, there are also possibilities of tax reductions, and exemptions of social costs. The Ministry of Agriculture specifies categories of farmers to share scarce water discharges and helps them to postpone their bank debts. The Ministry of Trade imports quantities of staples to stabilise prices (Nada, 2014).

The most vulnerable sector is agriculture. Farmers are involved, in a series of adaptive responses, in early development of drought and are encouraged to take action to help mitigate its effects. However, all these decisions need backup information and early warning.

The government tries to ensure good water management and good operational condition of the irrigation network (dams, barrages, regulators and navigation locks) to achieve the desired efficiency of water use and water saving (OWAS and AWF, 2009). Although the storage is sufficient to meet normal years (55.5 km3/year), the government has made emergency plans to counter the drier years including:

Reducing annual releases from the Aswan dam through more efficient regulation

Extending the irrigation winter closure period

Reducing the area under rice

Improving the Nile's navigable channel to maintain levels to supply irrigation offtakes (Abu-Seid and Abdel- Dayem, 1992).

The last dry period is now cited as one of the important factors influencing current water resources management. This includes the Jonglei canal scheme to reduce evapotranspiration losses in the Sudd and the need to supply an ambitious land reclamation programme. While Egypt is fairly well protected against the effects of inter-annual variability by over year storage at Awsan, the 1980s droughts showed that it is vulnerable to inter-decadal variability, as in 1988, where Egypt was very close to a major water shortage (El-Kady, 2003).

DROUGHT RISK MANAGEMENT POLICIES/PLANS

Egypt does not have a dedicated organisation for drought nor a drought management plan. All action, plans, and strategies are seen as water management issues. Egypt had come out of a prolonged period of low flows lasting from around 1978–1987, unprecedented in the historical record back to 1870. Several Ministers involved in water and drought management responded by including the establishment of more robust contingency planning and early warning systems alongside strategic assessment of water use and planning in response to low flows during the 1980s (Hulme, 1994; Abu-Seid and Abdel-Dayem, 1992; Abu-Seid and Hefny, 1992; Conway and Hulme, 1993).

In 1988, the Ministry of Water Resources and Irrigation (MWRI) developed a simulation model based on storage in Lake Nasser (Aswan dam) to review options for reservoir operation under a set of possible Nile flows and downstream releases. The dry period initiated the establishment of planning studies and models department responsible for monitoring and forecasting which was based on upstream flows and levels with one month's lead time (Abu-Seid and Abdel-Dayem, 1991). This department has evolved into the MWRI's Nile Forecast Centre (NFC), which uses modelling to develop a forecasting system for the Blue Nile and the White Nile and uses satellite estimates of rainfall over the upper basin (Schaake *et al.*, 1993). The MWRI has also undertaken some research into seasonal forecasting (Elwan *et al.*, 2002). Finally, there is also a Nile Basin Management Decision Support System (partially funded by USAID through FAO) to implement a computerised control scheme for the operations planning of the Equatorial Lakes in the Upper Nile. This now includes models of all the sub-components of the basin, lakes, reservoirs and other environmental components and has been used to explore climate and management scenarios in parts of the basin (Georgakakos, 2004).

A Dutch funded 'Lake Nasser Flood and Drought Control Project', based in the MWRI, was established in 2002 with the aim of analysing the impacts of flooding and also climate change on operation of the Aswan dam (Mohamed and Savenije, 2000; Strsepek *et al.*, 2001; Kandil, 2003). In 1999, the MWRI included a focus on policies to shift integrated use approaches, which include both supply and demand management.

Although the government now has a strategy for demand management and IWRM, water management still remains highly centralised and sector based with no real involvement of users. Four main ministries share responsibility for the management of water and sanitation: the MWRI in charge of the resource (surface and groundwater quantity and irrigation); MSEA in charge of protecting the resource and the environment; MWWU in charge of drinking water and sanitation; and MOHP in charge of public health (quality control). Alongside these core ministries, other ministries are also involved according to their particular water interests, such as the Ministry of Agriculture and Land Reclamation (MALR), Ministry of Housing, Utilities and New Settlements (MHUNS), Ministry of Health and Population (MHP), Ministry of Transport, and the Ministry of Local (Rural) Development.

INSTITUTIONS INVOLVED IN DROUGHT MANAGEMENT

There are established committees, with members representing different entities, whose purpose is to coordinate and integrate activities in relation to water resources planning and management. There are also laws and regulations governing water use and the development of resources, such as groundwater (Attia, 2004).

The review of existing institutions involved in climate change which discusses the impact of drought, does not integrate drought management as a component of the national development policies and strategies programme.

The institutions involved in climate change that could contribute to developing a drought management framework include:

Ministry of State for Environmental Affairs (MSEA) with three entities: Egyptian Environmental Affairs Agency (EEAA), an inter-ministerial National Committee of Climate Change (NCCC), and National Authority for the Clean Development Mechanism (CDM)]

Ministry of Electricity with two entities: New and Renewable Energy Agency 1986 for promoting renewable energy, Regional Centre for Renewable Energy, and Energy Efficiency for coordinating energy policies at national level

Prime Minister – Supreme Energy Council (SEC)

Ministry of Water Resources and Irrigation with four entities: Nile Forecast Centre (NFC), Environmental and Climate Research Institute (ECRI), National Water Research Centre (NWRC), and Ministerial Committee for Climate Change to supervise climate change policies

Ministry of Agriculture and land reclamation (MALR) with two entities: Climate Laboratory Agricultural Centre, and Ministerial committee for climate change to supervise climate change policies into the national plans

Others stakeholders include:

National Authority of Remote Sensing and Space Science (NARSSS) and its Climate Change Department for monitoring the earth/NOAA/SPOT data

Institute for Higher Studies of Environment, Alexandria University, monitors the shores of the Mediterranean Sea

National Institute of Oceanography and Fisheries monitors the shores of the Red Sea

Faculty of Science in Ain Shams University controls the quality

faculty of science of Cairo University - research activities

Egyptian Authority of Meteorology

Alexandria Research Centre for Adaptation to Climate Change (ARCA) - policy oriented research on climate change adaptation.

Egypt has made significant progress in establishing the institutional framework and building national capacity in water management and climate change. At present, no organisation is involved in drought management, as such. However, the essential foundations for a unit responsible for the management of drought exists, even if the components are dispersed among various institutions, as is the case of water and climate change. Establishing such a unit requires strengthening coordination among all institutions and stakeholders and the need for establishing a common database that all can have access to, in order to exchange and make good use of the information.

3.1.4 Vulnerability to drought

The distribution of Egypt's population, land-use, and economic activity along a narrow T-shaped strip of land along the Nile and the coast around the Nile delta, make the country extremely vulnerable to any potential impacts on its water resources.

Agriculture is the most vulnerable sector; it is mostly irrigated and so highly dependent on the Nile River which is, in turn, dependent on climate conditions and water management practices of others far outside national boundaries. It provides livelihoods for 55 percent of the population, many of whom rely on small plots of less than 0.4 hectares. Although the contribution to GDP has fallen over time, it still accounts for about 14.5 percent and 20 percent of total exports and foreign exchange earnings, respectively. Industries related to agriculture, such as processing, marketing, and supplies, account for a further 20 percent of GDP (ICARDA, 2011). Any water flow deficit due to prolonged drought upstream invariably undermines this sector and economic growth.

Egypt is also engaged in a massive expansion policy for irrigated agriculture in the Western Desert and Sinai. This will reduce its flexibility and increase Egypt's exposure to the risk of future water shortage and inability to meet demand for water (Wichelns, 2002).

Water availability of 703 m^3/capita/year (FAO, 2010, data from 2008) is also a source of vulnerability and means that Egypt is classified as a water scarce country (Falkenmark, *et al*. 1989). Increasing population indicates further aggravation for water supplies.

Energy resources are ranked as least vulnerable as only 23 percent of electricity comes from hydro schemes on the Nile (Agrawala *et al*., 2004).

Another risk may come from the other riparians along the Nile. Beyond the agreement between Egypt and Sudan, there is no recognised treaty or agreement on the Nile among all the riparians. The ten countries that share the Nile basin do not all share norms within the basin (Waterbury, 2002) despite the Nile Basin Initiative (NBI) where countries can cooperate. But even after decades of discussions, there is no consensus among upstream countries and Egypt and Sudan. Another treaty was signed between upstream countries but did not include Egypt and Sudan. Egypt will suffer from upstream drought if procedures are not put in place to better manage the water resources in the Ethiopian Renaissance Dam.

For those rural communities outside the Nile valley for whom even the meagre rainfall in-country is vitally important, such as Sinai, drought periods render their livelihoods even more vulnerable. The last drought in Sinai extended from 2000 to 2010. Drought affects the livelihoods of Bedouin, which includes rainfed farming, grazing, and employment, and reduces food production, decreases purchasing power, and increases the number of internally-displaced people. Drought has caused some deep dislocation in the societal fabric, with serious repercussions on human welfare (SWIM, 2013).

3.1.5 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

The completion of Aswan Dam in 1972 was the most significant step that government has taken to regulate the Nile flows during the whole of the year rather than just during the flood season.

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS PRIOR TO OR DURING DROUGHT

Farmers can contribute in reducing crop losses and alleviate drought impacts in accordance with their shared water:

By choosing less sensitive crops in case the drought features started already in early spring in time of sowing

By preparing irrigation plans in the early stages of drought development

By deciding on an early harvest in case cropping outlooks are not good (Tamer, 2014).

NATIONAL AND REGIONAL POLICIES

For the moment, Egypt is well adapted to current climate variability. However, there is a need to formulate plans to adapt to potential long-term reductions in water availability and to integrate such solutions as part of water management. These include:

Water conservation for the agricultural (e.g. drip irrigation) and the industrial (e.g. recycling) sectors

Minimise pollution by upgrading water quality and sanitation with high priority to recycling of industrial and sewage waste

Water collection through building catchments and dams in flash flood areas, such as Sinai, and reactivate old rainwater catchments systems and use them for rainfed cultivation

Solar water desalination plants and wind energy

Launch public awareness campaigns on water shortage and water quality, and test socioeconomic impacts of selected measures.

INSTITUTIONAL AND RESEARCH MEASURES

Allocate resources (human and funds) to promote impact studies of climate variability at involved Ministries and Universities.

Strengthen cooperation and exchange of information between the departments of different ministries, research institutions and universities working on the different aspects of water resources.

Develop methodologies for assessment of impacts, including scenarios for impacts on water budget, evaporation, and impacts on each sector.

Improve capacity in government departments and universities for training and implementation of water demand management approaches.

Develop a programme for groundwater management to protect reservoirs from overexploitation and pollution.

RELIANCE ON VIRTUAL WATER

This is water embedded in (food and other) imports. It has economic and political implications and it is widely held that national food security remains an important political aim. In terms of adaptive capacity, the Ministry of Water Resources and Irrigation has strong technical expertise and capacity in water management (good for supply side options) but less capacity in terms of socio-economic and institutional management more appropriate for implementation of water demand management options.

ON THE SUPPLY-SIDE

Adaptation options include measures to improve rain-harvesting techniques, increase extraction of groundwater, recycle water, water desalination, and improve water distribution.

These responses are about adaptation to potential reductions in water supply over the medium to long-term. Waterbury (2002) identifies slack within the system which is or may be achieved through four main opportunities: reliance on virtual water, economic measures to improve water use efficiency, rainwater harvesting, and drainage schemes in southern Sudan.

See Appendix 6 for more water-related measures.

3.1.6 Measures to build resilience to drought

INSTITUTIONAL AND RESEARCH MEASURES

Strengthen the newly established Institute of Environment and Climate Change in the Ministry of Public

Work and Water Resources to study climate change impacts

Encourage meteorology departments in universities and in the Ministry of Defense to allocate resources (human and funds) to study impacts of climate variability and change in Egypt

Strengthen cooperation and exchange of information among the departments of different ministries, research institutions and universities working on the different aspects of water resources

Develop an institutionalised methodology for assessment of impacts, including scenarios for impacts on water budget, evaporation, and impacts on each sector

Improve capacity in government departments and universities for training and implementation of water demand management approaches

Develop a programme for groundwater management to protect reservoirs from overexploitation and pollution

SELECTED ADAPTATION OPTIONS FOR AGRICULTURE RESOURCE MANAGEMENT

Drought tolerance is one of most important targeted traits for crop improvement programmes using biotechnology. The goal is to eventually offer the drought-tolerance trait to farmers, royalty-free, so they are able to achieve harvests that are more reliable.

Moving away from water-intensive types of production to other activities where the water requirements are lower per unit of production by value. Today Egypt imports a substantial amount of wheat, which is a way of importing virtual water.

3.1.7 Issues

Adapting to drought and climate variation will have close resonance with adapting to water scarcity and is likely to require implementation of water demand management strategies, which may require capacity building and awareness raising across institutions and society.

Egypt needs to implement drought early warning systems and a drought preparedness programme, and improve long-term forecasting.

A key vulnerability for Egypt is the fact that the River Nile and its tributaries flow through eleven countries, each with its own development agenda. The Nile Basin Initiative (NBI) still does not enable a consensus to be achieved between Egypt, Sudan, and the upstream countries. A treaty or agreement on the Nile is needed that includes all the riparian States which avoid the problems of unilateral actions.

3.1.8 References

See Annex.

3.2 SUDAN

3.2.1 Background

Sudan comprises vast plains interrupted by a few widely separated ranges of hills and mountains. The population is 38.0 million and growing at 2.0 percent annually (World Bank, 2014). The rural population is 67 percent of the total – 9 percent nomads, 14 percent in poverty. Agriculture and livestock are essential to Sudan's economy and its diversification away from oil. Together they contribute 35 percent of GDP. Rural-to-urban migration has been steady and high between 1983 and 1995, with urban population growth of 4 percent (World Bank, 2015). This trend is due mainly to recurring droughts (which are increasing in frequency), major civil conflicts, and declining developmental investment in the rural areas. Male migration and displacement have increased the number of woman-headed households. Sudan's scarce natural resources (about 80 percent of the population depend on the natural environment for survival) have been the underlying drivers for the country's main conflicts since its independence in 1956. Most are resource-based, often between pastoralists and farmers. More than half the country is classified as desert or semi-desert, with another quarter being arid savannah (World Bank, 2015).

Rainfall is erratic and varies widely from north to south. The severity of drought experienced depends on the variability of rainfall both in amount, distribution, and frequency. Since the 1930s, the Sahara Desert has encroached southwards between 50 and 200 kilometres (UNDP, 2009) into semi-desert and savannah. Drought threatens the cultivation of some 12 million hectares of rainfed, mechanised farming and 6.6 million hectares of traditional rainfed farming. Pastoral and nomadic groups in the semi-arid areas of Sudan are also affected. Agriculture provides 90 percent of the raw material for local industries and employment and income for more than 80 percent of the population. Some 90 percent of cultivated areas depend exclusively on rainfall. Amount and distribution of rain is thus a central determinant of crop success (UNDP, 2009).

3.2.2 Drought history

Periods of drought have occurred throughout Sudan's history and in most cases have been followed by famines and outbreaks of disease (Babiker, 1985; 1990). Table 11 indicates diversity in the spatial incidence of drought and famine, with frequent occurrences concentrated in the western and eastern regions.

Two widespread droughts occurred during 1967-1973 and 1980-1984, the latter being the more severe. During the same period, there were localised droughts in 1987, 1989, 1990, 1991, and 1993, mainly in western Sudan and parts of central Sudan (INC, 2003). In North Darfur, since 1917 in El Fasher and since 1946 in Geneina and Nyala, the rainfall was lowest in the 1980s. However, most significant is the increased frequency of drought, 16 of the 20 driest years on record have occurred since 1972 (UNEP, 2008).

Severe droughts affected the country in 1684, 1886, 1913, 1940, 1967-1973, and 1980-1984. Successive years of drought in certain parts of the country during 1985-1993 caused severe food shortages, social disruption, and widespread health and nutritional problems.

The history of drought is exemplified by the well-known droughts of 1984 and 1990, which were accompanied by widespread displacement and famine, while localised and less severe droughts were also recorded during the late 1960s, late 1980s, and early 1990s(UNEP, 2007).

The effects of drought differ in different parts of the country: widespread in the west; moderate in the east and south; and less at the centre. The worst impacts were felt in the central and northern states, particularly in Northern Kordofan, Northern state, Northern and Western Darfur, Red Sea and White Nile states (UNEP, 2007).

3.2.3 Government policy on drought

As described by Teklu (1991), the absence of public policy and institutional capacity to predict, prepare, and intervene during the 1984-85 drought was notable in view of the country's long history of drought-related famines and its past record of successful application of legislated famine prevention policy (famine codes). The lessons of 1984-85 made the government realise the need to improve the production and income base of the rural population; to moderate fluctuations of production, prices, and income; and to establish a permanent institution to deal with relief and rehabilitation, as integral components of a broad framework of drought impacts prevention and preparedness. A number of administrative committees and a high-level policymaking relief committee were then established by the end of 1984.

The government still relies on aid agencies to support the population; although at the end of 2009, it implemented a cereal subsidy programme to lower or stabilise prices. However, the programme has been constrained by a lack of coordination with other actors.

REACTIVE RESPONSE AND EMERGENCY RELIEF

The droughts of 1982-84 and the great famine of 1984-85 revealed the limits to the ability of the rural population to subsist on its own. The onset of the 1984-85 drought was noted as early as 1983, and people moved on a permanent basis from the drier areas of Northern Sudan. The government response was to ban sorghum exports in 1984, increase the area under sorghum cultivation in the irrigated areas, and ship 5,400 tons of sorghum as food-aid to the affected areas (Teklu, 1991).

A sample of rehabilitation activities undertaken by the international organisations and NGOs (USAID; SCF; IFAD; CARE/Netherlands; UNSO/WFP/UNDP; UNICEF; OXFAM; etc.) in 1988-1989 in Northern Kordofan includes (Teklu, 1991):

Smallholder credit for cash crop production

Restocking of gum Arabic trees and other forestry

Restocking of small animals (mainly goats)

Home garden development

Irrigated agriculture

Grain storage (village level)

Cheese-making.

These activities cover rehabilitation of land and water (restocking of gum arabic trees), asset reconstitution (restocking of goats), and promotion of agricultural production (through provision of production credit). They likely contributed to the establishment and protection of the coping capacity of the affected population (Teklu, 1991). Specific programs included:

Food-for-Work planting such as the Gum Belt Project: the primary goal of the project is to halt degeneration of the environment, but it has secondary goals of creating additional employment and improving the income position of participating farmers.

Improved Agricultural Technology: This was a powerful tool for mitigating the drought crisis, and provided respite for drought displaced people from a large surrounding area.

Credit for Production and Consumption: The Agricultural Bank of Sudan (ABS) initiated a cooperative-based credit programme for production enhancement and consumption stabilisation. The programme caters primarily to the credit needs of small farmers in rainfed agriculture. ABS provides targeted loans to finance production and storage.

Restocking of Livestock: Goat-restocking action represents an asset-rehabilitation effort in a post famine period. It targets poor female-headed households in the drier

TABLE 11
History of drought and impact in Sudan 1886-2011

Years of Drought	Areal Extent	Name and Damage	Source
1684	Sennar region	"The great famine"	O'Fahey and Spaulding (1974)
1835-38	Central Sudan	"Years of famine"	Hill (1970)
1836	Central Sudan	Cholera spread through country	Hill (1970)
1885	Central and eastern Sudan	Slight famine	Al-Oudal (1983)
1888-89	Central, northern, eastern, and western Sudan	Hundreds of thousands died of hunger and disease. People sold their children as slaves to save their lives and later bought them back with higher prices.	Slatin Pasha (1896) Duncan (1952) Farwell (1967) Churchill (1899) Holt (1970) MacMichael (1934)
1890	The Nile area	Locusts and mice consumed the products	Farwell (1967) Duncan (1952)
1906	Affecting all Sudan	Severe famine	
1913	Localised; Mainly northern Sudan	Poor rain, corn brought from India and issued free of charge in distressed areas and cheaply elsewhere	MacMichael (1934)
1914	Central Sudan	"The year of the flour" (flour brought from India because of poor rains)	Henderson (1965)
1927	Central and eastern Sudan	Slight famine	Al-Oudal (1983)
1940	Localised (part of Sudan)		
1967---1973	Localised (part of Sudan)		Teklu (1991)
1980---1984	Localised (part of Sudan)		Teklu (1991)
1984	Localised (part of Sudan)	Severe famine: 8.5 million people were affected and 7.8 million livestock were lost	Teklu (1991)
1985---1990	Localised (part of Sudan)		Teklu (1991)
1987	Affecting all Sudan	3.45 million people were affected	Teklu (1991)
1988	Affecting all Sudan	2.5 million people were affected	Teklu (1991)
1990	Localised (part of Sudan)	600 000 people were affected	
1991	Affecting all Sudan	8.6 million people were affected	
1992-93	Localised (part of Sudan)		
1996		160 000 people were affected	
1997-98	Localised (part of Sudan)	1.0 million people were affected	
2000	Localised (part of Sudan)	2.0 million people were affected	
2003	Localised (part of Sudan)	325,056 people were affected; food shortage in some areas	
2007-08	Localised (part of Sudan)	565,335 people were affected	
2009	Localised	Famine affecting part of South	
2011	Affecting most of South	food shortage in some areas	

areas, to have most effective impact on child nutrition and health, knowing that the children are the most vulnerable in the post famine period (Simpkin, 2004).

PROACTIVE RESPONSE

During the past 30 years, there has been a significant increase in the awareness of climate variation issues. In 1998, the government established a climate variation unit. In addition, several organisations are extensively involved at the national level in climate variation-related activities. These organisations include academic and research institutions; other relevant government agencies such as those in the energy, water, agriculture, and health sectors, non-governmental organisations, and the private sector. Moreover, the new climate variation institutional arrangement started to play a leading role in integrating climate variation issues into national agendas. The recently established Higher Council for Environment and Natural Resources is mandated with coordinating and integrating environmental concerns into all national and sectoral development plans and strategies. However, significant gaps remain with respect to the ability of these newly established institutional frameworks to effectively manage climate variation-related concerns (Osman-Elasha, 2010).

EARLY WARNING SYSTEMS

Unlike most of its neighbours in the Sahel and Horn of Africa, Sudan did not have a well-developed formal early warning system, at least until mid-1990s. However, there is already extensive experience with early warning and response systems in Sudan in relation to diseases, conflicts, fires, and floods.

The Greater Horn of Africa is prone to extreme climate events, such as droughts and floods, with severe negative impacts on key socio-economic sectors. After the devastating 1980s droughts, a Drought Monitoring Centre was created in 1989 covering 24 countries in the Eastern and Southern Africa region, Sudan included, under the auspices of WMO and UNDP. In 1998, the Drought Monitoring Centre, Nairobi (DMCN) was devoted to the GHA region, which was absorbed by IGAD in 2000 as a specialised institution and was then changed to IGAD Climate Prediction and Applications Centre (ICPAC). ICPAC now plays an important role in providing the IGAD sub-region with weather and climate advisories and more importantly, timely early warnings on extreme climate events. Climate information is used to improve crucial decisions required in all the components of integrated disaster management, namely early warning, prevention, mitigation, preparedness, relief and rescue, rehabilitation, and reconstruction (UNISDR, 2009; Simpkin, 2004).

3.2.4 Institutions involved in drought management

Different government institutions and departments are playing critical complementary roles in drought early warning systems; these institutions are (Eldridge *et al.*, 1986):

Sudanese Government Ministries: Meteorology Department (Technical Authority for Remote Sensing (RSA)); Ministry of Agriculture and Natural Resources (National Drought and Desertification Central Unit (NDDCU); A Higher Council for Coordinating Drought and Desertification Control Programme s (HCCDDCP)); Ministry of Irrigation; Ministry of Animal Resources; Ministry of Health; Ministry of Education; Ministry of Finance and Economic Planning (Strategic Reserve Authority (SRA)); National NGOs Coordinating Committee on Combating Desertification (NCCD)

Multi-Governmental Organisations: United Nations Development Programme (UNDP); World Food Programme (WFP); Food and Agricultural Organisation (FAO); UN High Commissioner for Refugees (UNHCR); and World Meteorological Organisation (WMO): USAID

Non-Governmental Organisations (NGOs): Save The Children Fund; OXFAM; CARE; League of Red Cross and Red Crescent Societies (LRCS); Sudan Council of Churches; Medicins Sans Frontiers

Other: Livestock and Meat Marketing Corporation; Agricultural Bank; Local, District and Regional Councils; and Market authorities (for monitoring and taxing purposes)

Cooperation among EWS efforts in Sudan: A close working relationship has been established between the Sudanese Relief and Rehabilitation Commission (RRC) and UNEOS. The RRC has over-all responsibility for coordinating relief and rehabilitation efforts in Sudan. The RRC-UNEOS EWS team works closely with several Sudanese Ministries, international aid agencies, NGOs, and UN agencies.

The government has adopted the livelihoods economy methodology and approach (income, expenditures, and coping mechanisms) as a basis for providing early warning information and currently uses GIS and remote sensing.

The country is divided into different climatic zones for the purposes of early warning

EWS and information on drought among others are gathered at the Federal, State, and Regional levels. This information is routinely analysed and provides data for the monthly early warning bulletins that highlight food security and food balance sheet together with other relevant EW information which is disaggregated by state and by category.

The Humanitarian AID Commission (HAC) shares the EW information with its key partners on a daily basis or as and when required through an email mailing list.

The government has put in place technical committees to coordinate sectoral working committees and groups. HAC provides overall coordination in collaboration with the UN.

3.2.5 Vulnerability to drought

SOCIO-ECONOMIC IMPACTS OF DROUGHT

The country's inherent vulnerability may best be captured by the fact that food security is mainly determined by rainfall, particularly in rural areas, where 70 percent of the total population lives. Quantity and distribution of rain is thus a central determinant of crop success. Fluctuations in crop yield are attributed almost solely to fluctuation in rainfall. Variations in temperature and rainfall patterns also represent a priority threat to food security (UNDP, 2009).

Drought represents a steadily aggravating phenomenon, especially in the north where the rural population is forced to internally immigrate towards the southern cities, abandoning their farms and agricultural lands, and creating social and economic problems. For a country known for its vast agricultural resources, this is both unfortunate and ironic (Teklu *et al*. 1991). Drought events also impact ecosystems, as dry spells kill otherwise long-lived trees and reduce vegetation cover, leaving land more vulnerable to overgrazing and erosion (UNEP, 2007).

Most droughts are followed by famine and outbreaks of disease, malnutrition, and epidemics; social disruption; immigration in search of employment opportunities, and increasing violent-conflicts over the resource base. A large drop in agricultural production occurred in 1984-1985. This decline translated into a large drop in farm employment. A strong link between agricultural production and income (from crop production, local off-farm wage employment, and livestock) increased the extent of income failure. The 1984-1985 famine was the outcome of a long process of drought, absent or misplaced public food and agricultural policy, and insufficient public response (Teklu *et al*., 1991).

The most vulnerable groups are traditional rainfed farmers and pastoralists. According to the Interim National Constitution (INC) (2003), Sudan witnessed two widespread droughts during 1967-1973 and 1980-1984, the latter being the more severe and affecting land cultivation of about 12 million hectares of rainfed mechanised farming and 6.6 million hectares of traditional rainfed lands.

AGRICULTURE AND LIVESTOCK IMPACTS OF DROUGHT

The total area considered as drought prone is about 69 000 km^2 and this area produces 90 percent of the cultivated food crops and 85 percent of fire wood. Drought affects humans and livestock causing feed and water shortages and human and livestock displacement may sometimes cause tribal conflicts (Amna, 2012).

In 1913 and 1940, about 1.5 million people were affected. In 1984, 8.5 million people were affected and 7.8 million livestock were lost. In central Sudan, the 18 recorded years of drought within the last half-century are certain to have had a major influence on the vegetation profile and soil conditions as seen in 2006, leading some people to become relief-recipients and less work-oriented (Amna, 2012).

Subsistence farmers and pastoralists vulnerability to drought is also related to social factors such as the tendency to maximise herd size rather than herd quality. Despite their vulnerability, local populations have little access to measures and practices that can increase their resilience in the face of climate variability (Tambel, 2010).

Relative to baseline expectations, the INC indicated an average warming range of 1-3°C and average variation in precipitation of -5.8 percent by 2030 in some areas (INC, 2003). The Sahelian belt which runs through Sudan is very likely to suffer the impact of climate variation. Since the 1930s, the Sahara Desert has encroached southwards into semi-desert and savannah land (UNDP, 2009). Climate variation is expected to increased rainfall variability and droughts (UNDP, 2009).

The Landsat STM map of 1983-1984 showed that the semi-desert (455 000 km^2) and some parts of the northern fringes of the low rainfall woodland savannah were severely affected by drought and environmental degradation. Some 74 million hectares of range lands area was considered as severely degraded lands (Abdelrrahman, 2008). As a result, the vulnerability study of the INC (2003) suggested that the nation as a whole may be hard hit by even modest variations in temperature and precipitation. The Agriculture & Forestry vulnerability assessment suggested that, in 2030, the humid agro-climatic zones will shift southwards, rendering areas of the north increasingly unsuitable for agriculture. Crop production is predicted to decline by 15 percent to 62 percent for millet and by 29 percent to 71 percent for sorghum.

3.2.6 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

The National Adaptation Programme of Action (NAPA), funded through UNEP, applied many practical programmes to mitigate drought impacts as governmental projects, which included rangeland rehabilitation, improved water harvesting practices in drought-prone areas, improved sustainable agricultural practices under increasing heat stress, biodiversity conservation and restoration as a coping mechanism for rangeland protection, water harvesting and special irrigation methods, expanded food storage facilities, managed rangelands to prevent overgrazing, replaced goats (which are heavy grazers and are sold at a lower value) with sheep (which have less impact on grassland and are sold at higher value), planted and maintained shelterbelts, planted backyard farms or jubraka to supplement family food supplies and incomes, supplied microcredit and educating people about its use, and formed and trained community groups to implement and maintain these various measures.

Among the main constraints affecting the ability of institutions to respond to drought impacts, is a lack of awareness of more effective options.

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

The current coping strategies of local communities are inadequate to effectively cope with climate variability. Farmers typically reduce risk by efforts to accumulate savings and diversify productions systems. Specific coping strategies include reliance on pastoral systems as a complement to farming (i.e., small herd owners maintain a small household vegetable gardens).

When droughts are severe or annually recurrent, farmers have employed new risk strategies. In the absence of food relief, diets become increasingly dependent on whatever food stores are available as well as wild foods. Households also sell their assets, such as livestock and land. Some move to other regions to stay with relatives. Others have no option but to migrate to refugee camps on the outskirts of Khartoum with whatever possessions remain to them. The return to their original homesteads is highly uncertain.

Between these extreme options, household coping strategies involve a combination of reducing non-essential household purchases and drawing down whatever stocks of food have been accumulated. Efforts intensify to secure off-farm income (El Bashir and Ahmed, 2006). Options to cope become increasingly irreversible as conditions worsen. A good example is the drought that affected small farmers in North Kordofan in the 1980s (Osman-Elasha, 2009). Many farmers were forced to sell or slaughter their sheep and cattle herds to cope with diminished fodder and water availability. Many farmers abandoned their homesteads and migrated to urban areas. As households proceeded along the hierarchy of coping strategies to reach such decisions, it was clear that they did so because of increasing vulnerability to food insecurity. Generally the viability of such strategies in the face of recurring droughts is poor.

See Appendix 7 for more water-related measures.

3.2.7 Measures to build resilience to drought

There is an urgent need to build resilience and adaptive capacity of rural communities relative to their agricultural and water resource management practices, focusing on alternative water catchment techniques, alternative cropping strategies, and improved rangeland management.

Rainfall performance influences farmers' cropping and pasture availability for pastoral livelihoods, and therefore are directly linked to questions of food security, animal welfare and, thus, human security for all forms of livelihoods. Farmers must build resilience by selecting crops resistant enough to survive in stressed climatic conditions, such as sorghum and millet. Pastoral and other mobile livelihoods have equally developed forms of resilience and adaptation strategies such as: adaptation via migration to areas with favourable grazing grounds, accumulation of wealth in cattle enabling pastoralists to buy grain even at inflated prices during droughts (De Waal 1989, Gray and Kevane 1993, Nugent and Sanches 1999), migration to seek paid labour in urban centres especially in Khartoum, charcoal production, and dependency on external aid (Gray and Kevane 1993).

To enhance the effectiveness of farmer risk minimisation strategies (i.e., the first phase in the above hierarchy of coping strategies), a variety of resources are needed. These range from improved knowledge systems (e.g., extension services on optimal crop choices, pastoral rotation options to enhance fodder productivity, trends in seasonal rainfall forecasts), to resources to enhance household income diversification (micro-credit schemes, revolving funds, crop insurance), to poverty alleviation programmes that provide much-needed rural development resources and infrastructure that are able to exploit synergies between global climate variation concerns and local poverty alleviation.

Some simple improved technologies were introduced to build the resilience of food production systems. For example, the government introduced micro-scale irrigated agriculture (through development of boreholes), improved water harvesting and storage, and supported direct pumping from the river. They made available improved seeds, and developed a number of highly marketable horticultural crops. They have improved the health and productivity of livestock. These interventions have significantly reduced vulnerability and enhanced local food security. The government has also supported actions to improve national resources and enhance ecosystem resilience. They have created shelterbelts around villages and farmlands to protect against desertification, re-seeded to improve rangelands, and reduced the demand for wood fuel by supporting the distribution of improved stoves and gas cylinders (Abu Diek and Fenton, 2013).

3.2.8 Issues

Weak drought contingency planning framework: Sudan's current drought contingency planning framework contains a weak component for ensuring food reserves in the face of drought. The Strategic Reserve Authority (SRA) was established in September 2000 and is an autonomous body accountable to the Minister of Finance and National Economy. To date, the SRA has been ineffective in achieving its objectives due to the lack of a clear strategic vision, a shortage of funds, and a lack of a transparent system to allocate scarce food stores among competing entities.

Poor institutional Capacity: Institutional capacities to address some of the urgent adaptation needs are inadequate as they relate to food security issues. There is an urgent need to improve the link between adaptation needs and national policy-making. This calls for urgent institutional capacity development efforts at national and sub-national levels.

Reform of policies and legislation: The current policies, especially in the agricultural sector, are leading to increased land degradation and impoverishment of the rural communities. This is manifested in the expansion of crop cultivation even in marginal areas at the expense of forests and rangeland. This practice should be reversed by intensifying crop production for food security and increasing the areas of forests and rangelands.

Land tenure systems are complicated and consequently their role for optimum utilisation of natural resources is confused and ineffective. Rules and regulations protecting the environment as a whole are available, but are not activated. There is a clear need for a proper land use plan that caters for the needs of all land users.

The current levels of governance (local, state, and federal) are inadequate and generally have adverse effects on natural resources.

3.2.9 References

See Annex.

4. Iraq and Syria

4.1 IRAQ

4.1.1 Background

Iraq has mainly an arid and desert subtropical climate, with cool winters and hot, dry summers. It consists of the alluvial plain between the Tigris and the Euphrates rivers surrounded by mountains in the north and the east and by desert areas in the south and west, which account for more than 40 percent of the land area. Agriculture is the second major economic sector after oil, and is the main source of livelihood for poor and food-insecure people, as well as the largest source of rural employment. In 2011, agriculture contributed 7.6 percent to GDP.

Rainfall is very seasonal and occurs in the winter from December to February, except in the north and northeast of the country, where the rainy season is from November to April. Average annual rainfall is 216 mm, but ranges from 1200 mm in the northeast to less than 100 mm over 60 percent of the country in the south (FAO, 2003) (Figure 8).

Iraq's population tripled between 1970 and 2009, growing from 10 to 32.1 million with an annual growth rate of 3.1. Almost 71 percent of the population is located in urban areas (UNDP, 2014). Iraq is heavily dependent on food imports to satisfy local needs, especially in years of drought (Lucani and Saade, 2012).

More than 75 percent of the land area is rangelands. These areas are unsuitable for farming as they are too dry and have poor, rocky soils and rough topography, but are widely used for grazing livestock. The agricultural sector faces various challenges, such as soil salinity, drought and shortage of irrigation water in the summer.

Rainfed farming occurs in the north while the central and southern areas depend entirely on irrigation mainly from Tigris and Euphrates rivers (UNDP, 2014). Both rivers originate in the eastern mountains of Turkey and enter Iraq along its north-western border with Turkey and Syria and provide over 75 percent of the renewable water resources (UNESCO, 2014). Only 32 percent of surface water in the Tigris originates inside Iraq, and only 3 percent in the Euphrates.

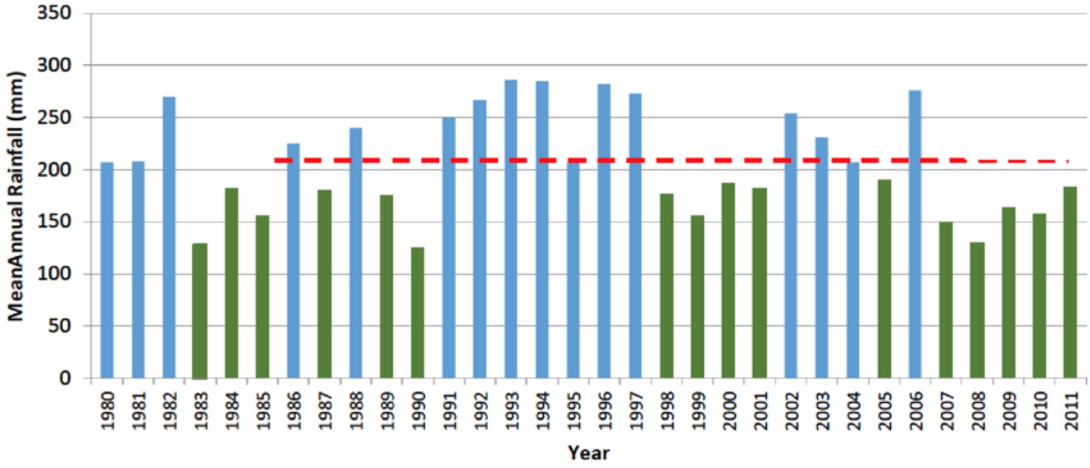
Iraq has large reserves of groundwater in the foothills of the mountains in the northeast and in the area along the Euphrates. The safe yield of these aquifers is about 2 percent of the nation's annual water budget (World Bank, 2006).

4.1.2 Drought history

Almost all governorates are prone to drought and the SPI calculated for each governorate shows that the severity has increased over the past 12 years. Four droughts were recorded in 2000, 2006, 2008, and 2009. Eleven governorates were affected in 2008 (UNESCO 2014).

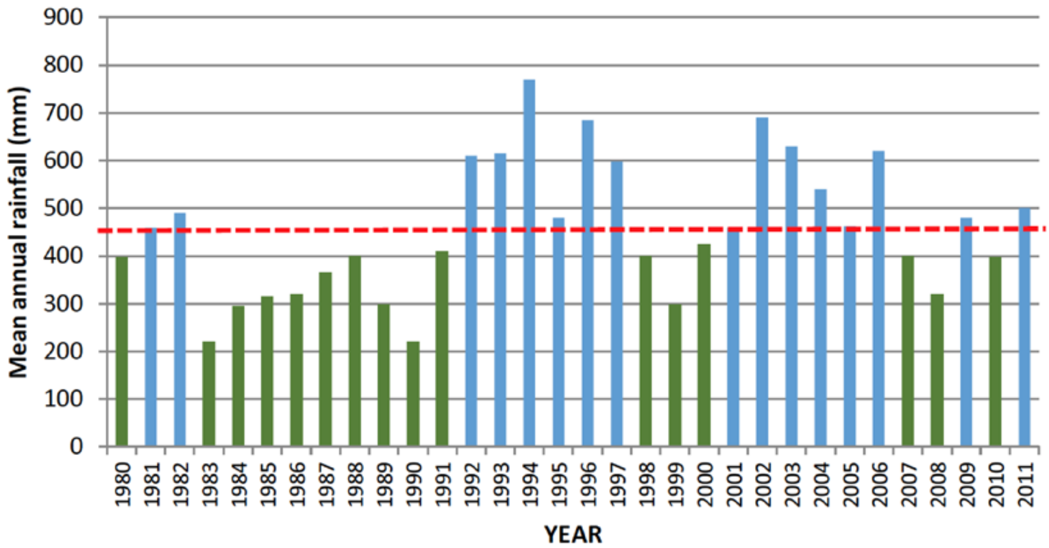
In 1969, drought affected 500 000 people and caused economic damage of US$2 million. More recent droughts were recorded in 2007-2009, and from 2010-2011.

FIGURE 8
Mean annual rainfall period 1980-2011



Source: Adopted from UNESCO (2013)

FIGURE 9
Mean annual rainfall of Kurdistan Region 1980-2011



Source: Adopted from UNESCO (2013)

At a regional level, the Kurdistan region experienced severe and prolonged drought between 1980 and 2011 (Figure 9).

4.1.3 Drought impacts

Meteorological information is sparse and drought is only assessed after it has already produced its effects. Iraq lacks an early warning system and drought indicators, mainly due to the lack of accurate data recorded on precipitation, temperature, and other meteorological parameters.

Drought impacts include a reduction in surface water flow, lowering of groundwater levels, drying-up of open shallow surface wells, increasing water salinity and soil salinisation, progressing desertification, decrease in agricultural production, growing frequency of dust storm conditions, and an associated increase in respiratory infections.

Over the past 30 years, flows in the Euphrates-Tigris river system were reduce to almost 50 percent of the average annual flow in drought years. The Intergovernmental Panel on Climate Change expect a decline of 29 percent in Tigris flows and 73 percent in Euphrates flows in the future as a result of declining rainfall in the main catchments in Turkey's highlands (Voss *et al.*, 2013). In addition to that, the absence of international water sharing agreements among the three states (Iraq, Turkey and Syria) about the policy of operating water reservoirs built upstream on the shared rivers in Turkey and Syria will result in instability of available water resources from one year to another. The foreseeable decline in rainfall will place a growing burden on the rivers.

Recurrent droughts and periods of water scarcity negatively affect food production, aggravating the current imbalance between food supply and demand inside the country. In 2011, the number of food insecure Iraqis was 5.7 percent of the population (1.9 million people) (WFP, 2012). Since the internal supply is not enough to satisfy the needs of the population, food consumption is largely satisfied through food imports, which reached a peak between 2006 and 2008. Droughts cause food insecurity and poverty to increase, especially in rural areas where most of the population relies on agriculture as its main source of livelihood.

Recurrent droughts during the last decade severely affected the agricultural sector with relevant damage to the production of both rainfed and irrigated crops. The drought that affected the country in the two consecutive years, 2008 and 2009, damaged almost 40 percent of the cropland in the country, especially in the northern governorates. From 2006 to 2007, barley production fell from 422,900 tons to 238 500 tons and wheat from 486,400 to 396,800 tons (UNESCO, 2014). Drought during 2008 and 2009 damaged almost 40 percent of cereal crops in the north (Raphaeli, 2009). In central and southern Iraq, the total production for irrigated barley decreased by 21 percent between 2007 and 2008, while wheat production fell by 31 percent. Large amounts of water are wasted due to poorly maintained distribution systems and to inadequate irrigation management. In the irrigated areas, rice was reduced by 44 percent in 2009 compared to 2005 levels.

In addition to agriculture, several industries are affected by water scarcity, which may result in capital losses and layoffs, thus increasing unemployment. Hydropower generation represents the most important renewable energy source in Iraq accounting for nearly 10 percent of the electricity generation mix in 2010 (IEA, 2012). This reached a peak of 20 percent in 2005 but it dropped back to 7 percent in 2009, suggesting a possible effect of drought (UNESCO, 2014). Water-related migration registered an increasing trend in the last few years. The south of Iraq experienced a huge population movement due to the drainage of the Marshlands; people were displaced due to the insufficiency of water. Between December 2007 and June 2009, 4,263 families (25,578 individuals) were displaced due to drought in Iraq (UNESCO, 2014). According to the Ministry of Health, the highest number of diseases transmitted through contaminated water and food were registered between 2007 and 2010, during the most severe droughts (UNESCO, 2014).

DROUGHT IMPACTS ON NATURAL ECOSYSTEMS

The interaction between agriculture, society, and the environment is illustrated through two major natural ecosystems in Iraq: marshlands in the Mesopotamian plain in the south and rangeland in Al Jaseera area in the north. Both ecosystems are highly affected by drought events.

Marshlands: The historical Mesopotamian marshes used to be fresh water bodies. The drought of 2009 generally caused severe impacts on Iraq and on Iraqi marshlands environment, in particular. These impacts can be summarised as: decreased water quantity and cover area, reduced water quality, more concentrated pollution, increased soil salinity and abandoned agriculture lands, disrupted and fragmented marshlands ecological systems, decreased fauna and flora diversity, and increased human and animal diseases outbreaks (UNEP, 2010).

Rangelands: Rangeland occupies 9 percent of the total area of the country which contributes to feeding 90 percent of livestock (Omer, 2011). The drought impacts can be summarised as: degraded vegetation cover and loss of fodder species and their nutritional value, reduced carrying capacity of pastures, altered wildlife habitats and loss of flora diversity, amplified erosion, and increased desertification risk.

4.1.4 Government policy on drought

REACTIVE RESPONSE TYPE

During drought, the government provides drinking water tanks for communities, seed, fertiliser, agricultural equipment, and crop loss settlements. Little effort is made to create mitigating measures to counter the effects of cyclical drought episodes. No formal plan is in place, only ad hoc measures during emergencies.

Relief actions are sometimes implemented by civil society institutions, international humanitarian agencies, and the Iraq Red Crescent Society/International Committee of the Red Cross/ Red Crescent in responding to crises (Goodyear, 2009). Currently, at the provincial and regional levels, the governor addresses natural disasters by forming disaster response committees to define appropriate action to deliver humanitarian relief and support any reconstruction or rehabilitation initiatives. Currently, the Kurdistan Regional Government (KRG) has no plans for responding to disasters while some regions have established Emergency Response Cells. Twelve out of eighteen governorates have stated they have experienced drought in the past, and most of them do not have any action plan in place (UNESCO, 2014).

According to UNESCO (2014), when drought is declared higher committees are formed from representatives of various governmental agencies and bilateral committees.

In general, there is some coordination between the Ministry of Water Resources and the Ministry of Agriculture. Other ministries are usually brought in as they are needed to help facilitate a course of action. Such coordinated efforts include:

In a drought season, the Ministry of Water Resources and the Ministry of Agriculture immediately form a bilateral committee to decide upon the water shares allocated to the agricultural sector, the areas to be irrigated, the types of crops to be allowed (both winter and summer crops), as well as the compensation to be allocated for farmers in response to crop loss.

Committees are also formed between the Ministry of Water Resources and the Ministry of Municipalities and Public Works (and the Mayoralty of Baghdad) to allocate the various municipal water quantities for residential and industrial uses. This includes the quantities to be allocated and the specific river water elevations at particular water intakes.

Committees are formed between the Ministry of Water Resources and the Ministry of Electricity to also determine the minimum river water elevation needed to guarantee certain generation capacities at power generation plants.

Other types of larger committees and sub-committees are formed to implement a particular course of action. For example, the Ministry of Interior is included in such committees when the Ministry of Municipalities decides to deliver water tankers to certain communities in order to coordinate with the various municipalities and local governments. Other committees are established when a water shortage, disease or epidemic occurs; these committees include the Ministry of Health and the Ministry of Migration.

The formation of the Higher Committee for Drought is a promising first step towards improved coordination. During a workshop held in Amman from 2 to 5 March 2014, the awareness and desire was to evolve the current coordination mechanisms in drought risk management, and to develop an institutional framework for the implementation of tasks that involve all those concerned, rather than the formation of committees.

4.1.5 Drought risk management policies/plans

During recent droughts, the government and the High Level Committee for Disaster Risk Reduction (HLCDRR) have identified drought as one of the most serious disaster risks. Iraq has thus called on the United Nations to provide support in formulating a national framework for integrated Drought Risk Management (DRM).

Drought is a key issue in the United Nations Development Assistance Framework UNDAF 2011-2014 which states that the "Government of Iraq has institutionalised improved mechanisms to prevent, mitigate and respond to natural and manmade disasters." For this reason, the Priority Working Group on Environment has placed great emphasis on drought risk preparedness, mitigation, and management (UNDP-UNESCO, 2011).

EARLY WARNING SYSTEMS

There is no drought early warning available. Data on rainfall and climate are weak, and the primary approach to drought is a reactive crisis management approach rather than risk management approach. Both the Ministry of Water Resources and the Ministry of Agriculture have weather stations, however, neither entity uses collected data to forecast future occurrences and/or probabilities. In previous years, the Baghdad Directorate of Meteorology applied a methodology developed in the 1970s, which could provide probabilities for one year in the future. Recently, the directorate has begun eight pilots to use time series analysis to better project future probabilities to support a warning system. The results of this effort need to be further developed and validated. The Erbil Directorate of Meteorology does not yet have the capacity to conduct such analysis (UNESCO, 2013).

4.1.6 Institutions involved in drought management

Iraq's water administration is highly centralised where several ministries and government agencies are directly or indirectly involved in water shortage/drought management.

Some entities collect, monitor, and analyse weather and climate related data in an effort to forecast the possibility and the extent of a future drought.

Another group of government stakeholders are responsible for announcing a drought event and are primarily concerned with water as a resource and developing action plans on how to manage the resources in a drought event.

Other groups of stakeholders have action plans on how to deal with the impacts during a drought, usually socioeconomic impact including issues, such as unemployment and migration. Furthermore, the various stakeholders can be divided into agencies that operate at the national level and agencies that are primarily concerned with the Kurdish Regional Government. Although none of the government ministries have units that specifically address drought risk management, a few ministries have specific units or responsibilities related to drought. Aspects related to data collection and analysis, databank maintenance, development of drought mitigation and action plans, and plans related to combating desertification are all activities that such a unit would undertake. Those stakeholders and governmental agencies (various ministerial departments), related to drought monitoring and mitigation, are summarised as follows:

Ministry of Water Resources (MOWR) (State Bureau for Groundwater) – through its responsibilities for water resource management including the management of 9 large dams and 18 major barrages, for hydrologic analysis and related modeling, as well as central and field offices for management of water quantity and quality. Also plays a key role in rehabilitating marshlands and responding to hydrological disasters including drought and seasonal water scarcity. Formulates water management strategy to rehabilitate the areas affected by drought and to reduce the risk of future hydrological disasters (UNDP, 2013).

Ministry of Agriculture – through its efforts to combat desertification, conduct research, and provide extension services related to the water use and efficiency

Ministry of Science and Technology – through its research on dealing with water shortages and studies related to better use of water and protection of quality

Ministry of Transport - Directorates of Meteorology – through its prediction modeling activities in precipitation, temperature, moisture, wind, and related meteorological data

Ministry of Environment – through a number of programmes focused on desertification and climate change, as well as involvement in protection and monitoring of water quality

Ministry of Planning – through the Central Statistical Organisation and the senatorial offices, which issue periodically reports and statistical indicative data related to drought and agricultural production

The Ministry of Municipalities, which also has water interests, does not have a unit addressing drought and its management.

PREVIOUS AND ONGOING DROUGHT-RELATED PROJECTS AND DONOR/LENDER ACTIVITIES

Past and ongoing activities related to drought management of select projects include:

UN Projects: UNEP initiated the Desk Study to assess environmental vulnerabilities in Iraq; Improvement of Drainage Conditions in Major Agricultural Areas; Water Treatment (Iraq UNOPS); Drought Mapping Analysis (UNEP with JAU 2008-2009); Evaluation of Food and Crop Nutrition Situation in Iraq (FAO); Agricultural Baseline Data Collection (FAO); Rehabilitation of the Date Palm Sector in Iraq (UNIDO/FAO); Rehabilitating water networks in Iraq (UNOPS).

USAID Projects: Inma Agribusiness Programme, Iraq; UNEP-UNESCO Joint Project: "Natural and Cultural Management of the Iraqi Marshlands"; ACIAR/AusAID Iraq Project; Iraqi Marshlands project (2004-2009); Agriculture Reconstruction and Development Programme for Iraq (ARDI); Marshlands Restoration Project (IMRP); Audit Of USAID/Iraq's Agriculture Reconstruction And Development Programme; Water Systems Planning Model (WSPM) for the Strategy for Water and Land Resources in Iraq (SWL RI).

JICA Projects: Irrigation Sector Loan; Assist agriculture in Iraq by developing irrigation infrastructures; Basrah Water Supply Improvement Project; Improve water supply to access safe water; Action Plan on Leakage Reduction for Baghdad Water Supply System; Water Supply Operation and Maintenance; Provide training to help develop human resources in the water supply sector.

ICARDA Projects: Rain Water Harvesting and Supplemental Irrigation at Northern Sinjar Mountain, Iraq; Wheat Productivity Under Supplemental Irrigation in Northern Iraq; Salinity Management in Iraq; Combating Salinity in Iraq; Water and Livelihoods Initiative (WL I), Iraq (Abu Ghraib Benchmark); Development of conservation cropping systems in the drylands of northern Iraq.

Other projects: (SWL RI II) Strategy for Water and Land Resources of Iraq; Ministry of Agriculture Activities; IOM Activities on water sector.

4.1.7 Vulnerability to drought

In general, people living in rural areas whose income depends on agriculture production, livestock, forestry, and fishery are the most vulnerable to the effects of drought and the most exposed to the risk of poverty and food insecurity (UNESCO, 2014).

During the drought from 2007 to 2009, cropped areas throughout Iraq experienced were reduced and production and livestock were decimated. The situation in 2009 caused a significant number of rural inhabitants to move in search of more sustainable access to drinking water and livelihoods.

The impact of drought spreads well beyond agriculture. As greater demand for water increases with increasing population and development, periods of water shortages often result in serious impacts on sectors such as energy, health, and ecosystem services. One of the most significant effects of drought is the irreversible migration of the affected rural population, usually to urban areas.

The most vulnerable community groups (UNDP, 2013) to drought are inhabitants of the rural areas. Farmers and herders (Bedouins) using marginal lands are particularly vulnerable. Other groups vulnerable to drought are: internally displaced persons (IDPs); rural communities under poverty line; and women head of households.

The most vulnerable natural resource assets are rainfed agriculture, rangeland, and wetland ecosystems. The marshlands constitute a special ecosystem whose environmental significance surpasses Iraq and the region. Their water in-flow (quantity and quality) was modified by dams and waste-dumping and were partially drained in the 1990s (Garstecki & Amr, 2011).

4.1.8 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

The current political and security situation in Iraq remains unstable and has negative impacts on basic services. There are no government programmes specifically for drought relief. The main focus is on humanitarian support to communities, such as emergency shelter, water and hygiene kits, health, nutrition, and food.

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

Some indigenous practices that formerly existed:

Farmers practiced rotation cereal/fallow by leaving half the land as fallow, sowed barley instead of wheat, combined crops and livestock farming, and used crop residues as feed or sold it for grazing to herders.

In irrigated areas, farmers diversified cropping, chose crops that use less water, and reduced the area irrigated.

Herders moved with flocks to more humid areas and/or sold animals to buy feed.

4.1.9 Measures to build resilience to drought

See Appendix 8 for details.

4.1.10 References

See Annex.

4.2 SYRIA

4.2.1 Background

The Syria Arab Republic lies on the east coast of the Mediterranean Sea. It has mountains, fertile plains, arid areas, and deserts over an area of 185,180 km^2. The population is 22 million, 47 per cent of whom live in rural areas. The climate is hot and dry in the summer, and mild and rainy in the winter (mainly in the western region). Most of the country is semi-arid to arid, a factor which strongly affects renewable water resources in the country. The average annual rainfall is 256mm.

Syria has limited water resources with renewable freshwater resources per capita of 312 m^3/year (World Bank, 2014). There are two main sources: surface water both internal and rivers shared with other countries, and groundwater (Luomi, 2010). Syria is largely dependent on agriculture with a total cultivated area of about 4.9

million hectares. Livestock production accounts for between 35 and 40 percent of the country's total agricultural production, and occupies 20 percent of the labour force in rural areas. Agriculture contributes more than 26 per cent of GDP and employs 19 per cent of the total population.

4.2.2 Drought history

Droughts have occurred almost every second year over the past half century, and may become even more frequent in the future. The severe drought that began in 2006 was responsible for a large number of farmers abandoning their farms and migrating to the cities, and is considered by some as a factor in the civil war which has seen major loss of life.

Table 12 lists examples of past droughts taken from available historical records.

Touchan *et al*. (2005b) developed the first regional May-August rainfall reconstruction for Syria, Lebanon, Turkey, Cyprus, and Greece; and investigated the relationship with large-scale atmospheric circulation. This indicated that the countries were drier between the late 14th and early 15th century, in the early to mid-18th century and in the second half of the 19th century. A more recent trend towards drier conditions since the 1960s is also shown. This corresponds well with historical archives, which suggest that a number of significant climate events are associated with catastrophic historical and cultural changes. For instance, major drought and famine was reported in Syria in 1725-1726 (Pansac, 1985). Frequent droughts, causing yield reduction exceeding 20 percent of the normal, occurred in 1970-1973, 1977-1979, 1983-84, and 1989 in Syria (Dias, 2005). The recent most severe droughts affecting the majority of zones occurred

TABLE 12
Historical droughts in Syria

Year or period	Impacts
46	In Syria, there was a very great famine (Marusek, 2010).
333	There was a great famine that struck Syria along with a plague (Marusek, 2010; McCormick, 2012).
336	There was drought, famine and plague that depopulated Syria and Cilicia [Southeastern Anatolia] (Marusek, 2010; McCormick, 2012).
683	There was a famine in Syria and Libya (Marusek, 2010; McCormick, 2012).
689	A famine afflicted Syria and many moved out of it into Romania (McCormick, 2012).
525-26 and 568-69	home gardens involving animals; multipurpose woody hedgerows; apiculture with trees; aqua forestry; multipurpose woodlots.
600-01, 658, 676-78, 687, 693, 721, 742-744	In these dates drought struck Syria. Written sources reliably document fourteen drought and heat events in the eastern Roman Empire between 500 and 599 A.D. (Bookman Ken-Tor et al.).
1161	The contemporary written reports mention 8 or 9 droughts that strike Syria and Egypt (Ken-Tor et al., 2004; Migowski et al., 2004); 718 A.D. A famine struck Syria (Marusek, 2010).
3200 years ago (1180)	There was a great famine and earthquake in several places including Damascus (Syria), Antioch (Turkey), Tripoli (Libya), etc. wherein 20 000 men were killed (Marusek, 2010).
1725–1726	This study of data from coastal Syria showed that the onset of a ca. 300-year drought event 3200 years ago coincide with Late Bronse Age Crisis. This climate shift caused crop failures, dearth and famine, which precipitated or hastened socio-economic crises and forced regional human migrations at the end of the LBA in the Eastern Mediterranean, andunderlines the agro-productive sensitivity of ancient Mediterranean societies to climate (Kaniewski et al., 2013).

Source: Classifications of Traditional Agroforestry Practices in Turkey, Tolunay et al., 2010.

in 1999–2001. Since 2006, the country has endured four consecutive drought years. Poor and erratic rainfall since October 2007 caused the worst drought to strike Syria in four decades. Rainfall in eastern Syria fell to 30 percent of the annual average in 2008 – the worst drought in 40 years.

Skaf and Mathbout (2010) computed the annual Standardised Precipitation Index from rainfall time series data for the period 1958-59 to 2007-08 for 15 stations covering different climatic zones in Syria and found that the most extreme drought in terms of intensity, duration, and areal extent corresponds to 1972-73, 1999-00, 1998-99, and 2007-08. In the coastal region, extreme droughts were observed during 2000-01 in which the mean SPI value was less than -2.3. During 1961 to 2009, Breisinger *et al.*, (2011) showed that on average, drought evolved in Syria in time and in space from 1970 onward in 4 out of the 5 agricultural zones and lasted almost 10 consecutive years. Following these droughts, the intensity and frequency of the drought periods varied across Syria and its different agro-ecological zones.

Over the past half century, nearly 40 percent of the time drought occurred in zones 2, 3, and 4 (Table 13 and Figure 10). In zone 5, however, multiyear droughts are more frequent, which can be more harmful because water storage (in reservoirs, soil, and aquifers) and food storage may likely be depleted before drought ends. The frequency and length of droughts varies significantly by agro-ecological zone. Zones 1, 2, 3, and 4 have witnessed longer drought periods ranging from 4 to 9.5 years (Table 13). Zone 5, on the other hand, has witnessed the most frequent occurrences of drought during this 50-year period. And overall, except for zone 1 and to a lesser extent zone 5, droughts have become more frequent and have lasted longer in Syria (Al-Riffai *et al.*, 2012).

Zone 5 makes up the majority of Syria's surface area but has the lowest population density of all five agro-ecological zones (Figure 10). The north-east is expected to become a "hot spot" of vulnerability to climate change, which will have increasing effects on the region, such as a decrease in the discharge of the Euphrates and other rivers and declining mean annual rainfall (from a 5 to 10 per cent decrease in the north-east and a 10 to 25 per cent decrease in the Badia region). The effects of climate change in the country are already evident from the cycles of drought, which have shortened from a cycle of 55 years in the past to the current cycle of seven or eight years.

4.2.3 Drought impacts

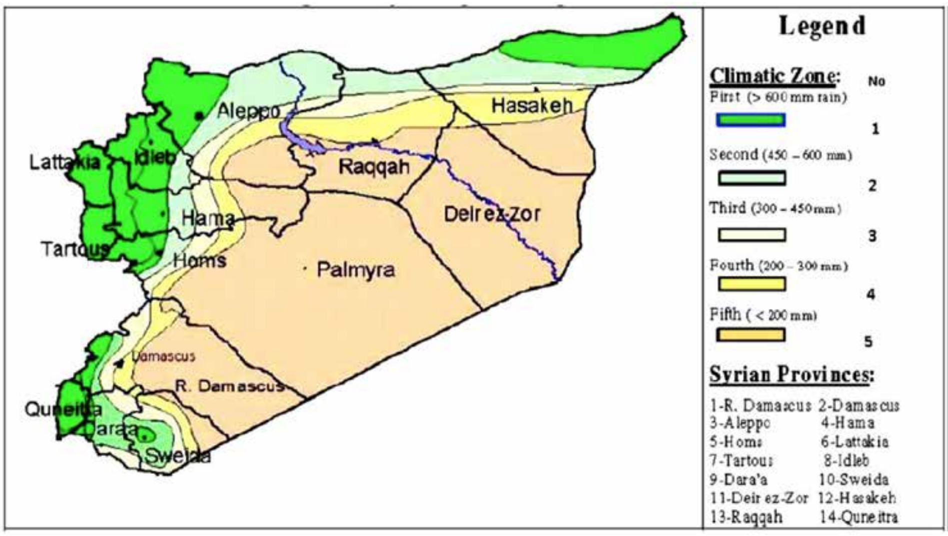
Most rivers crossing Syria flow from neighbouring countries and during drought conditions, they may affect agriculture and life stability depending on the relation with neighbouring countries. Water resources are highly vulnerable, especially with respect to competition for water supply among agriculture, power generation, urban areas, and environmental flows.

TABLE 13
Drought characteristics in the five zones of Syria from 1961-2009

Drought characteristics	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	National
Number of drought years	13.0	19.0	19.0	21.0	16.0	22.0
Number of droughts ≥ 2 years	2.0	3.0	2.0	2.0	5.0	5.0
Average length of drought period	6.0	5.3	4.0	9.5	2.6	4.4

Source: Al-Riffai et al. (2012)

FIGURE 10
Agro-ecological zones in Syria



Source: FAO. (Goodbodyet al., 2013)

During the 1983-84 drought, the national sheep flock declined by 25–30 percent (2.5 million head) due to starvation, crisis slaughter, and emergency export (World Bank, 1986). Meat prices collapsed and grain prices rose causing a serious crisis in the nascent private sector poultry industry, with numerous bankruptcies (USDA, 1985).

In 1999 to 2001, the worst drought in 40 years seriously affected crop and livestock production. Production of barley and wheat was 70 percent and 28 percent below average respectively (FAO/WFP, 1999). The country's agriculture sector, which until recently employed 40 percent of the country's workforce and accounted for 25 percent of GDP, was badly hit but farmers themselves were worst affected. Approximately 1 million farming families were severely affected, particularly in rainfed areas of the northeast. The vegetation in the Badia grazing lands was severely affected increasing the costs of fodder and forage, while depressing sheep values due to distress sales and affecting 47 000 nomadic families (329 000 persons) (De Pauw, 2005). In Dayr As Sawr governorate, more than half of all herders were forced to migrate, and those who remained relied on food assistance, as they lost 50 to 80 percent of their herds.

In 2007-2008, nearly 75 percent of 206 000 households suffered total crop failure affecting farming in the middle north, southwest and northeast of the country (UNOCHA, 2008). Wheat production in non-irrigated areas fell by 82 percent compared to previous years (Katana, 2011) reducing the ability of families to meet daily needs. The country's emergency wheat stocks were exhausted thus increasing national food insecurity and adding numbers to those already living in extreme poverty. This contributed to the increase in food prices. To bridge the gap, wheat was imported for the first time. Normally, Syria is self-sufficient in providing food for its 22 million citizens (UNOCHA, 2008).

In 2009, approximately 30 000 families migrated and in 2010, as many as 50 000 families, mostly small-scale farmers migrated. In some areas, up to 70 percent of the population, including whole families, has gone to the cities in search of alternative work after two years of drought and failed crops (ACSAD/UNDP, 2011).

Although rainfall in 2009 and 2010 was greater than in the three previous years, it was poorly distributed. This had a positive impact on pasture land but crops again failed in the rainfed areas, particularly in the north east. In 2010, a drought lasting one month at a critical time caused crop failure from severe yellow rust disease, which spread rapidly due to the severe climatic conditions that affected wheat in irrigated areas.

Health data indicated an increase in the prevalence of anaemia, malnutrition and diarrhoea (especially among children less than five years of age and pregnant women) by more than two-fold compared to the same period in 2007. A shortage of drinking water also resulted in the rural areas of the north-eastern region. The impact of successive droughts has been dramatic for both small-scale farmers and herders (United Nations, 2009).

4.2.4 Government policy on drought

REACTIVE RESPONSE TYPE

The traditional approach to drought management has been reactive, relying largely on crisis management. In response to the previous drought impacts, the government implemented emergency measures to assist drought-affected populations, including herders and farmers, by providing subsidised extra feed rations on a loan basis to be repaid next season. It also provided free food baskets and water for the most vulnerable drought-affected households, free veterinary medicines and vaccines, increased the purchase price of cereal crops to enable farmers to cope with drought, rescheduled repayment of farmers' loans, and authorised the importation of barley grain to cope with the feed shortage. The Government also initiated the rural women's development programme to provide vulnerable women with interest-free loans to start small projects and gain a new source of income (UNOCHA, 2008; FAO, 2008).

Ad hoc decisions were made to mitigate drought impacts but the degree of preparedness was poor even though a national drought strategy had been in preparation since 2000 and was officially approved in 2006. Implementation has not yet taken place beyond pilot projects and the establishment of an inter-ministerial national drought steering committee chaired by a representative of the Prime Minister. There is a lack of capacity and the scope of the challenge is high for the governmental services.

Therefore, like past droughts, response measures have been the rule to address recent droughts. In 2008, the government responded to the drought crisis by providing 5,600 Tons of food aid to 96,600 severely affected households; and in 2009-10, every two months they distributed 150kg of wheat flour, 25kg sugar, 25kg of bulgur, and 10kg of red split lentils, one litre oil, 2kg ghee, and 1kg tea to households in Hassakeh.

In 2008-2009, the government supplied farmers and herders with subsidised livestock feed covering 13 percent of farmers' annual needs; free medicines and vaccines for livestock; opened access to protected pastures; made market interventions to increase the purchase price of cereal crops, and rescheduled payment of farmers' loans. They also provided fuel support for irrigation and improved irrigation equipment, relaxed lending policies by public lending institutions, provided loans and cash grants, rescheduled payment of late loans, organised micro-loans for women entrepreneurs, and hired new teachers for the rural schools.

Similar programmes of support were provided in 2009 and 2010 (SPC, 2009; United Nations, 2009).

INSTITUTIONS INVOLVED IN DROUGHT MANAGEMENT

Ministry of Agriculture and Agrarian Reform

Ministry of Irrigation

Ministry of the Environment

Within these ministries, General Commissions on Agriculture, Scientific Research, and Hydrological design also work on water and drought issues

Ministry of Education (MOE)

Ministry of Health (MOH)

Inter-Ministerial Committee directly headed by the Ministry of Agriculture

Directorate for Drought Management to identify drought-prone areas, build a new early warning system and set up emergency plans

Local administrations (governorates)

Local representations of the ministries of agriculture and irrigation

Two centralised commissions the Badia Commission and the State Planning Commission (SPC), both directly linked to the Prime Minister's Office.

DROUGHT RISK MANAGEMENT POLICIES/PLANS

Between 2004 and 2006, FAO worked with the government to develop an effective early warning system for rangeland drought (FAO, 2007). The project aimed to strengthen institutional capacity with particular emphasis on pastoralists and agro-pastoralists. An early warning system office and a steering committee were organised and a set of drought indicators were identified. The collection, organisation, and processing of drought monitoring data (physical and social data) was established and monthly drought bulletins produced since 2005 in English and Arabic (Erian, 2010). However, there are gaps in the system (FAO, 2007). These include a need for an independent body or unit responsible for drought management; a standard management approach; regional sharing of drought information; better coordination among the various ministries and organisations; and drought mitigation plans which go beyond dealing with emergencies.

In 2009, the government adopted a National Drought Strategy with implementation guidelines and created an Inter-Ministerial Committee directly headed by the Ministry of Agriculture. A new Directorate for Drought Management is being established to identify drought-prone areas, build a new early warning system and set up emergency plans (WFP, 2009).

For the longer term, the government has undertaken studies on "non-agricultural" solutions, such as the development of tourism and agro-industries as well as transporting water from the Tigris River to the steppe to irrigate some 150 000 hectares of land in Al-Hasakeh. The objectives were to keep farmers on their land, provide employment opportunities, and offer new sources of income to farmers without land for most of the agriculture season, and ensure better livelihoods for the rural population.

For herders, the plan is to strengthen grazing management and land rehabilitation projects (such as grazing reserves) and invest in water harvesting methods to improve livelihoods. An expansion of grazing reserves, using a cheaper system of direct seeding of a larger mix of native species, could permit all-year grazing, thus reducing the need for transhumance. Moreover, the authorisation of cultivation in certain areas, such as land depressions, where tree cultivation may be envisaged based on appropriate soil topography, could also diversify herders' livelihoods while ensuring the sustainability of the Badia region.

For more efficient action, government institutions, including local administrations, local representations of the ministries of agriculture and irrigation, and the centralised commissions linked to the Prime Minister's Office, were decentralised to create a presence in the drought-affected areas. However, these institutions lack capacity and need training to address the various dimensions of drought. There is also a strong need to create more efficient inter-institutional coordination, participation and a more inclusive approach working with civil society and international partners (De Schutter, 2011).

4.2.5 Vulnerability to drought

Rural populations are most vulnerable to drought. Their resilience is poor and it takes time for emergency services to mobilise and reach them. They mostly rely on agriculture and livestock farming for their food security and livelihoods and this is threatened during severe drought. Migration is a key coping strategy but farmers are likely to return home when conditions improve. Coping with many thousands of displaced people can create major problems.

The impact of successive droughts has been dramatic for both small-scale farmers and herders. In the affected regions, the income of these groups dropped by as much as 90 per cent. Many families were forced to reduce food intake: 80 per cent of those affected were reported to live on bread and sugared tea. The effects of drought on livestock and rangelands are linked. With decreased range resources, livestock are more vulnerable to drought. The current livestock population can no longer be maintained on natural rangelands throughout the year. This results in a chronic inadequate feed supply for livestock, with dramatic consequences in dry years (United Nations, 2009).

4.2.6 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

The Government is fully aware of the gravity of the drought crisis and is taking tangible steps to mitigate this by adopting a National Drought Strategy with implementation guidelines and by creating an Inter-Ministerial Committee directly headed by the Ministry of Agriculture. Furthermore, a new Directorate for Drought Management is being established to identify drought-prone areas, build a new early warning system and set up emergency plans. Since 2008, the government has launched several relief interventions across all sectors, from food assistance to supporting farmers and herders to build resilience (WFP, 2009).

The UN Country Team (UNCT) has helped the government with a Syria Drought Appeal in 2008 and a UN Syria Drought Response Plan (SDRP) in 2009. WFP implemented an emergency operation (EMOP) targeting food assistance to 40 000 small-scale herders and their families living in the Syrian Steppe to mitigate the losses of livestock and to preserve their food security. WFP also implemented a school feeding project for 29 000 children living in the northeast, which reinforced the impact of the EMOP.

The government has developed a water resources management system, which includes 165 dams, which guarantees the functioning of the irrigation systems. As a longer-term solution, the government has pledged to increase investments in the northeast and to build a new dam in the area (Luomi, 2010).

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

To cope with drought, herders sell their animals, often at a much reduced price in order to maintain a portion of their flock. Herders have in the past moved their flock in line with seasonal availability of water and forage. But this coping mechanism is changing. Today, they use vehicles to transport water to the herds and move some animals to new pastures. Thus, early grazing and overgrazing are common.

Migration is also a last resort adaptive measure. When droughts last several years, people in Badia decrease their food intake, and if they lack the capacity to restore and sustain livelihoods, large numbers of children drop-out of schools and families start migrating towards urban centres to look for job and incomes.

4.2.7 Measures to build resilience to drought

See Appendix 9 for details.

4.2.8 References

See Annex.

5. Iran

5.1 BACKGROUND

The Islamic Republic of Iran lies in western Asia. It covers 1.5 million km^2, 85 percent of which is arid including huge desert areas in the central and southeast (Khorasanisadeh, 2011) with a population of 76 million (Statistical Centre of Iran, 2012). The long-term average annual rainfall is 224–275 mm (Amiri and Eslamian, 2010). Severe drought is recognised as a feature of Iran's climate. Several main rivers have their origin from the mountainous areas in the north and west. More than 50 percent of population lives in the west and north, where 70 percent of water resources are located (Motiee *et al*., 2001).

Lack of water is a major limitation for agricultural development. Per capita water usage in the urban areas is high. In Tehran, water use is 239 litres/capita/per day (in Western Europe the average is 150 litres). At the same time, more than 25 percent of the drinking water in cities is reported lost because of poor infrastructure (UN-Interagency, 2001). The pressure on water resources is increasing as demands for water expand. Increases in population, rising living standards, and the expansion of irrigated agriculture have drastically increased water use to the extent that the sustainability of Iran’s water resources is now under threat (Riahi, 2002).

Agriculture plays a key role in the national economy and consumes over 90 percent of the total national available water resource. Iran is a water scarce country and it has been confronted with drought disaster in many places in recent years (Hayati and Karami, 2005). Wheat and barley are the main crops cultivated. Wheat dominates accounting for 70 percent of cereal production. Irrigated wheat accounts for one third of the total wheat area, thus the bulk of the wheat crop depends on the performance of seasonal rainfall. Most of the rainfed wheat crop is concentrated in the north west. Small amounts of rice and maize are also grown (GIEWS, 2014).

Based on the research and assessment carried out during the Climate Change Enabling Activity Project under UNFCCC and using the scenarios proposed by IPCC, the average temperature in Iran will increase by 1.5-4.5 °C which will cause significant changes in water resources, energy demand, agricultural products and coastal zones (Amiri and Eslamian, 2010).

5.2 DROUGHT HISTORY

Citing the Iranian Students’ News Agency, Bizaer (2018), indicated that “drought [in Iran] has gripped most parts of the country for at least a decade now, and precipitation has decreased drastically to its lowest level on record in 50 years.”

Although Iran has a history of drought, over the last decade, Iran has experienced its most prolonged, extensive, and severe drought in over 30 years. The droughts of 1998–2001 and 2003–2011 affected many farm families and rural communities across most of central, eastern, and southern Iran. A review of long-term annual rainfall trends (over a 32-year period) indicated that in some parts of Iran drought has a return frequency of 5–7 years, while the national expectation was every 20–30 years (Eskandari, 2001).

Drought can therefore be regarded as a normal part of the environment.

Sanainejad *et al*. (2003) studied drought periods in northeast Iran (Mashhad) over a 32 year period (1968–1999) using the Standardised Precipitation Index (SPI). They showed that every 10 years, there is a severe and prolonged (more than a year) drought period. The duration and frequency of drought events are also increasing but their severity has decreased. The most severe one-year drought occurred in 1971. Ansari *et al*. (2010) used data from Khorasan (northeast of Iran) to show that between 1968-2000 drought occurrence was more frequent and also lasted longer than in previous years. The longest drought duration was 3 years from 1995–1998.

Drought during 1998-2001 affected 37 million people in 12 out of 30 provinces and caused severe water and food shortages (Shahid and Khairulmaini, 2009).

Safari *et al*., (2013) showed temporal and spatial variation of drought and that most of the regions had between 4 to 8 years of drought during 1983-2008 (i.e. dry years in Damane were 1983-85,1990-91,1996-97,1998-99, 999-00, 2000-01, and 2007-08; in Eskandari: 1980-81, 1984-85, 1990-91, 1996-97, 1999-00, and 2007-08). Localised droughts occurred in the eastern areas of the province, with 2007-2008 as the widespread driest year. Continually, within the years 1956, 1960, 1964, 1970, 1973, and 1982, and the years from 1988 to 2006, more than 60 percent of the whole country has experienced drought.

5.3 DROUGHT IMPACTS

A number of studies have characterised droughts in different parts of Iran using various methods including the northwest of Iran (Rasiei *et al*., 2009); temporal and spatial variability of drought in the west of Iran (Nikbakht *et al*., 2013); hydrological droughts in the northwest of Iran (Daneshvar *et al*., 2013); impacts of droughts on agricultural productions of Iran (Sayari *et al*., 2013); and meteorological drought in Iran (Asrari *et al*., 2012).

Although Iran has a history of drought, critical features of the drought 2003–2011 are not only its widespread nature and severity, but the fact that its impacts have been exacerbated by the proximity to the previous drought in 1998 to 2001. Farm families lacked the opportunity to recover and millions of people residing in the18 provinces were seriously affected (OCHA, 2000).

Many internationally-renowned wetlands and lakes have completely dried up, e.g. the Hamoun wetland in Sistan and Baluchestan Province, and Lakes Kaftar and Bakhtegan in Fars Province. In all other rivers, water levels have fallen to critical levels. Most of the traditional groundwater irrigation systems (qanats) have experienced reduced discharge or have completely dried up. The increasing number and severity of bushfires and sandstorms has negatively impacted wildlife and the livelihoods of local people. Many plant and animal species are severely affected and some face extinction (OCHA, 2000, 2001). Tehran Times (2014) reported that in 2013-14, Lake Orumieh, a UNESCO biosphere reserve that is home to about 200 bird species and 40 kinds of reptile, was almost completely drained. Some 20 years ago the lake measured 140km by 55km, but now only 5 percent of the water remains. Major rivers in the cities of Isfahan and Shiras, and on Iran’s border with Afghanistan, have dried up.

Water supplies have been affected in rural and urban areas impacting 90 percent of the population.

Water scarcity poses the greatest threat to security with declining water resources. Some 12 major cities, including Tehran and Shiras are now considering rationing. The Ministry of Energy has called on people in Tehran to reduce consumption by 20 to 30 percent. In 12 provinces, people are facing critical shortages of safe drinking water and have to rely on water tankers to deliver water (OCHA, 2001). In many villages, saltwater has percolated into wells making them unusable. In some cases, people have migrated to other villages or cities (OCHA, 2000). The Ministry of Jihade-Agriculture estimated that during the period 1999-2000, the unprecedented drought affected 18 of the Country's 28 provinces, and some 12 million people in both rural and urban areas have suffered shortages of drinking water (FAO-ALAWUC, 2004). The effects of drought produced complex impacts that span many sectors. The three-year drought from 1999 to 2001 severely affected 10 of the 28 provinces leaving an estimated 37 million (over half the country's population) vulnerable to food and water insecurity. Twenty provinces experienced rainfall shortfalls during winter and spring 2001. Water reserves were down by 45 percent in July 2001; 800 qanats (25 percent of 3170 qanats in Yasd) dried up (Khorasanisadeh, 2012).

Agriculture typically uses 93 percent of total water resources, half is from surface resources and half from groundwater (Ardakanian, 2005). Drought directly affects more than 2.6 million hectares of irrigated farms and 4 million hectares of rainfed agriculture (OCHA, 2001). Sarindasht County, one of the most productive agricultural regions of Fars Province, experienced severe drought conditions between 2003 and 2011, with a 3.4m drop in the groundwater water table, and a reduction in the wheat area of more than 50 percent. The Ministry of Jihade-Agriculture estimated a national water shortage of 1.2 billion m^3 for farming. Even the Northern provinces were affected, which are usually well-watered and used to produce much of the wheat, rice, and citrus fruits (FAO-ALAWUC, 2004).

Agricultural losses in irrigated areas were severe, an annual reduction of 2.8 million tons of wheat and 280 000 tons of barley, as well as the loss of the value of stubble as fodder. Production of alfalfa was down 38 percent (OCHA, 2000). Production of rainfed wheat and barley was also significantly reduced by 35–75 percent (OCHA, 2001). Many fruit trees (e.g. banana plantations in Sistan and Baluchestan Province) perished and 1.1 million hectares of orchards growing almonds, apricots, mangoes and other fruit were affected (IRI, 2001).

In 1999-2000, Iran imported nearly 7 million tons of wheat, making it one of the largest wheat importers in the world. The government recently approved an emergency aid package for US$183 million to assist drought-affected farmers (Khorasanisadeh, 2012). In 2014, cereal imports were forecasted at 12.6 million tons including 6 million tons of wheat, some 24 percent more than the previous year (GIEWS, 2014).

Drought severely affected the number and productivity of commonly-raised livestock because of its impact on rangelands and pastures (Salami *et al.*, 2009). In 1999, forage production was down by 10-70 percent, which eliminated about half the animals on the rangelands in Fars province (Nasemosadat, 2000). Some 800 000 small animals died due to malnutrition and disease (OCHA, 2000). Over 75 million head were affected and over 200 000 nomadic herders lost or continued to lose their only source of livelihood (OCHA, 2001). In 2000, farmers sold roughly 80 percent of their livestock. In 2001, 2.6 million hectares of irrigated lands and 4 million hectares of rainfed agriculture experienced drought impacts. UN estimated the damage to agriculture and livestock at US$2.5 billion in 2001, up from US$1.7 billion in 2000 (Khorasanisadeh, 2012)

An analysis of family responses to severe drought

Researchers analysed the social impacts of drought on two villages in Fars Province on different types of farm families, specifically the less vulnerable, the resource poor, and the very resource poor. All three groups experienced economic impacts of drought, but more importantly they all suffered major social impacts as well. The less-vulnerable families sought diversified sources of income in order to cope with drought. The vulnerable families (resource poor and very resource poor) were more affected by social and emotional impacts than less-vulnerable families. Many resource-poor families indicated a serious loss of income during drought, one third of the very resource-poor families had been without any crop income for 6 years. Limited access to irrigation water and an inability (lack of resources) to improve their access to water or their irrigation system led to the drought affecting them extremely hard; while most of the less vulnerable families could only cultivate about a third of their land. As a result, they were greatly affected by a loss of agricultural income. Although the vast majority of vulnerable families also reported a major loss of farm income, their conditions were completely different. Resource poor families believed that their production was down by about 60 percent. The prolonged drought had created significant hardship for them. The loss of income through reduced cultivation area, insufficient irrigation water, low water quality and failure of cotton crop (because of diseases and pests) meant that their farm income was seriously eroded. This was often coupled with increases in expenses such as the need to dig new wells, deepen shallow wells, or replace irrigation equipment.

Source: Keshavarsa et al. (2013)

During the 1998-2001 drought, thousands of villages were partially or completely evacuated and the nearby cities were crowded by the rural people. A UN Technical Mission to Iran reported that "over 60 percent of the rural population may be forced to migrate to cities" (UN Tech. Mission Report, 2000). Such immigrations create many social and cultural problems in the urban areas and for the emigrants (Siadat *et al*., 2001). The extreme drought conditions of the period 2003–2011 led to widespread migration, particularly from villages to the cities (Keshavarsa *et al*., 2013).

In 2001, the occurrence of many diseases were reported due to water and consuming water from water tankers. Drought not only reduces crop yields, but also affects employment conditions in rural areas. According to the recent United Nations Report, the costs of damage due to drought was US$120 million in 2000 and increased further in 2001 (Sabetraftar and Abbaspour, 2003).

5.4 GOVERNMENT POLICY ON DROUGHT

Iran has put in place many governmental agencies and institutions to help investigate, plan, and manage drought. Within the Ministry of Interior, the Country Drought Head Quarter (CDHQ) was established. Its purpose is to assess the impact of drought and develop and allocate financial aid and compensation to ease and reduce the consequences of drought among agricultural communities. The CDHQ may also involve the participation of other ministries such as the Ministry of Jihad-e-Agriculture.

REACTIVE RESPONSE TYPE

In large-scale natural catastrophes, the immediate relief aid is primarily the responsibility of the Ministry of Interior, and the Disaster Task Force (DTF). Generally, this task force deals with all forms of catastrophes, such as floods, earthquakes, landslides, and droughts. The most important role of the DTF is to coordinate and supervise the activities of different government organisations. In addition to the headquarters in Tehran, there are local DTF offices at provincial, town, and district levels, headed by the governor of the region. Members of these offices include heads of different local departments such as Jihad-e-Agriculture, Agricultural Bank, and Regional Water Authorities.

Relief operations are mostly decided after the disaster has occurred. For example, during the three years of drought in the 2000s, most of the planning and decisions on budg*et al*locations were made after drought onset. There is usually a few weeks to months between the decisions and the actions, particularly for the remote towns and villages.

Emergency assistance includes deployment of large numbers of water tankers, installation of stationary public water tanks, water pumps, pipes, human and animal medicines, supplies of emergency animal fodder, and many other interventions, such as a buy-back scheme for livestock from destitute herders, and further subsidised loans to help herders defer payment of interest and principal on outstanding credit.

In 2000, the government allocated US$138 million to mitigate the effect of drought. More than half of the budget (US$75 million) was used for projects: 168 urban, 1,252 rural and nomadi;, 362 irrigation water supply projects, 155 watershed management projects, and 859 projects for construction of small earth dams and maintenance of damage qanats; 1,421 mobile and 1,222 stationary water tankers. Some US$11.2 million was allocated to line ministries for providing medicine for livestock, seed for drought affected farmers, water to Abadan and Khorramshahr in Khousistan, Chabaharin Sistan and Baluchestan and Ghom, and feed and water for wildlife. A grant of US$37.5 million was distributed between 120 000 drought affected farmers and herders.

In June 2001, the Cabinet designated the next six months as the "Water Crisis Period" in the country to address this severe problem affecting the population (OCHA-IRN, 2001; Siadat and Shiati, 2001).

More recently the government allocated a further US$500 million for drought mitigation with half the sum allocated to the Agricultural Bank in order to provide loans to drought mitigation projects.

DROUGHT RISK MANAGEMENT POLICIES/PLANS

There is no drought risk management plan in Iran. Since the 3rd Development Plan (1999-2003), many institutions have entered the drought issue in their mandate but there is no specific department or division or programme related to drought management. The activities related to planning and mitigation are fragmented and overlapped among the stakeholders. However, at national level, the National Disaster Task Force, affiliated to Ministry of Interior, can be considered as responsible for coordinating various institutions through its national, provincial, and local task forces and working groups. But the Task Force is almost totally organised for crisis management and not risk management, although its mandate does refer to drought risk management (Mohsenin, 2005). The Natural Disaster Task Force was established in 1996 by Ministry of Interior and its range of assistance covered all types of disasters (Garshasbi, 2014).

In 2008 under the new National Disaster Management Law passed by the parliament, the National Disaster Management Organisation (NDMO) was formed to manage disasters, to disseminate information, supervise different phases of disaster management, and also recovery of disaster stricken areas (Bakhtiari, 2008).

DROUGHT MONITORING AND EARLY WARNING SYSTEMS

Iran Meteorological Organisation (IRIMO) is charged to establish the National Drought Warning and Monitoring Centre (NDWMC). In 2001, ministries established the National Committee of Agricultural Drought (NCAD). It includes the Ministry of Agricultural Jihad (MoJA) which is in charge of providing a data bank on field crops and livestock; the Iranian Space Agency (ISA), a subsidiary of Ministry of Communication and Information Technology (MOCIT) which is the authority in charge of remote sensing and communication networks; the Ministry of Energy (MOE) which collects information on hydrological indicators concerning river water level, stream acceleration, river discharge, water quality, snow masses and transferred sediment rate; and the Department of Environment (DOE) which is in charge of preserving the environment and effective use of natural resources to ensure sustainable development of the environment, prevent destruction and contamination of the environment, and preserve biodiversity all over the country Garshasbi, 2014).

IRIMO is affiliated to the Ministry of Roads and Transportation and monitors common drought indices, such as Standardised Precipitation Index (SPI), Percent of Normal (PN), Palmer Drought Index (PDSI, PHDI, CMI), Surface Water Supply Index (SWSI), and Vegetation indices (NDVI, VCI, SVI). But, Rasiei *et al.* (2010) reported that lack of reliable and updated precipitation datasets is the most important limitation that hinders establishing a drought monitoring and early warning system. To overcome this obstacle, they evaluated the applicability of GPCC and NCEP/NCAR precipitation datasets for drought analysis.

In 2013, IRIMO's National Committee of Global Framework of Climate Services (GFCS), established the National Centre for Climatology (Mashad Climate Centre) to predict seasonal precipitation and temperature and provide drought early warning (GFCS, 2013). The Drought Early Warning System (DESIR) aims to build capacity for improved national climate services, drought risk reduction in agriculture and water resources, and produce knowledge based information for policy-makers to develop adaptation and mitigation strategies. This is a pilot project of National GFCS Committee, which aims to provide at least three months advance warning. It is hosted by National Centre for Climatology (Climate Research Institute). By March 2015, the National Drought Early Warning Climate Outlook Forum (DECOF) will be established (GFCS, 2013).

5.5 INSTITUTIONS INVOLVED IN DROUGHT MANAGEMENT

The main ministries and organisations associated with drought and related to Disaster Task Force include (Mohsenin, 2005):

Ministry of Jihad Agriculture (Field Crops Deputy/National Committee of Agricultural Aridity and Drought; Horticulture Deputy; Water and Soil Deputy; Agricultural

Research and Education Organisation (AREO); Forests, Rangelands and Watershed Organisation (FRWO))

Ministry of Energy (Deputy for Water Affairs)

Department of Environment

Iran Meteorological Organisation (IRIMO)

Agricultural Bank

Insurance Fund of Agricultural Products

Management and Planning Organisation (Water and Agriculture Affairs Office)

Presidential Bureau (Crisis Task Force/under construction)

Universities (Sharif University/Research Bureau for Water and Environment; Tarbiat Modarres University (Water Engineering Research Centre)

Ministry of Interior (National Disaster Task Force; Provincial Governors; District Governors), and the National Disaster Management Organisation (NDMO).

THE MINISTRY OF JIHAD-E-AGRICULTURE

The Ministry of Jihad-e-Agriculture is the principal organiser of financial aid and compensation to livestock holders, nomads and agricultural sectors that suffered direct losses from drought. This ministry is also in charge of taking measures to limit the damage to the forests caused by wildfires as a result of drought. Part of the ministry duties include: preparation of comprehensive drought reports; promotion of national water saving measures; continuous support of drought awareness among the public; and providing training to key participating parties about efficient ways of using natural resources in drought crisis.

THE NATIONAL DROUGHT MANAGEMENT CENTRE (NDMC) AND PROVINCIAL DROUGHT MANAGEMENT COMMITTEES (PDMC)

The National Drought Management Centre (NDMC) is part of the early detection of risks and consequences of drought and drafts national plans of action and strategy.

The Provincial Drought Management Committees (PDMC) respond to drought emergencies when an alert status is assigned to a specific province. First, an official declaration of drought is made public by the General Governor. Then, the PDMC requests an assessment of the impact in the region in order to coordinate decisions and communications. Later, PDMC focuses on identifying the most impacted or critically affected regions. This information is communicated to NGOs and institutions that provide help.

THE NATIONAL AGRICULTURAL DROUGHT MITIGATION CENTRE (NADMC)

There are plans to create the National Agricultural Drought Mitigation Centre. Its mission is monitoring, evaluating drought damage, and planning critical measures that will minimise the overall impact of drought. Furthermore, NADMC will be a key coordinator among the various stakeholders as it will act as the main information provider.

5.6 VULNERABILITY TO DROUGHT

Rainfed crop production is highly vulnerable to drought conditions, and farmers in the northeast who depend on rainfed cereals production usually suffer most. Based on history, severe droughts forced the affected farmers to move to cities in search of alternative jobs (Bannayan, 2010). Most of the rainfed wheat crop is concentrated in the northwest (Asrari *et al*., 2012).

Irrigated agriculture is most affected after rainfed agriculture. The irrigation sector is usually the first water user to be restricted in case of drought.

Livestock are highly vulnerable as drought affects rangeland plant cover. Losses in agricultural and livestock production and the environmental damage have often been high, forcing people to migrate from their villages to other areas in search of water (Akbar, 2012).

Some 90 percent of the rural and nomadic followed by urban population are severely affected by water scarcity (OCHA, 2001). The loss of traditional authority, social cohesion, and collective practices, such as common property resource management, have aggravated the vulnerability of poor farmers and women to climatic variations.

Southeastern and central Iran are the most vulnerable regions where 18 of the country's 28 provinces are located.

Many internationally known wetlands and lakes, e.g. the Hamoun wetland in Sistan & Baluchestan province, Lake Kaftar, and Lake Bakhtegan in Fars province, Lake Orumieh in northwestern Iran are almost or completely dry are vulnerable to frequent and long-lasting drought years (UN-OCHA, 2001; Tehran-Times, 2014).

5.7 PRACTICES TO ALLEVIATE DROUGHT IMPACTS

MEASURES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

The government has declared June to December as the "Water Crisis Period" and has issued decrees to conserve water including drinking water rationing; reduction or elimination of cultivated areas of crops such as summer vegetables or rice in certain locations; providing special funds to support farmers who are willing to improve their irrigation systems; and investing in constructing water reservoirs and modern irrigation networks.

The government formed the National Drought Committees with members from all the ministries and organisations directly concerned with water-related issues such as crop insurance programmes; training and education; promoting awareness and facilitating the participation of local populations, particularly women and youth with the support of non-governmental organisations; environmental protection by enabling existing legislation, and enacting new laws and establishing long-term drought policies and programmes of action.

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

Farmer's adaptive strategies include a wide range of well-established agronomic practices and alternative income strategies. Iranian farmers take pride in being founders of the Qanat water systems, which can provide sustained flows throughout the dry seasons.

Traditional pastoral organisations also rely on collective systems to manage natural resources. They also have developed sophisticated mechanisms to predict drought and the basis on which they decide their migratory movements (Battista and Baas, 2004).

5.8 MEASURES TO BUILD RESILIENCE TO DROUGHT

The most important issue in drought risk management is the Agricultural Product Insurance Fund which started in 2005, insuring 90 types of agricultural and livestock products (Bakhtiari Ali, 2008). Rules and regulations were set by the Farmers Insurance Plan (affiliated with the Bank of Farming) for insuring drought-affected crops and livestock were appreciated as practical and lawful procedures to assist needy farmers. This is the first time that drought-affected farms have been officially insured by the Bank. Shiras University announced its willingness to assist with the plan (Nasemosadat *et al*., 2000).

President Hassan Rouhani has identified water as a national security issue, and planned "Transferring water from the Caspian Sea to refill Lake Orumieh" (Teheran Times, 2014). More measures are indicated in Appendix 10.

5.9 ISSUES

A special unit for drought management is needed to coordinate all activities related to drought in different ministries in order to provide effective drought early warning, assess drought conditions, develop mitigation actions and plans to reduce risk in advance of drought, and develop response options that minimise economic stress, environmental losses, and social hardships.

There should be a national drought management committee including all stakeholders empowered by updated legislation.

5.9.1 References

See Annex.

6. Lebanon, Jordan, and Palestine

6.1 LEBANON

6.1.1 Background

The Republic of Lebanon is at the eastern end of the Mediterranean Sea with a population of 4.4 million (UNDP, 2012) and an annual population growth declining from 4.84 percent in 2003 to 0.96 percent in 2012 (World Bank 2013). It is a small country 10,452 km^2 with a north-south coastline of 210km and an east-west inland penetration of 50km. Lebanon is classified as a highly urbanised country with more than 85 percent of its population living in towns and cities (UN, 2008a). The population in Lebanon is unevenly distributed among regions; one third resides in the Greater Beirut Area (GBA), and only 12.5 percent resides in the governorate of Bekaa, which is the largest administrative region by surface area (MoE, 2005).

Lebanon has a Mediterranean climate with rainfall between October and March. Annual average rainfall ranges from 1 000-1 400mm in the mountains, 600-800 mm on the coast, 600-1 000 mm in the south, and 200-600 mm in the Beqa'a region (MOE/ECODIT 2002; MoA, 2003).

Water availability in the dry season is limited due to the very low water storage capacity, the difficulty of capturing water close to the sea, and the shortcomings of the existing water delivery systems and networks. Most water is lost to the sea through 17 perennial and seasonal rivers. Almost all surface water resources are attributed to ground karstic aquifers (MED EUWI, 2009). There are few dams and lakes to store water during the drier months of the year.

Annual water demand is 1 500 million m^3 (WB, 2009 & MOEW, 2010); 61 percent goes to agriculture, 18 percent for domestic use, and 11 percent for industrial use (MoEW, 2010). The total annual renewable sources in Lebanon falls below the international benchmark for water scarcity (1000 m^3/capita) at 839 m^3/capita in 2015 (Gebran, 2010). Theoretically, this exceeds the needs of Lebanon till the year 2030, but water pollution and misuse of water in agriculture and other sectors such as industry has placed a great strain on available water resources (MoEW, 2010).

Lebanon is upstream on three transboundary rivers: the Hasbani flowing south to Israel, while the Al Khabir and Orontes flow north to Syria (Jägerskog, A., (2007). The water-sharing agreement between Lebanon and Syria is considered a good basis for cooperation between the two countries. However, implementation of the agreement seems to have been held up due to financial, administrative, and political problems (Stephan R. M., 2010).

The agricultural sector's share of GDP, between 1999 and 2007, averaged 5.8 percent. Employment in agriculture is steadily declining, from 3.9 percent in 1999 to 2.2 percent in 2005. Only1-3 percent of the annual public budget is allocated to agriculture services. Productive lands are decreasing because of poor inheritance laws which make agriculture unprofitable. The government supports wheat cultivation as a strategic crop for food security, and to maintain the value of rainfed arable land. Lebanon is a net importer of wheat. The country's "real" arable land resides in large areas, representing altogether around one-third of its total land mass (CDR, 2005). Agricultural production is concentrated in the Bekaa valley, which accounted for 42 percent of total cultivated land in 2005 (UNFCCCD, 2011)

6.1.2 Drought history

Drought episodes occurred on eight occasions from the 1930s until early 2000s when rainfall fell by an average of 40 percent of average precipitation.

Rainfall was low in 1932, when just 335 mm was recorded (Figure 11). Rainfall in 2013-2014 was one of the lowest since then compared to the average year. The Lebanese Agriculture Research Institute (LARI) reported a 57 percent decrease in rainfall in the Beqaa while nationally rainfall decreased between 40-50 percent. Many springs and wells ran dry, as did surface reservoirs. These conditions may worsen as climate change takes its toll on the environment, causing a decrease in rainfall and more frequent drought years (Bayan, 2014).

6.1.3 Government policy on drought

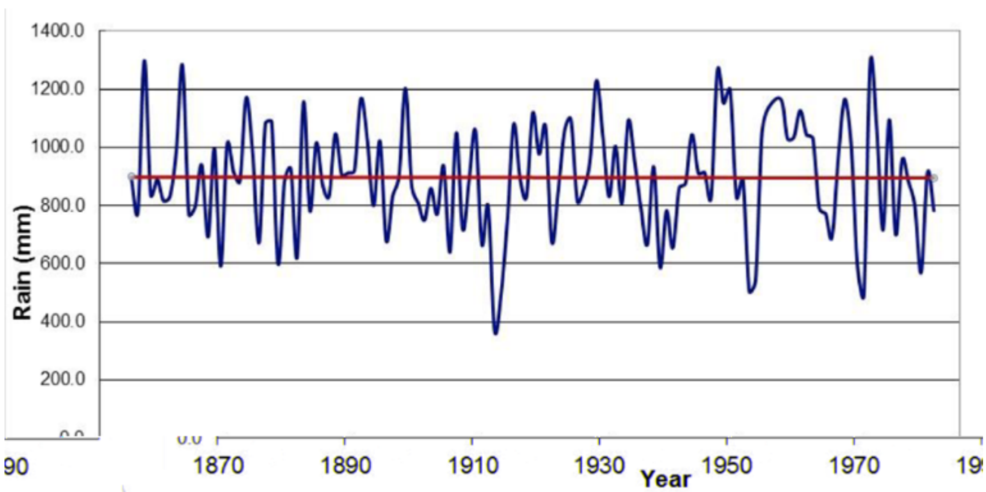
There is no specific plan or strategy for drought but all action and plans target water shortage as a result of drought impact.

Lebanese authorities have taken the following measures to tackle water challenges, according to the National Policy Dialogue on Integrated Water Resources Management Planning (IWRM) (EUWI, 2009):

In 2000, a water sector reform process started and institutional reforms were implemented, such as the restructuring of the ministry responsible for water resources and condensing the 21 regional water authorities into four regional authorities in 2002.

The Lebanese Ministry of Energy and Water prepared a national strategic water sector

FIGURE 11
Average Rainfall Variation in Lebanon for the period 1876-2005.



Source: AUB, 2014

plan with a horizon up to 2018, including elements of IWRM and calls for consideration of water resources within a complete policy and planning cycle.

A Water Code was established to help the Ministry of Energy and Water in its institutional support of a water governance framework and its technical approach for IWRM implementation.

The Ministry of Energy and Water strategies for satisfying the country's water needs, mainly consisted of increasing the water supply by building dams and lakes, extending drinking water projects, increasing the quantity of irrigation water, building wastewater treatment plants and cleaning river courses.

The government identified potential reforms for restructuring the water sector with IWRM in wider watershed management as (EUWI, 2009):

Updating the 10-year strategic water management plan, as well as preparing a national water master plan and approving the Water Code.

Strengthening the capacities of the Ministry of Energy and Water and preparing a short and medium-term investment plan for the water sector.

Ensuring that operation and maintenance of water supply and sanitation services are contracted out to private operators and that operation and maintenance of the small and medium-scale irrigation schemes are gradually transferred to Water Users' Associations.

The Ministry of Energy and Water has:

Developed a long-term surface water development plan (with 2030 as a horizon), that features the construction of 18 dams and 23 lakes, as well as two regulation weirs in the Beqaa (EUWI, 2009). A plan from 2000 to build 27 dams and artificial lakes has not been seriously implemented (ReliefWeb, 2014).

Established a groundwater department as a result of a 1962-69 United Nations Development Programme study. The government also passed laws to organise and monitor well drilling and operation. There has been recently some effort to access well-drilling data but very little has actually been done. No records of private wells drilled by landowners or developers are available, although they are required by law to obtain drilling permits and there are also rules governing extraction (Macksoud, 1998).

Started artificial recharge of some underground aquifers to fight saltwater intrusion, including in the aquifer East of Beirut Bay. (Jaber, 2001).

The government aims to adopt policies to eliminate the over-exploitation of water resources, improve water-use efficiency, and the use of treated wastewater in agriculture. Emphasis is to be placed on "water productivity as opposed to land or crop productivity" (Kirsti Krogerus, 2010). Since the early 1970s, the government has sought to restructure the water sector administration and institutions, introducing laws in 2000. The USAID, in coordination with the Ministry of Energy and Water, decided to support the Litani River Authority to operate as a real river basin agency. The development of a common database for water use, planning, and control, having institutional benefits while educating people about water shortages and pollution problems is an important ongoing effort (Kirsti Krogerus, 2010).

REACTIVE RESPONSE TYPE

In July 2014, in response to the water crisis, the Public Works Parliamentary Committee called for a state of emergency. A number of strategies were proposed to address water shortages. These include importing water, guidelines for reducing consumption, and a surge in dam building. Importing water with flexible barges from Turkey is not only costly, but removes incentives for a sustainable solution to the problem. Imposing general water use restrictions were also proposed, including reducing irrigation, taking public control of illegal wells, organising the distribution of water trucks, and fining those who are overusing water (such as car washing or cleaning sidewalks). By 2014 these initiatives had not been implemented, and were considered to be far too little too late, and did not address the real issue, that of severe mismanagement of what is meant to be an abundant resource. Riachi (2014) suggested that effective exploitation of groundwater offers the most cost-effective solution. Groundwater, however, is currently overexploited. This has resulted in a severe depletion of the water table, salt water intrusion in coastal areas, and higher concentrations of pollutants. According to official documents, there are now 50 000 private boreholes, averaging five wells per square kilometer (Riachi, 2014).

The government reaction to the 2014 drought was weak, in part due to the lack of legislation that would have enabled the government to declare a water emergency, but also due to the fact that there was no proper institutional framework to establish effective and integrated drought management plans and a drought emergency plan. As such, many people kept on using water as if there was no problem while many people had to pay exorbitant amounts of money to secure water for their household use. Moreover, some 50 percent of the household and tourism sectors relied on private water vendors to meet their water needs. It is expected that this would impact underground aquifers (Bayan, 2014).

Lebanon has now released the National Water Sector Strategy (NWSS); a plan for water and drought management. Although the NWSS does not tackle drought management immediately, it hints on proper water management that indirectly falls under securing water for national use. Some of the shortcomings in water management are due to political bickering; the focus should be on post-drought actions and the lack of awareness and coordination amongst ministries. More importantly, Lebanon does not have a drought management plan and so, the key recommendation would be to initiate one (Bayan, 2014).

6.1.4 Institutional framework for the water sector

Water sector management is disaggregated. The management of water falls under three ministries: the Ministry of Energy and Water (MoEW), the Ministry of Agriculture (MoA), and the Ministry of Environment (MoE).

The Ministry of Energy and Water is responsible for regulating and managing water resources, including the preparation of the water master plan, conservation of surface and groundwater resources and the design and implementation of large projects and dams. It is also sets specifications for water development and services, evaluates the quality of water services and approves water tariffs and pricing mechanisms.

The Ministry of Environment is the designated national focal point to the UNFCCC, and is the main stakeholder responsible for responding to climate change impacts.

The Ministry of Agriculture is responsible for irrigation and water conservation.

The Council for Development and Reconstruction (CDR) as a sort of planning ministry is responsible for the preparation of general plans, investment, and implementation of reconstruction and development, and mobilising external financing for priority projects within the investment plans (World Bank, 2010).

Several line ministries and governmental institutions are involved in climate change activities of which several are related to drought management and water scarcity. The most prominent are:

Ministry of Environment: The most active governmental institution on climate change issues and is the focal point for all official activities related to the Kyoto Protocol and Post-Kyoto negotiations. It is also the Designated National Authority (DNA) responsible for implementing and overseeing the market-based mechanisms (CDM and Carbon Trading) allowed under the Kyoto Protocol.

Ministry of Agriculture: Involved in implementing the National Action Plan within the UN Convention on Combating Desertification. It is also involved in reforestation, biodiversity management, and water conservation.

Ministry of Energy and Water: Involved in water resources management and more importantly in setting energy regulations and power generation alternatives.

Ministry of Interior and Municipalities: Responsible for many environmental regulations, oversight of municipalities for regulating power generation (community generators commonly used in Lebanon) and waste management at the municipal level.

Ministry of Public Works and Transportation: Active through transport and traffic management. It is also the line ministry responsible for Department of Meteorological Services which deploys and maintains the network of weather stations.

Council for Development and Reconstruction: Responsible for major development projects throughout the country and involved in solid waste landfill projects.

Ministry of Industry: Responsible for industrial permitting and oversight of adherence to industrial regulations and standards.

In 2014, among the major organisational changes, the inter-ministerial committee proposed by the Parliamentary Committee of Public Works, Energy and Water is made up of a mix of different ministerial water stakeholders and provides proposals directly to the Council of Ministers to address drought (Bayan, 2014). Another important committee is the Water Scarcity Task Team, chaired by the MoEW. Its main role is to address challenges of the water crisis. The board stressed the importance of having a national water board, and not only as a reactive step (Bayan, 2014).

DROUGHT RISK MANAGEMENT POLICIES AND PLANS

Lebanon's drought management still requires a proper institutional framework in order to establish effective and integrated drought management plans that incorporate monitoring, public participation, contingency planning, a drought management unit, a standard management approach, the monitoring of drought risks and early warning systems, and a database for drought data collection on national scale. Some regulations have been set on the quality of drinking water and wastewater discharge, but are not fully enforced. Standards for irrigation water or guidelines for water reuse do not exist (EMWater, 2004).

Lebanon is expected to face a water deficit in the near future. The Ministry of Water and Energy is in charge of developing and implementing water supply and sanitation, however, as of 2010, there was no specific document outlining the government's policy in the sector. As a proactive action, the government has made some important reforms to improve water sector governance, most notably by restructuring water-related agencies and revising its regulatory framework. Primarily the government condensed its water management agencies into four public establishments, at the same time revising the 2000-2009 Strategy Plan and updating it through 2018 (MoE, 2010).

6.1.5 Vulnerability to drought

Agriculture is one of the most vulnerable sectors to drought and climate variation as it is directly affected by changes in rainfall. Limited availability of water and land resources, together with increasing urbanisation, creates additional challenges for future development. In general, direct effects of climate on agriculture are mainly related to lower crop yields or failure owing to drought. The elevated upland basin of the Bekaa is the main agriculture region. Fruits, horticulture, and vegetables are the main cultivated crops (CDR, 2005). Around half of the 270 000 hectares cultivated in Lebanon are irrigated. Some 42 percent of cultivation is concentrated in the Bekaa (Ministry of Agriculture, 2013). Industrial crops account for 25 percent of the cropped area and two thirds of agriculture output value (FAO, 2014). Cereals and olives occupy over 50 percent of the cropped area. Wheat and cereals are moderately vulnerable to variations in climate-related factors.

Geographically, the most vulnerable area is in the Bekaa, where extreme conditions such as reduced precipitation and frost occur more frequently than in other regions.

Groundwater resources are at risk because of water quality in the coastal area which is currently deteriorating, especially with excessive pumping and reduction in natural recharge (Khawlie, 1999; El Moujabber *et al*., 2004).

Population growth is also a vulnerability issue and a determining factor in water availability. The country's water infrastructure needs upgrading and its coverage increased. It is estimated that almost half of the water distribution networks suffers from leakage (MoEW, 2010), leading to losses and contamination. With a constant flow of people escaping war in Syria, Lebanon's water crisis is expected to hit sooner than expected as the population swells well beyond the capacity of the country's limited natural resources (WFP, 2013).

6.1.6 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

Dams were one of the major mitigation measures used so far. Water stored in dams mostly originates from winter precipitation. Although some extensions, developments and rehabilitation works have been executed and others are still on-going and planned, only three dams (Shabrouh in Kesrwan- Mount Lebanon; Barissa in Donnieh- North

Lebanon; and Yammouneh spring in Baalbeck) have been built so far.

According to Lebanon's 2011 UNFCCC communication, its main adaptation measures are:

Protecting groundwater from salinisation in coastal areas

Implementing management strategies to reduce water demand in the domestic, industrial and agriculture sectors

Developing watershed management plans

Implementing pilot initiatives to test the feasibility of alternative water sources and develop standards and guidelines (UNFCCC, 2011).

However, the legal requirements for developing watershed management plans are poorly enforced, and standards have not been established regarding the reuse of wastewater, grey water and storm water or aquifer recharge (Lebanon UNFCCC, 2011).

6.1.7 Measures to build resilience to drought

See Appendix 11.

6.1.8 Issues

Several constraints relate to water rights in communal and private springs. The sector is deficient and/or lacks adequate legislation and enforcement of regulations related to forest management and planning, in addition to overlapping mandates and poor coordination among governmental bodies.

There is a major lack of enforcement in permitting and control of groundwater abstraction and the inadequate tariff system hinders water conservation. The legal requirement to develop watershed management plans are poorly enforced, while standards pertaining to the reuse of wastewater, grey water and storm water, as well as aquifer recharge are not available.

Another issue which is influencing the decrease in productive lands is the decrease in the average lot size due to inheritance laws, thus rendering agricultural exploitation unprofitable.

6.1.9 References

See Annex.

6.2 JORDAN

6.2.1 Background

Jordan's arable land is less than 5 per cent of its land area. It has a Mediterranean climate characterised by hot, dry summers and cool, wet winters. Generally, the dry season extends from May to September (Al Jaloudy, 2006).

Jordan is divided into three main agro-ecological zones. The rift valley that has a sub-tropical climate and an average annual rainfall of 350mm in the north to less than 50mm in the south towards the Red Sea. It is important for growing irrigated vegetables, citrus, and bananas. The northern and southern highlands experience annual rainfall between 350-500 mm and are suited to cultivating wheat, summer vegetables, olives, and fruit trees. The eastern and southern deserts include the Badia (semi-desert zone) which covers 90 percent of the country and experiences cool winters and hot summers with annual rainfall less than 100mm. This is primarily rangeland for grazing but some marginal areas are suited to rainfed barley.

6.2.2 Drought history

Studies of tree-rings dating back to 1777 show noticeable extreme dry individual years: 1800, 1827, 1895, and 1933. One-year droughts occur every 9.3 years and two-year droughts every 51.3 years (Seyad, 2009). Touchan *et al*. (1999) supported these figures and indicated severe two-year droughts in southern Jordan in 1783-1784, 1870-1871, and 1914-1915.

Drought analysis, using 1938-2005 rainfall also confirmed recurring one-year droughts on a 10-year cycle with 2 and 3-year droughts on a less frequent cycle, although they did occur during 1975-2000. In a 25-year period, a 1-year drought has a 90 percent chance of occurring whereas a 2-year or more drought has a 15 percent chance (Touchan *et al*., 1999). Generally, since 2000 more frequent 2 to 3-year droughts have occurred south of the Jordan River basin.

Rainfall data analysis using the Standardised Precipitation Index (SPI) indicates that successive droughts have occurred in 1947, 1960, and 1999 with severe droughts expected once every 20-25 years. The extreme droughts were rare events with return periods between 80 and 115 years (Shatanawi, 2013).

Semawi (2012) studied drought occurrence between 1923-2007 and suggested that over the 84 year period, 20 years were below average; 10 years experienced severe drought – 1932, 1933, 1947, 1958, 1960, 1962, 1981, 1989, 1995, and 1999; and 10 were mild drought years – 1925, 1952, 1955, 1970, 1976, 1978, 1998, 2004, 2006, and 2008.

These types of analyses demonstrate that drought is a recurrent feature of Jordan's climate (Table 14).

6.2.3 Impacts of drought

When severe drought occurs, it is the agricultural sector that is most affected through the reduction of agricultural production. The consecutive three years of drought from 1998 to 2000 had substantial negative effects on agricultural production, natural resources, and socio-economic development. The increase in frequency and intensity of drought during the last two decades has reduced cereal and animal production affecting the agriculture sector and the important role it plays in generating foreign exchange, employment, domestic food and feed.

During the 1997 drought, 30 percent of the sheep flock died or was slaughtered prematurely. In 1999, only 1percent of cereals and 40 percent of red meat and milk were harvested. As a result, the food security of 25 percent of the population (4.75 million people) was threatened and 180 000 farmers and herders were seriously affected

TABLE 14
Drought frequency and intensity using SPI of dry years in main regions of Jordan (1972-2004)

Regions		**Jordan valley region**					**Mountains region**						**North & East desert region**					
Synoptic Stations		**Baqura**	**Wadi El-Rayyan**	**Deir Alla**	**Ghor Safi**	**Aqaba**	**Irbed**	**RasMuneef**	**Amman**	**Er-Rabbah**	**Tafieeleh**	**Shoubak**	**Mafraq**	**Wadi Dhulail**	**Rawished**	**Ma'an**	**Al Jafer**	**Safawi**
No. of Dry Seasons		19	16	20	15	18	17	20	19	21	16	9	19	18	15	15	17	20
Drought intensity frequency	Mild	15	13	15	10	15	10	14	7	15	11	10	10	15	13	8	14	14
	Moderate	3	0	4	2	3	4	3	8	5	4	6	6	1	2	5	3	5
	Severe	1	3	1	2	0	2	3	2	1	1	3	2	2	0	2	0	1
	Extreme	0	0	0	1	0	1	0	2	0	0	0	1	0	0	0	0	0

Source: Mohammad Semawi (JMD) in Hattar (2007)

by the drought conditions; making the small farmers and herders the ones who were the most affected. Livestock losses were mostly among sheep and goats. Over the short period of 1996 to 1999, livestock numbers decreased from nearly 2.4 million sheep to 1.6 million, from 0.8 to 0.6 million goats and from 62 000 to 57 000 dairy cattle (Hattar, 2007).

Less than 10 percent of Jordan's total land area is cultivated, only 5 percent is used for agricultural production, and 1-2 percent is irrigated, mainly in the Jordan Valley and highlands (FAO, 2005). This leaves the country heavily dependent on rainfall, a factor that has hindered agricultural growth.

According to ESCWA (2005), limited rainfall during the agricultural season 1998-99 led to a sharp drop in dam water levels.

In the late 1990s, agricultural production fell and agricultural GDP in 2003 was only half the 1991 level. With a view to expanding the irrigated area, the country's economic development plans emphasised soil and water conservation. Agricultural production uses 70 percent of the country's available water resources but only adds 6 percent to the country's GDP (Wardam, 2004). But, overall, the upstream and downstream linkages like agribusiness services and agro-industry contribute 28 percent to GDP and as such, it is considered to one the most important economic pillars for integrated development (ESCWA, 2007).

In 1986, a drought year, Jordan produced 22 000 tons of wheat, compared to 130 000 tons in the 1987 wet season. Rainfed and irrigated fruit and vegetable production were severely reduced in 1999 (FAO/WFP, 1999).

Irrigated zones are more productive but they suffer from the low quality water and poor land and water management. Ecosystems are transformed due to drought and so too are human activities that depend on the rangeland. The natural rangeland provides 70 percent of feed for animal grazing but today this has declined to 20-30 percent (Roussan, 2002).

In 1958 to 1962, at least 70 percent of the camel herd died due to drought. In 1997, 30 percent of the sheep flock died or was slaughtered prematurely (Oram and de Haan, 1995). In 1999 rainfed and irrigated fruit and vegetable production was severely reduced. Crop yields fell from 200-400 kg/hectare in non-drought years to 0-50 kg/hectare in drought years.

In 1999, the Badia rangelands and most mountain pastures failed to produce edible biomass during the spring. Wheat and barley production fell by 88 per cent. On average, wheat and barley provide 10 per cent of domestic requirements but, in 1999, production met only 0.6 per cent of domestic demand (FAO/WFP, 1999).

Both surface and groundwater are highly dependent on rainfall and so any variation in rainfall or temperature reduces water availability (ESCWA, 1).

Following three of the driest winters on record, dam water levels reached an unprecedented low in 1999 and 2001, with storage falling as low as 3 per cent in 8 main reservoirs. Jordan is the only country in the region rationing water year-round owing to shortages. Households receive, on average, 80 liters/day, delivered only one day (12-24 hours) a week under a rationing system (UNHR, 2014) instituted 36 years ago. Although public piped water supplies reach 95 per cent of the population, the quality of water supply suffers from interruptions and cross contamination, which constitute a serious threat to public health.

6.2.4 Governments' policy on drought

DROUGHT REACTIVE RESPONSE TYPE

In 1999, the government's financial emergency assistance for the drought relief programme was US$58 million. A similar amount was allocated in 2000. In 2000, the estimated total production loss was US$160 million (DePauw, 2004). The national drought mitigation programme focused on providing:

Feed and water to small sheep herders, the water was free and the feed was in subsidized prices

Vaccines and drugs for animals

Flexibility in feed imports and the export of live animals

Delayed reimbursement and/or forgiveness of agricultural credits for the most-affected communities

Low interest rate loans for farmers to buy the needed materials

Collective spraying of free insecticides conducted by the Ministry of Agriculture

Water and food aid to the nomadic population living in the driest area of the country, the steppe of Al Baddia (Bedouins) and in similarly affected areas of other regions

Renting land from Jordan Valley farmers to keep it fallow and prevent rural-urban migration (World bank, 2005)

Restricting irrigation water to 30 per cent in the Jordan Valley (FAO/WFP, 1999), and

50 per cent to tree crops in the Highlands (World bank, 2005)

Continuing to purchase field crops from the farmers at a subsidized price.

DROUGHT RISK MANAGEMENT POLICIES/PLANS

Jordan has developed a water strategy that stresses the need for improved water resource management, efficiency in the conveyance, distribution, application and use of water resources, and that public agencies adopt a dual approach of demand management and supply management, using appropriate technology to enhance their resource-management capabilities.

So far, the following four policies have been enacted:

A groundwater management policy

An irrigation-water policy

A wastewater-management policy

A water-utility policy.

The irrigation water policy, formulated in 1998, addresses issues such as sustainable agriculture, resource management, technology transfer, water quality and efficiency. Among its most important elements are:

The promotion of the sustainable irrigated agriculture by protecting groundwater resources (among other methods)

The development of new sources of water, such as wastewater

The use of modern technology, such as genetically engineered plant varieties to enhance agricultural yield, and advanced irrigation technologies

The enhancement of water management at the farm level by promoting night irrigation, automation, scientific scheduling

The monitoring of irrigation water quality at the source and during conveyance

Improvement in management and administration

The introduction of better water pricing, covering at least operation and maintenance costs, and, where possible, capital costs

The introduction of regulation and controls to discourage crops with high water needs through economic and market forces

Index-based weather insurance that represents an emerging innovative market scheme for managing risks associated with drought

Pumping water from the Red Sea to the Dead Sea

Pumping water from the Disi aquifer in the country's Deep South up to the capital

Encouragement and strengthening of the joint dialogue between riparian countries on all levels, political and technical, to reduce the drought risk from transboundary water issues

Promoting soil and water conservation measures and improving agricultural production

Community participation and political commitment, networks, resource availability, and emphasizing self-reliance and drought resilience

Drought risk management/drought monitoring and early warning systems, plans, and policies

Vulnerability assessment, drought mitigation, response actions

Preparedness of plans to reduce drought impacts

Drought awareness, knowledge management, and education.

GOVERNMENTAL INSTITUTIONS AND PARTIES CONCERNED WITH DROUGHT

Currently, three ministries are involved in water supply, management, and use: the Ministry of Environment, Ministry of Agriculture, and Ministry of Water and Irrigation. The National Centre for Agricultural Research and Technology Transfer (NCARTT) is involved in drought monitoring, under which integrated water resource management, management information systems (MIS) for crop water requirements, Badia projects, and other related projects would be unified. In general, Jordan has adequate data-collecting institutions for drought monitoring, including strong GIS capacity. However, the current response to drought is not institutionalised and has been ad hoc and crisis-oriented without adequate information exchange and coordination. Drought vulnerability assessments are not conducted, nor are any early warning bulletins issued. (ESCWA 1, 2005).

Water demand management, as a component of a drought mitigation strategy, remains a challenge in Jordan. Although the Ministry of Water and Irrigation has undertaken several steps to improve water management and use, such as increased water conservation awareness, increased use of water saving technology, replacement of water conveyance pipes, increased use of treated wastewater in agriculture, and a ban on new well licensing, water demand management through water pricing has largely not been instituted, particularly in the agricultural sector. Water supply is considered a right and any manipulation of water demand through pricing is viewed as highly political. Farmers with well licences pump water at no cost, beyond sustainable and allowable levels, resulting in over-exploitation, falling water tables, and decreasing water quality from saline intrusion. Although recent attempts to regulate water use and pricing, particularly for private wells, have raised the price, integrated water resources management remains a challenge since significant changes in the institutional structures would be necessary to enable a more multidisciplinary and integrated approach to drought monitoring and early warning MoE (World Bank, 2005).

The main stakeholders involved in the last drought were (Semawi, 2014, MoE, 2008):

Ministry of Environment: Drought responsibility and is the official coordinator of the members concerned with drought and desertification.

Ministry of Agriculture: The main body for addressing drought actions through its large number of technicians and agricultural engineers that carry out field surveys and assessment to address the agricultural concerns of the crisis. The ministry is a member of the Ministerial Committee on Drought, and played an important role during the 1998-2000 drought.

Ministry of Water and Irrigation: through The Water Authority has major role in water sector.

Agricultural Council: Has an advisory role.

Ministry of Interior: A member of the emergency governmental committee. Its major role is to act as administrative ruler in the process of implementing the programmes launched by the government for drought mitigation.

The Jordan Valley authority: Carries out follow-up actions of irrigation projects in Jordan Valley and has responsibility for allocating water for agricultural use, industry, and domestic purposes and establishes priorities amongst these uses.

Civil society institutions and non-governmental organisations.

Research and academic institutions.

Private sector.

Several international agencies have helped in different ways to strengthen the country coping capacity. These include FAO; United Nations Development Program (UNDP); the Global Environment Facility (GEF); The World Food Programme (WFP); USAID; IFAD. Some have helped to establish the Network on Drought Management for the Near East, Mediterranean and Central Asia "NEMEDCA Drought Network".

DROUGHT EARLY WARNING AND MITIGATION

In 1999, the emergency measures did not fully mitigate the impact of the drought. Government response to drought has been reactionary as there is no drought monitoring and early warning system, no national drought preparedness, and mitigation plan, nor are drought standards yet established. But the Drought Strategy, Drought Action Plan, and Integrated Water Resources Management have been worked up and coordinated by the Ministry of Environment (ESCWA, 2013). The seriousness of the 1999-2001 drought emphasised the necessity for developing strategies to mitigate future droughts and their impacts.

The National Centre for Agricultural Research and Technology Transfer (NCARTT) has begun to develop a drought monitoring strategy, including a drought-monitoring unit reporting to the Prime Minister, relying on drought data from a network of 291 weather stations and complemented by GIS, and remote sensing information (Semawi, 2014). The Centre of Drought Monitoring and Prediction (CDMP) is under establishment at NCARTT with support from WFP/UN (MoE, 2007). Until a drought institution is in place and operating, the government continues to address drought and its impacts in an ad hoc and segmented manner.

The government recognises the urgent need to develop an appropriate strategy and action plan for drought preparedness and drought management policies. FAO assisted

Jordan in 2005 to formulate its "National Drought Mitigation Strategy" (TCP/JOR/3001(A), and organised a national workshop on "Policies and Programmes to improve Food Security in Drought affected areas". Preparatory work was initiated to establish a Drought Early Warning Unit in collaboration with the World Food Programme (WFP) (FAO Achievements in Jordan, 2011).

6.2.5 Vulnerability to drought

Jordan is one of the more vulnerable countries to drought. Some of the drought impacts include: water supply shortages in the summer; dried springs (decreased discharges in 850 springs); decrease of groundwater levels by 1m/year on average over the last 30 years; decrease in runoff; changes in agricultural patterns in the Jordan Valley and highlands; and increasing imported fruits and vegetables, from Syria, Lebanon, and Egypt (IFAD, 2010).

AGRICULTURAL VULNERABILITY

Agriculture is most vulnerable and can affect all the regions of Jordan. Those most vulnerable are people who require emergency food assistance including (Bogan, 2014): small-holders engaged in subsistence cultivation and who have lost not only their crops but also their inputs; small-scale herders with less than 30 breeding sheep and goats; and landless rural households having, as their principal source of income, work in the agricultural lands of others, in particular during harvest time. Large numbers of landless rural households have lost this source of livelihood in drought years.

WATER RESOURCE VULNERABILITY

Water scarcity, population pressures and inadequate water resource management amplifies Jordan's water resource vulnerability to drought. In 2013, annual freshwater per capita was only 106 m^3, which is well below the critical water scarcity level of 500 m^3/capita/year. Jordan's high population growth (2.2 percent in 2013) has placed increasing pressure on scarce water resources (WB, 2015). Unlike the GCC member States, Jordan does not possess the financial resources for desalination plants. Drought exacerbates Jordan's water resource vulnerability by diminishing water replenishment rates and thereby reducing the annual renewable water resources available.

In 2000, rainfall was only 56 percent of the annual average, and Jordan's six dams were only 33 per cent full (ESCWA1, 2005). This exacerbates the fact that many aquifers go out of production every year because of over-pumping (Fariz and Hatough-Bouran, 1998). Irrigation and domestic water conveyance losses are also significant, more than 50 percent (UNHR, 2014).

Surface waters are also vulnerable to conflict in the region. The Yarmouk and Jordan Rivers originate outside Jordan's political boundaries and Jordan is a downstream riparian country. Jordan's groundwater aquifer recharge is largely internally generated and is vulnerable to drought in-country, and any reduced groundwater discharges increase the pressure on surface water resources.

Guidelines for the implementation of groundwater protection areas for all public water supplies are being prepared. Implementation of these guidelines requires not only legal, but also technical, and institutional support. Technical support includes carrying out relevant hydro-geological studies, and inventorying possible sources of contamination for the groundwater.

ENVIRONMENTAL VULNERABILITY

Drought deepens the effect and extends the area prone to desertification. The Azraq Oasis, although a national reserve, remains threatened by drought and water scarcity. Azraq's aquifers supply Amman with 25 per cent of its water (Fariz and Hatough-Bouran, 1998). Unsustainable use of this water, particularly in drought years, threatens not only to lower water tables, but also to diminish water quality through infiltration of brackish water because of over pumping. This greatly increases the vulnerability of the oasis and its wildlife.

Overgrazing in the Badia has also exacerbated environmental vulnerability to drought, causing the destabilisation of soil structures and the loss of many soil-fixing organic materials. This damage makes these lands more vulnerable to other forces of erosion, such as run-off, wind, and drought (Fariz and Hatough-Bouran, 1998).

SOCIO-ECONOMIC VULNERABILITY

Jordan, with its limited natural resource base, has been largely dependent on external trade, foreign income, and remittances from expatriates for economic development. The country remains highly vulnerable to external shocks, including neighbouring wars and drought. The high population growth rate has placed increasingly high pressure on Jordan's scarce natural resources, particularly water and arable land, which is already low at 0.08hectares/capita. This has in turn, greatly decreased the country's food security, as the food import bill increases with population growth.

Although agriculture only contributes 2 percent to GDP, it is still a fundamental sector of the national economy. Agriculture is the main income source for about 15 to 20 per cent of the population - it employs about 6 per cent of the workforce (FAO, 2001), and is a generator of activities in the other economic sub-sectors. Droughts affect all crops and farming systems. While irrigation provides a buffer against more significant losses, access to surface irrigation water is cut in dry years.

Drought virtually wipes out rangeland vegetation, leaving many livestock herders facing bankruptcy and many small farmers without income and with increasing debt. Although the subsidies for cereal feed were helpful, farmers who could not purchase feed had weak livestock with high levels of disease. Most coped by selling slaughter stock at lower weights and prices (FAO/WFP, 1999). Smaller herders faced bankruptcy and left the Badia to seek employment in urban areas.

Small landholders sold assets to pay debts and landless labourers found themselves jobless with no alternative job opportunities. Small landholders who had lost their harvests and inputs, small-scale herders, and landless rural households were most vulnerable and hardest hit. In 1999, FAO instituted an emergency food assistance programme to serve 180 000 of those hardest hit. Although this did mitigate the impacts of the drought, the response was more ad hoc and reactive than preventative.

6.2.6 Practices to alleviate drought impacts

MEASURES AND PRACTICES ADOPTED BY THE GOVERNMENT

The government has implemented a range of policies to reduce water consumption in irrigated agriculture. The following are the major policies (El-Habbab, 2006):

Enforced limits on planting crops with high water requirements

Prevention of planting summer crops in the Jordan Valley, due to the high water requirements

Discourage planting fruit trees and limit planting of banana trees

Encourage advanced methods as drip irrigation, spray irrigation and micro-sprinkler irrigation

Install pressure pipe network for irrigation water conveyance and distribution

Penalty is introduced to face those who are violating the regulation of water exploitation

The government hired a number of agricultural farm units in the Jordan Valley and put it out of the irrigation system temporarily to save water consumption

The government encouraged the farmers to construct desalination plants

The government reduced the amount of water supplied to the farmers in the Jordan Valley to 60 percent compared with the normal practice

No more agricultural credits for irrigated agriculture (olives) in the highlands area or to cultivate banana in the Jordan Valley

Water rationing for irrigation depending on water pressure prevailing in the respective area, size of the farm unit and the crops planted; and rationing plan for cities generally remains unchanged because drinking water supply to municipalities has priority (El-Habbab, 2006; WORLD; UNHR, 2014)

The identification of suitable business insurance policies for risk-prone farmers and herders

The government of the Hashemite Kingdom of Jordan calls upon the international community, governments and institutions, for the necessary aid and assistance to the Jordanian people to face the emergency (i.e. lack of Rainfall).

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

Farmers and herders are adopting measures to cope with drought. They may search for other ways to supplement their incomes by migration, take part-time job in towns, adopt seasonal migration to towns, undertake livelihood diversity that allows the spreading of risks, use water-harvesting techniques, and improve soil moisture conservation measures. Coping strategies for nomads include feed stocking and shifting grazing and selling part of the livestock flock.

6.2.7 Measures to build resilience to drought

Jordan has developed a water strategy that stresses the need for improved water resource management, efficiency in the conveyance, distribution, application and use of water resources, and that public agencies adopt a dual approach of demand management and supply management, using appropriate technology.

So far, four policies have been enacted including: a groundwater management policy; an irrigation water policy; a wastewater management policy; and water utility policies. The most important elements of these are listed in the Appendix 12.

6.2.8 Issues

Attempts to collectively use small holdings through cooperatives and overcome land fragmentation by amending the land laws have failed due to social and religious reasons.

A system for feed allocation based on expectations of drought severity and targeting areas most severely affected should be developed to overcome the problems of costly untargeted feed subsidies that mainly benefit larger farmers, without helping small livestock producers.

Alternatives are needed to avoid environmentally damaging barley-barley system of feed production, currently preferred by farmers in the low rainfall areas.

The uncertainties over property rights in low rainfall areas are a major constraint, both to environmentally sound land management and investment in technology and land improvement, especially with respect to rangelands, where animals are owned privately but the resource may be common.

Some technological options could help to improve sheep nutrition in rangeland, including the use of feed blocks and straw treatment and various animal health measures.

6.2.9 References

See Annex.

6.3 PALESTINE

6.3.1 BACKGROUND

Palestine comprises Gaza and the West Bank, which are geographically non-contiguous. Of the 4.42 million Palestinians, growing at a rate of 4.0 percent and living under Israeli occupation, 2.72 million live in the West Bank, including East Jerusalem, and 1.7 million in the Gaza Strip (WB, 2008). Palestine lies close to Jordan and is a semi-arid area with extremely limited water resources.

The West Bank is situated in the central highlands of Palestine. The area is bordered by the Jordan River and the Dead Sea in the east and the 1948 cease-fire line in the north, west and south and covers a total area of 5,800 km^2. The main water resource is groundwater. The per capita water availability, equal to the water use for all purposes, is only 50 m^3/cap/year which makes the West Bank an extremely water scarce area. Although the Palestinians can hardly meet their needs now, the situation will be even worse because of the expected increase in the population and developments in the social, commercial, industrial and environmental sectors (UNOCHA, 2014).

The West Bank has a Mediterranean climate. Rainfall shows considerable spatial and temporal variation, with long-term annual average rainfall of 450mm/year in the West Bank and 327 mm/year in the Gaza Strip. The annual average rainfall varies between

700-850 mm on the western slopes, 500 and 800 mm in the hilly areas and 100 to 150 mm in the Jordan Valley. Evaporation is particularly high in the summer due to a rise in temperature, intensive sunshine and low humidity (PWA, 2012).

6.3.2 Drought history

Droughts were recorded in Palestine during the 5th and 6th centuries with notable severe droughts from 523 to 538. During the 520s records indicate a decline in rainfall. Written sources reliably document 14 droughts in the eastern Roman Empire between 500 and 599 AD. They destroyed valuable vineyards in the Negev. A 15-year drought from 523 to 538 dried up the Siloah spring. Records link the 536 drought with the migration of Arab pastoralists into the Roman Empire.

In more recent times, De Pauw and Wu (2010) calculated the annual Standardised Precipitation Index (SPI) based on historical rainfall records from 1901 to 2007. They show widespread droughts in 1915, 1925, 1932, 1933, 1946, 1947, 1952, 1958, 1960, 1962, 1978, 1981, 1993, 1995, 1998, 1999. 1915 and 1999 were the most extreme. Many of these years align with the analysis of drought years in Jordan which is close by. Although the picture is not as clear as in the surrounding countries, there is still a visible trend towards more dry years and fewer wet years in the second half of the 20th century. Table 15 shows the number of drought years in each decade from 1901 to 2014.

The two worst drought seasons with below average rainfall were 2007-2008, when the rainfall was 55 percent of the historic mean in the West Bank, and in 2010-2011 when rainfall was only 66 percent of the mean in Gaza Strip.

Below average rainfall rapidly affects groundwater recharge and severe drought lasting a few years can have serious consequences on groundwater levels. Analysis of recent droughts has shown that groundwater recharge has fallen by 5-7 percent through this period (Froukh, 2010).

It should be noted that there is no metrological information about Gaza because of the damages caused by the Israeli occupation in 2007 to the metrological stations (ARIJ, 2011).

6.3.3 Drought impact

WATER SECTOR

Groundwater is the only source of water supply in the West Bank, and rainfall is the only source for recharging the groundwater aquifers. Palestinians have no access to the

TABLE 15
Drought years and number of dry years per decade in Palestine (1901-2014)

Decade	1	2	3	4	5	6	7	8	9	10	11
Dry years	1915	1925	1932, 1933	1946, 1947	1952, 1958	1960, 1962	1978	1981, 1985, 1986	1990, 1993, 1995, 1998, 1999	2000, 2001, 2004, 2005, 2008	2011, 2014
No. of dry years	1	1	2	2	2	2	1	3	5	5	2

Jordan River or any other surface water source, due to the diversion of the water from Jordan River tributary upstream to the Israel National Carrier. The West Bank suffered in the last decade from severe droughts resulting in a significant drop in the water table. Within the political boundaries of the West Bank there are three groundwater basins which extend beyond the political boundaries of the West Bank, along which Israel has drilled hundreds of wells, although they have prevented the Palestinians from drilling wells upstream or inside West Bank (Froukh, 2010). The groundwater basins are almost over-exploited and recent droughts (2000 to 2009) have contributed to a significant drop in the water table. The latest recharge studies have indicated that the average recharge is around 20 percent of rainfall (Favara *et al*., 2003). As a result of the drop in recharge and increase of pumping from wells, the water table in many wells of the West Bank, especially in southern Hebron area, have dropped significantly (the recorded drop in Bani Naim wells in Hebron area ranges from 30-60m) impacting spring discharges and well yields (Al-Rimmawi, 2010).

MUNICIPAL SECTOR

Due to the chronic water shortages, the average per capita water consumption in the West Bank is 66 litres/day; two-thirds of the minimal amount needed according to the World Health Organisation (WHO). This includes water for livestock, meaning that the water consumed for personal use is even less; and water demand is expected to increase substantially in the future. This is due to improved standards of living and increases in population. To meet the demand for water, additional supply will be needed. Palestinians are being forced into the black market to purchase water, consuming up to 20 percent of their income. They are paying US$4/$m^3$ (including delivery costs) for water costing Israelis US$0.50-$1.00/m^3 (Froukh, 2010).

AGRICULTURAL SECTOR

The agricultural sector is still considered a cornerstone in poverty alleviation and food security provision in Palestine. This was severely hit by the droughts; indeed, rainfed farming in the West Bank has totally collapsed. Irrigated agriculture has also been affected since spring flows were reduced by the lack of recharge form rainfall. An estimated US$200 million loss resulted from the 2011 drought year (Froukh, 2010).

In 2007-2008, total rainfall was only 67 percent of the annual average in West Bank. The losses from rainfed horticultural production were estimated to be US$113.5 million and more than 200 000 small ruminants were affected (MoA 2008). In addition to agriculture, the water sector, food security, health, and shelter are affected by drought with the need for humanitarian support (Froukh, 2010).

ECONOMIC SECTOR

Restricted access to water resources due to Israeli occupation has resulted in foregone agricultural production and additional health costs in the order of US$1.9 billion (23.4 percent of GDP). The water situation in Gaza is particularly alarming and will have large economic impacts (Drakenberg and Wolf, 2013).

IMPACTS ON PUBLIC HEALTH (AND EDUCATION)

In Gaza Strip, 90-95 per cent of water distributed is unfit for human consumption due to levels exceeding recommended values for one or more contaminants as estimated by WHO. Some 26 per cent of all diseases observed in the area are water-related among which acute bloody diarrhea, viral hepatitis, liver and kidney diseases are the most common. The contaminants were multiplied by about 400 per cent over the period 1990-1998 (Drakenberg and Wolf, 2013).

6.3.4 Government policy on drought

The Palestinian Water Authority (PWA) and various organisations have implemented several measures or actions to minimise the impact of drought including:

Controlling groundwater abstraction from upper and lower aquifers to be within the sustainable yield limits

Investigating the possibility of improving groundwater recharge through utilisation of generated runoff

Purchasing extra amounts of water from the Israeli water company to provide villages with water supply

Encouraging farmers to use treated wastewater in agriculture, which will reduce the pressure on groundwater

Enforcing new legislation in new buildings to construct storm water harvesting storage tanks

Conducting public awareness to control water demand

Studying other potential sources such as desalination of sea water

Continuing to address international organisations to push for a water agreement that gives Palestinian their water rights to access surface water in the Jordan valley (Froukh, 2010).

In water sector reform, the PWA has long been concerned about the water sector in Gaza, particularly in relation to water supply. The action plan "Multi-Year Action Plan for Reform" in 2009 was developed to contribute to the overall objectives of the Water Sector Reform initiative. Some elements of the reform are to establish sustainable institutions within a legal framework; to improve water supply and sanitation strategies; to accelerate equitable access to a quality service, while providing efficiency and cost-recovery; to build the institutional knowledge, policies, and monitoring; and to improve water demand management awareness in line with water conservation policies (PWA, 2013).

REACTIVE RESPONSE TYPE

The Ministry of Agriculture (MoA) and many international organisation such as ACF, CISP, CARE, ACTED and Oxfam, and local and foreign associations, in emergency response, support most drought-affected food insecure farmers, herders and fisher folk in the West Bank and Gaza Strip. They cover different geographic areas and distributed water, seeds, and fodder, according to agreed criteria, such as distributing 25/litres/person/day, 9/litres/animal/day and 1 kg of fodder/animal/day for a minimum of 60 days.

According to UNOCHA, the funds needed to mitigate the 2007-2008 drought was estimated to be US$44 million. The amount actually spent was US$3.6 million (UNOCHA, 2008).

In 2009, a new body was formed – Water Scarcity Task Force (WSTF) to improve coordination among governmental institutes, local and foreign NGOs, and United Nation Organisations. After the drought in 2010-2011, the WSTF actively supervised many water scarcity assessments and coordinated and monitored the distribution of many humanitarian and emergency interventions in Palestine (WSTF, 2011).

The European Commission also launched emergency food assistance to victims of the drought, channelled via the Humanitarian Aid department through non-governmental and international organisations including United Nations agencies. The targeted populations were rural dwellers, in particular, the Bedouin communities and livestock herders in isolated areas of the West Bank. The funds were deployed for: emergency water, food, and seed distribution to people with insufficient quantities to cover their domestic and livelihood needs; emergency water and fodder for animals; improvements to water storage and harvesting installations; and provision of water trucks (EU Commission, 2009). Froukh (2010) reported also that humanitarian support included fodder, shelter for lambs, veterinary kits, tankered water and new filling points, and food aid.

MAIN INSTITUTIONS INVOLVED IN WATER RESOURCE MANAGEMENT

Palestine follows a modern approach to water resources management and applies many principles of IWRM, which is also the guiding principle of the EU Water Framework Directive. The legislation is quite recent, with a by-law establishing the PWA in 1996 and a water law defined in 2002 and currently under revision. The PWA is in charge of water resources management together with Ministry of Agriculture (MoA) for the resources related to irrigation, and with the Environment Quality Authority (EQA) for water resources protection and the conservation of ecosystems. PWA is also responsible for sanitation services in cooperation with EQA, the Ministry of Health (MoH) and the Ministry of Local Governorate (MoLG). Drinking water is supplied by the West Bank Water Department (WBWD), municipalities, and existing utilities. In the future, water and wastewater services will be provided by a National Water Utility together with four regional utilities (three in the West Bank and one in Gaza).

The WBWD is currently responsible for providing all water that comes from Mekerot (Israeli water company) to all Palestinian communities. In addition, municipalities and village councils are responsible for managing their water. Inter-ministerial coordination is undertaken by the Ministry of Planning (Attili, 2012).

DROUGHT RISK MANAGEMENT POLICIES

The Israeli policy of closing and confiscation has decreased Palestinian's access to natural resources and limited building of infrastructure needed to establish an early drought warning system required for monitoring and predicting the occurrence of drought. The current situation is characterised by: limited number of meteorological stations; inefficient distribution of low technology stations and rain gauges in the semi-coastal and highland agro-ecological zones; absence of meteorological stations in the eastern slopes and Jordan valley zones; and lack of data and information from historical records.

The Ministry of Agriculture has started to implement early warning systems for agricultural drought but some technical and financial limitations constrain the full operation of this system (MoA 2011a).

The political and technical contexts are the main reasons for the absence of comprehensive and proactive drought risk reduction strategies.

The priorities for the Palestinian Authority were directed toward the foundation of institutional, legal, and legislative frameworks and the formulation of policies and strategies to improve the water supply.

In addition to constraints imposed by the Israeli occupation, there is a lack of scientific and technical knowledge in drought management.

6.3.5 Vulnerability to drought

Agriculture and natural resources are the most vulnerable to drought.

The impact of drought on rainfed farming is greater than on irrigated agriculture. Agricultural drought is an important factor in aggravating the socioeconomic drought in the rural areas. Agriculture is diffused in the area and depends on old irrigation systems poorly managed and maintained because of limited funds. Farmers own little land and the quantity of water for irrigation is not enough to optimise the productivity.

The most vulnerable communities are the Bedouins that rely on water from springs during the winter time and completely on water trucking during the summer time. Networks and filling points are often far away and transport costs heavily weigh on their weak economic condition. The most vulnerable people rely on herding and are exposed to many Israeli-imposed restrictions regarding movement and access to water sources. The lack of cisterns due to Israeli occupation and the consequent low storage capacity do not allow them to have a safe quantity of water for the summer season, and they are compelled to depend on frequent travel with small water tankers. These communities should be the main target of future interventions for domestic water or for animal watering (GVC and UNICEF, 2010; Kasim, 2014).

The most vulnerable population lives in Gaza. Groundwater is over-exploited and contaminated (mainly from wastewater), and almost none of the groundwater meets internationally accepted guidelines for use as a domestic supply.

The fragmentation of Palestine which restricts freedom of movement means that communities face more difficulties in accessing essential services. For example, reduced access to water and land resources undermines the presence of already vulnerable farming communities, which negatively impact on their livelihoods.

6.3.6 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

In both West Bank and Gaza, residents have developed several mechanisms to cope with climate vulnerability. Palestine, like other poor states, have fewer policy options available to develop adaptive capacity in the face of drought. This space is even more restricted with the occupation. Rich Arab countries have more options. They may overcome physical water scarcity by building dams or through heavy investments in seawater desalination, or when water scarcity threatens food security, they may import food and the water used in its production ("virtual water") (Allan, 2009).

The terms of the "Oslo II" Agreement effectively prevent bulk clean water imports into the Gaza Strip and the full development of irrigation in the West Bank.

The Palestinian Water Authority and Coastal Municipal Water Utility (CMWU) have responded to shortages by mixing sources of safe and unsafe water to increase drinking water availability at a marginally safer quality level. By notifying the residents when it supplies water from a less polluted source and when it supplies unsafe water, which may still safely be used for washing, the overall coping ability of the community is increased. But the resilience of such enforced coping mechanisms in the long-term is precarious.

Several aid agencies have supported the Water Authority to reduce drought impacts:

The Austrian Development Cooperation funded various projects in both West Bank and Gaza to provide assistance in the use of non-conventional water sources and sanitation by more efficient management of wastewater and its reuse.

In partnership with UNDP and the implementation of Coastal Municipal Water Utility (CMWU) and PWA, the "Improve the Capacity of CMWU for Monitoring the Quality of Water Supply in the Gaza Strip" project aims to improve monitoring of water supply quality and mitigate the health risk of heavy metals in municipal water supply.

In partnership with PWA, Czech Representative Office will help to implement a 3-year Multi-Year National Water Allocation System (MYWAS) project. The project should provide a central water management system of Palestinian water resources, with emphasis on protection of water resources and ensuring access to the drinking water.

The EU is helping in water, sanitation, and solid waste management

Germany has been a longstanding partner of the Palestinian water sector. Since 2006, GIS has supported the Palestinian water sector through a multi-level approach (Attili, 2013).

Upgrading storage facilities should be a solution to emergency preparedness to match frequent drought events, mainly in the summer. Intervention to improve water access should alleviate the poor condition of these communities already suffering from limited access to grazing lands for herders, and limited access to markets for selling agriculture products (GVC and UNICEF, 2010; Kasim, 2014).

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

In Gaza, the increasingly poor drinking water quality has led to increased purchase of desalinated water from neighborhood level reverse osmosis vendors, or the purchase of under-the-sink water filtration units. Both coping mechanisms contribute to the ever-greater share of household income.

Coping with the water crisis in the agricultural sector is becoming evident through the selection of less water-intensive and more salt-resistant crops, such as palm trees instead of water-intensive citrus production. This practice is a return to tradition. Similarly, the lack of fertilisers in the market has led farmers to rediscover organic methods, as well as the use of partially-treated wastewater.

The piloting of solar food-drying techniques has resulted from shortages in cooking gas (UNDP, 2005). However, with increased crop water requirements and decreased water quality and availability, such minor coping mechanisms may prove insufficient to sustain farming livelihoods.

In the West Bank, it was common in the dry season for rural incomes to be supplemented by family members gaining seasonal employment in nearby cities as a form of traditional coping mechanism. This is evidenced from the extensive historical remains of the khirab (temporary villages) where they live until the conditions became favourable (Mason *et al*., 2012).

In the northern governorate of Tubas, which is economically dependent on agriculture, farmers are attempting to adapt to conditions of greater water scarcity by moving away from banana and citrus crops in the irrigated lands around Jericho. However, movement restrictions prevent reliable and cost-effective access to external markets for alternative cash crops (e.g. eggplants, tomatoes, squash, and maize), as well as livestock and dairy products.

6.3.7 Measures to build resilience to drought

See Appendix 13 for details.

6.3.8 Issues

Water scarcity and the lack of access and control of water resources are the main challenges. Research on rainfed agriculture and the use of brackish water for irrigation may provide new solutions to avoid over-exploitation and for the necessary future recharge of groundwater resources. Other solutions might be the construction of water reservoirs in Wadi valleys.

In 2000, a Water Policy was launched by PWA. Subsequently, in 2003, a national IWRM plan was defined, which was followed by a Master Plan in 2004 and an emergency plan in 2005. The Technical Committee for the National Water Council (NWC) has reviewed the Water Policy, but unfortunately these NWC plans have not been approved.

6.3.9 References

See Annex.

7. The Arabian Peninsula

7.1 SAUDI ARABIA

7.1.1 Background

The Kingdom of Saudi Arabia (KSA) is located in the SW part of Asia. It has a large land area of some 2.1 million km^2, which is mostly desert, and is surrounded by the Red Sea in the west, the Arabian Gulf in the east, and close to the Arabian Sea in the south. Along the Red Sea, the western highlands rise up to 3000m. Rangeland extends over 171 million hectares and forest lands cover 2.7 million hectares. Only 2 percent of the country's land area is considered arable (Muammar, 2014).

The climate is mostly arid, but varied among regions due to topographical features. The prevailing climate over most of the country is hot and dry desert. The seasonal variation in temperature may range from below zero to more than 40oC. The average annual rainfall is low, sporadic, and rarely exceeds 50-100 mm in the central and northern regions, and 25 mm in southern and northwestern areas. In the southwestern mountains, rainfall reaches 600mm (MAW 1988).

Temperature and evaporation averages are extremely high and so much of the rainfall is ineffective, which results in soil moisture deficits across much of the country throughout the year (Tag El-Din, 1989).

Water available is only 98 m^3 /capita/year (Muammar, 2014), which is well below the defined level of absolute water scarcity of 500 m^3 /capita/year.

7.1.2 Drought history

Examples of past droughts referred to in “The History of Saudi Arabia” (Vassiliev and Bowen, 1968) include:

In 1630 and 1680, Mecca in Hijas region experienced flash floods that at times threatened to destroy the Kaaba. During these years, it was also subject to periodic drought, famine, and disease

In 1783-1786, 31 Najdis experienced devastating drought leading to famine in Al Kharj

In 1804-1809, Arabia suffered a terrible drought in Najd

The Saudi state was also weakened by years of drought and famine that lasted up to 1809, and accompanied a cholera epidemic in Al Diriya

In 1826, 27 people died of famine resulting from drought. In early 1830s, the price of food fell and famine ceased thanks to good crops and relative stability

In 1835-36, the rain failed in Central Arabia resulting in wide-spread drought and famine and large numbers of Najdis moved to the region of Basra

Between 1902-1932, droughts hit Nejd, where lived Ibn Saoud, adding to a belief encouraging rebelliousness among Bedouin tribes that there was a supernatural reason for this drought and for the lack of rainfall

In 1908, a serious drought hit Nejd region and lasted three years, threatening the fragile oases and wells that made possible agriculture in the desert

In 1910 drought in Nejd caused unrest amongst Bedouin

In 1939, Saudi Arabia was again afflicted by a severe drought

Bedouin have nothing but livestock. Some of them engage in trade only when a drought occurs. They come to the towns and villages with their families. Arabs travel with their wives, sisters, mothers, and daughters who sell fat, wool, and animals since, as they say, a woman's sight is stronger in that matter.

During the drought period 1958-1966, herders lost between 50-90 percent of their livestock in central and eastern regions (Ministry of Municipal and Rural Affairs, 1991). In the 1950s, camel grazing provided work for about 30 percent of the population (Allred, 1968). The grazing land however, is only fit for camel herding, and it is likely that some nomads will continue to raise camels in these sub-marginal areas in the future. Recently, nomads were estimated to be less than 15 percent of the total population of the country.

Saudi Arabia was hit by the generalised drought of 1998-1999, one of the worst events that the country had faced for 30 years. The season was highly deficient in rain, and the maximum temperature varied in summer between 46 and 49oC which is enough to dry up the rest of inland vegetation areas and soil, particularly in the wide rangeland area. It impacted runoff water, the main source for filling dams, and shallow groundwater (Muammar, 2014).

7.1.3 Drought impacts

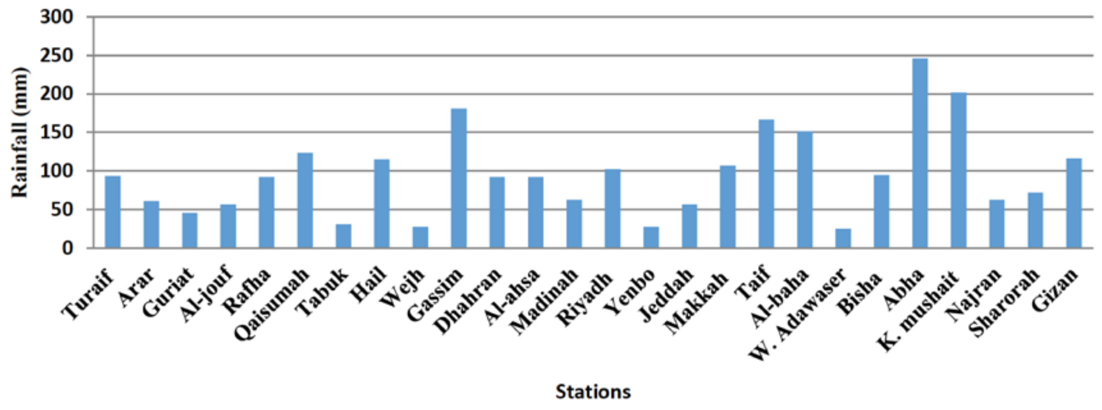
IMPACTS ON SURFACE WATER AND GROUNDWATER RECHARGE

The impacts of low rainfall in most of the Kingdom (Figure 12) is more to do with aridity than drought per se. Even rain, which is the only renewable water source, when it happens, comes in flash short duration storms of high intensity and most of it vanishes to evaporation, which ranges from 2 500 mm to about 4 500mm annually (Al Muammar, 2014).

The estimates for annual surface runoff water range between 2000 and 2400 million m^3 (Ministry of Planning, 1985). Most runoff occurs in the southwest highlands and coastal areas where rainfall is relatively abundant and more regular (Al-Turbak, 2010). This provided 10 percent of Saudi Arabia's supply in 1985 (UNFCC, Presidency of Meteorology and Environment, 2005).

Current levels of groundwater abstractions (mostly water for irrigation) far exceed the level of natural recharge of the main aquifers, and therefore exploit the sources well beyond their sustainable yield.

FIGURE 12
Average annual rainfall of some meteorological stations in Saudi Arabia



IMPACTS FROM INCREASING WATER DEMANDS

The growing domestic and industrial water demands are mainly satisfied from desalination plants and from the non-renewable (fossil) groundwater resources.

All cropping is irrigated but the demand for water has been decreasing. In 1971, the cultivated areas expanded from 400 000 hectares to 1.62 million hectares in 1992. The decline in cropping began in 1993 until it reached about 1.21 million hectares in 2000. The total irrigation water use, mainly from fossil groundwater also increased from about 6,108 million m^3 in 1970 to 19,074 million m^3 in 2000 (PME, 2005). Abstraction is now going down as the irrigated area decreased and then stagnated from 2007. The irrigation sector consumes most of the total water use of 80 to 88 percent (Abu-Ghobar, 2000; Abderrahman, 2001; FAO, 2009). The evolution of total water use in the KSA is shown in Table 16.

The national economy is dominated by oil but the government has always attached high importance to agriculture and food security even though environmental conditions are not favourable. The government used the agricultural development for food security, socio-economic developments, and for protecting the structure of local communities in rural areas by improving their standard of living. The effort since 1990 has enabled the agricultural sector to become an essential productive sector contributing significantly to the national economy. In 2014, the agricultural sector accounted for 6.7 percent of GDP, and equivalent to the GDP of the industrial sector.

The government provided support for the private sector to invest in agriculture including subsidies and others incentives. However, many old springs and shallow aquifers have dried up in the course of the past 20 years and some commercial farms

TABLE 16
Water uses in the KSA in Million m^3/yr. (2005-2011)

Uses\Years	2005	2006	2007	2008	2009	2010	2011	2011(%)
Agricultural	18,586	17,003	15,420	15,083	14,747	14,410	15,970	83
Municipal	1,748	1,848	1,978	2,007	2,123	2,284	2,423	13
Industrial	654	668	683	698	714	753	800	4
Total	20,988	19,519	18,081	17,788	17,584	17,447	19,193	100

have seen groundwater levels fall by more than 200m, lowering crops earnings, and forcing many to abandon their land and cropping activities completely (FAO, 2009). The rapid rise, last decade, in water consumption to over 15 000 million m^3 of mainly fossil groundwater led the government to cut down agricultural demand by reducing water consumption and wastage through corrective policies, such as reducing subsidies. If other alternatives are not found, drought impacts on water deficits will have a drastic impact on crop and on animal production, threatening the agriculture sector as a whole and the livelihoods of rural populations.

Tribal communities in the southwestern are heavily dependent on rainfed agriculture. Lack of sufficient rain or untimely rain will often hinder the efforts of these people to improve their agriculture. Lack of rain will force farmers to irrigate using groundwater as the main source of water across all the regions. But this is not ideal as it tends to be salty in many places and this will eventually mean the land becomes unproductive.

Increases in temperature and prolonged drought will reduce crop yields and increase the number and variety of pests; successive droughts will affect farmers particularly the small-income farmers. The tribal communities in particular are vulnerable to the biodiversity loss that could result from droughts.

7.1.4 Vulnerability to drought

WATER RESOURCES AND WATER SHORTAGE IMPACTS

The impacts of drought on water resources are expected to have significant effects on socio-economic conditions in the Kingdom. The welfare, development, and survival of urban and rural communities and the sustainability of the national economy are directly affected.

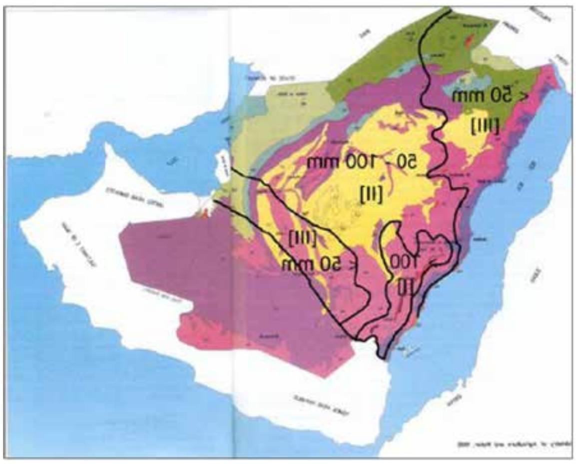
Saudi Arabia has neither lakes nor rivers and must rely on water from flash floods in wadis, shallow groundwater from alluvial deposits, deep groundwater from the fossil aquifers, desalinated sea water, and treated wastewater. Only the first two natural sources are renewable, but also the least abundant (Al-Turbak, 2010).

AGRICULTURE VULNERABILITY

The agricultural activities represent a major support for about 25 percent of the national population (about 30 million in 2014) who still live in rural areas. Deterioration of agriculture for rural communities represents a threat to the welfare of these communities. The rainfall distribution map of the Kingdom (Figure 13) shows three distinct regions of rainfall. The highest vulnerability areas are located mainly in the northwest and southeast. The middle vulnerability is in the central parts and the lowest in the southwestern mountains (PME, 2005).

Even with a low average annual rainfall, the rangelands sustain rural communities comprising 17 percent of the population

FIGURE 13
Desertification vulnerability classes as indicated



Source: PME, 2005

(World Bank, 2015). Drought, with its water deficit and increased temperature, has detrimental impacts on growth and survival of different types of flora and reduces its productivity in different regions. These impacts are expected to be severe in the rangelands, which provide natural grazing for sheep and camels of rural communities. Any mitigation action for supporting the cattle in different regions by replacing natural grazing with importing and supplying forage crops to nomads will be very difficult and economically unviable. The welfare of these communities will be seriously threatened. Consequently, the social structure in rural areas will be disrupted followed by social impacts that could arise as millions are forced out from their homelands.

Various types of measures have been taken by the government during the last three decades in all regions of the Kingdom to minimise effects of drought on rangeland. These include:

Implementing the green cultivated areas that are expected to help in improving the climatic conditions in terms of temperature, humidity, and rainfall

Management of rangelands in different regions to protect lands from desertification.

7.1.5 Government policy on drought

The government has focused in the past only on the supply side of water development. The tendency and attention now is to introduce both supply and demand management to avoid inefficient uses of non-renewable water resources. The agricultural sector is the largest and the most inefficient user of water and so the government has introduced measures to improve efficiency (Turbak, 2010; Gutub, 2013; Al Muammar, 2014). The government intends to focus on:

Developing aquifers and surface water based on long-term investigations to assess the availability of groundwater and surface water resources in different regions.

Supporting drilling thousands of wells, under the supervision of the Ministry of Agriculture, for domestic, agricultural, and industrial purposes.

Capturing rainwater by harvesting and building micro- and macro-dams for storing water.

Supporting the construction of 230 dams for water storage and groundwater recharge for domestic and agricultural uses.

Building 30 desalination plants to supply about 50 percent of the domestic water supplies.

Desalination of seawater and wastewater using renewable energy sources.

Expanding source of water and recycling water by constructing wastewater treatment plants. The Kingdom aims to recycle as much as 40 percent of the water used for domestic purposes in urban areas. Recycled water is now being used for irrigation of farm fields and urban parks.

Supplying industrial plants mainly by the treated wastewater.

Establishing the Ministry of Water and Electricity, in July 2001, to improve the national water planning and management in the country.

Developing and implementing regulations for water protection and conservation. These include well drilling permission, drilling supervision and specifications, groundwater protection zones, groundwater pumping schemes, protection of groundwater from pollution, surface water development and water conservation.

Introducing and implementing advanced water conservation support policy and encouraging the use of more advanced water saving devices in public and residential places.

Implementing pricing policy of water uses to restrict the user from wasteful practices.

Implementing modern leakage detection and control schemes in major cities. Implementing proper maintenance to water distribution network to reduce heavy losses of drinkable water through leakage.

Implementing of advanced irrigation water conservation schemes for large and small farms; and the modification of water pumping from aquifers by changing the agricultural policies to maintain the long-term sustainability of the aquifers.

Encouraging the recycling and reuse of water to a better extent by supporting the research in water resource field.

Educating the public to alter their water usage practices from casual habits and taking initiatives to organise public awareness meetings and workshops on a regular basis targeting the whole country.

Water campaign has been started by the MoWE in 2005 for the participation of the general public for water conservation by distributing water saving devices to house hold sector, to Government buildings, and to the private sector. The reduction of the household water consumption was estimated around 30 to 50 percent.

The major goals assigned to the KSA's 9th Development Plan (2010-2015) include: (MWE, 2010):

Preserving non-renewable aquifers in sensitive areas through limiting their use to drinking, while prohibiting their use for agriculture purposes.

Constructing more dams (74) to raise the total storage capacity in the country to1349 MCB.

Promoting collection and reuse of wastewater (56 treatment plants in service in 2007, expected to attain 70 in the end of 2010).

Reinforcing water conservation measures in agriculture through its Agriculture Strategy plan (2010-2030) which includes the promotion of Saudi agricultural investments in collaboration with countries with a high agricultural potential. This policy primarily aims at producing food, but also aims at saving 8.5 billion m^3 of irrigation water (Darfaoui and Al Assiri, 2010) by:

- Reducing area under wheat by 94 percent from 523 000 hectares in 2004 to 33,700 hectares by 2030
- Stopping alfalfa and other high water consuming fodder crop production except where they use treated wastewater. Also promote the development of feed

industries using agricultural waste products.

- Improve irrigation efficiency from 45 percent in 2010 to 65 percent by 2030, by improving agricultural and irrigation practices and using new irrigation water saving technologies and low water requirement crops.

Using virtual water imports, as another supply-side option, can attenuate water stress. Virtual water trading is becoming a more important element of water availability in arid countries like Saudi Arabia (Oki *et al*, 2003; Islam *et al*, 2007).

7.1.6 Practices to alleviate drought impacts

INSTITUTIONAL ARRANGEMENTS

There is no national drought policy commission, as such, but drought matters and climate change are included within natural hazards events that are the concern of several government institutions:

The General Presidency of Meteorology and Environmental Protection (PME) is also a Government Agency dealing with climate change, and shelter the RDMEC.

The Ministry of Agriculture is among the government institutions involved in policy making and design and implementation of activities related directly or indirectly to climate change, especially in relation to its impact on water resources, and crop production and protection

The Ministry of Water and Electricity is also involved by dealing with the incorporation of the climate change dimension in its planning and actions related to water

The Ministry of Health, which organises meetings, workshops and awareness raising actions on the impact of climate change on nutrition, human well-being and diseases

The Ministry of Higher Education

The Ministry of Interior

The Ministry of Finance and National Economy

The Ministry of Planning, The ministry of Municipality and Rural Affairs

The Ministry of Communication and ministry of Information

Specialised institutions, such as King Abdulaziz City for Science and Technology, General Council for Meteorology and Environmental protection, National Commission for Wildlife Conservation and Development and Prince Sultan Centre for Environment, Water and Desert Research (King Saud University)

The National Committee for the preparation of the natural disasters preparedness programme.

7.1.7 Drought mitigation and adaptation activities

Various activities related to drought mitigation and adaptation, are undertaken by government agencies and the private sector, in collaboration with others countries and international agencies and organisations. Such activities are focused on the country's main concerns, specifically the energy sector, water resources, and agriculture sector.

In collaboration with KACST and International Companies (IBM), KSA launched a research programme on solar-powered water desalination based on using advanced material membranes. The targeted solar concentrator system will capture energy to power a plant that will produce 30 000 m^3 of fresh water per day for a city of 100 000 people (IBM, 2010).

The MWE is preparing a National Water Strategy. It is currently updating the assessment of underground water status and is also in the process of conducting a study on water consumption in the different sectors, especially in agriculture (Darfaoui and Al Assiri, 2010).

The MOA adopted a programme to encourage farmers to modernise their irrigation systems and to promote the use of treated wastewater when irrigating authorised crops, but also to adopt measures related to good agricultural practice, such as farm management, and choosing low water demanding crops. A large technical cooperation programme (UTF) between the MOA and FAO includes several projects and activities related to improving irrigation efficiency, plant and animal production and protection, fisheries, forestry and range management. All these projects contribute directly or indirectly towards adaptation to drought and climate change effects. With the technical assistance of FAO, the KSA developed good technology in range seed and seedlings production. The seed is used to produce drought resistant fodder on private farms and rangelands. However, their use on a large scale is facing land tenure difficulties and lack of livestock producers' awareness and participation.

7.1.8 Measures to build resilience to drought

KSA has the scientific base for setting up a drought early warning system, as there is in place the "Drought Monitoring and Early Warning Centre Middle East (RDMEC)". Its output is mainly oriented towards meteorological forecasting than being part of a national drought management policy and preparedness plans which do not exist. This is confirmed by Darfaoui and Al Assiri (2010) who reported that the Agriculture Strategy plan (2010-2030) shows an intention to develop a national agricultural meteorology network and early warning system to improve water management and to predict droughts, pests, and extreme events.

The existing "Drought Monitoring and Early Warning Centre Middle East (RDMEC)" was approved by WMO Congress in May 2003 and located in Saudi Arabia to serve all Arab Countries. RDMEC programme follows up sustained meteorological observations and forecasting impact of the atmosphere on earth's surface state, vegetation cover, and groundwater, directly influenced by atmospheric factors. RDMEC also issues early warning on extreme phenomena that affect the KSA and other Arab neighbours. The RDMEC objectives include:

Monitoring droughts in the Arab States and zones

Studying the climatic variables, as well as, their environmental, economic and social impacts of Arab States

Issuing seasonal predictions to Arab States.

Issuing warnings on severe seasonal climatic events this may become extreme events.

Analysing the state of the vegetation cover and desertification in Arab States.

Developing databases for climate information and climate numerical statistical models.

Collaborating with World Centres in making use of the products of global climate expectation models and the development of their application to the Arab States.

In 2009, Presidency of Meteorology and Environment (PME) got the candidacy to be WMO/regional climate centre to provide the climate services for the South West Asia region. PME decided to take the responsibility to the general public and the region by establishing the Jeddah Climate Centre (JCC). JCC objectives include:

Provide regional climate predictions at monthly, seasonally and inter-annual timescale, particularly for south-west Asia in cooperation with other regional climate centres

Provide regional climate data base and archiving services

Improving collaboration between Presidency of Meteorology and Environment (PME) and climate research centres and institutions on related climatic observations, communications and computing networks for data collection and exchange

Strengthening climate research and development projects and coordinate with other Regional Climate Centres (RCCs).

The current early warning system uses meteorological data to issue a warning over a whole province or much wider region. It will be replaced with a new geographic warning system using GIS and order to include information about the population and provide details about population at risk. This will help emergency officials to take proper actions to minimise loss of life and properties.

RDMEC issues monthly and quarterly forecast reports on drought and other climate events in the KSA including environmental, economic, and social effects.

The Kingdom has lately considered drought hazard among the “natural disasters” so that the damage can be compensated as a measure to mitigate drought impacts.

7.1.9 Issues

There is little coordination among all parties involved in climatic change and drought to create synergies and design and implement an integrated drought management programme. Also, the coordination among stakeholders involving the professional organisations, the private sector, and the civil society was not mentioned anywhere. This is seen as essential for successful and efficient drought management and adaptation to climate change.

Great efforts need to be made to strengthen the capacity of all stakeholders to increase awareness about the options available and ways of incorporating drought and climate change adaptive measures in their programme and activities.

Drought planning is an essential component for combating desertification and climate change and increasing the resilience and sustainability of communities and nations to natural hazards. Because of the integrated nature of these issues, increasing efforts to better prepare for and respond to drought have the potential to help address a wide variety of other management issues.

7.1.10 References

See Annex.

7.2 KUWAIT

7.2.1 Background

Kuwait is a relatively small oil-rich state of 17,820km² which lies in the north-western corner of the Arabian Gulf. Most of the territory is desert, with a few oases. The terrain is generally flat or gently undulating, broken only by occasional low hills and shallow depressions. Throughout the northern, western, and central sections of Kuwait there are desert basins, which fill with water after winter rains; historically, these basins formed important watering places for Bedouin camel herds (Bourn, 2003). In 2013, Kuwait had a population of 3.37 million which was growing at 3.6 percent per annum. The arable land is only 0.6 percent of the total land, and the rural population account for 2 percent of the total (World Bank, 2014).

Kuwait has an arid climate with erratic, short duration rainfall and low annual average rainfall of 121 mm; 90 percent of it falls between October and April. The average annual evaporation is high around 4000 mm and always well exceeding available rainfall. The average daily temperatures during summer vary between 23oC and 43oC, and during winter between 5oC and15oC. Summer temperatures can be even higher when hot winds blow from the desert (MOP, 2001).

Water resources in Kuwait are very limited and there are no permanent rivers. The only existing conventional water resource is fresh groundwater but this is very limited. Fresh groundwater is found in two depressions located in the northern area of Kuwait. Two alternatives of non-conventional water resources are used; one is seawater desalination and the other is wastewater treatment and reuse (Kwarteng, 2000).

7.2.2 Drought history

A drought analysis study to assess hydrologic droughts affecting groundwater recharge was performed on rainfall data from the weather station located in Kuwait International Airport (Figure 14) for 1962-2011 (EPA, 2012).

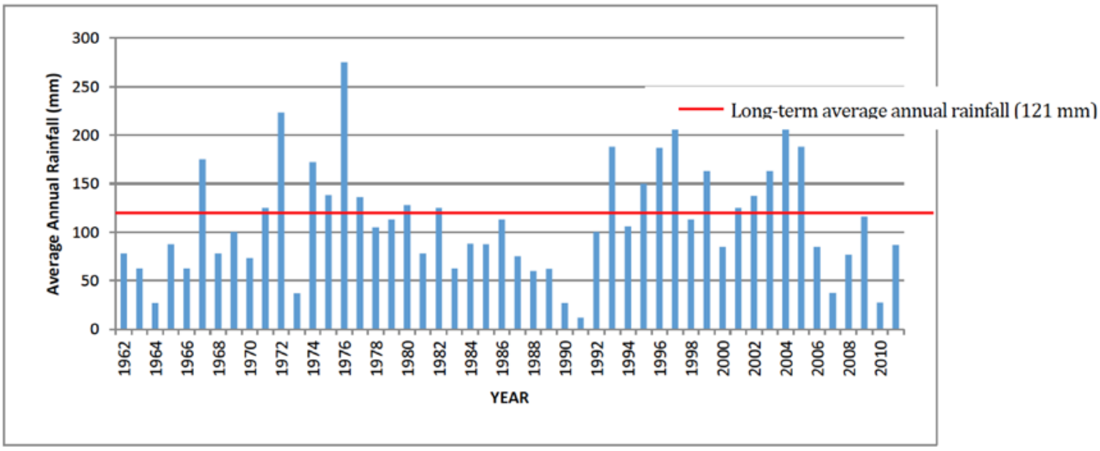
Dry years, below the overall mean, for 1962-2011, include nine drought events with different drought duration, some had 1, 2, 3, 5 or 10 consecutive dry years (Table 17; Figure 14).

Using a water planning software model, water consumption in Kuwait was found to exceed by 5 percent current expectations without climate change (EPA, 2012).

7.2.3 Government policy on drought

As a highly water-stressed country, Kuwait relies on desalinated water and fresh groundwater to meet drinking water needs. Brackish groundwater and treated

FIGURE 14
Average rainfall in Kuwait (1962-2011)



Source: Adopted from Kuwait Environment Public Authority (2012)

TABLE 17
Dry years within the period 1962 to 2011

Drought events	1962-66	1968-70	1973	1978-79	1981	1983-92	1994	1988	2000	2006-2011
Dry months		28	12	8	11	40+59	11			
Years if drought	5	3	1	2	1	10	1	1	1	6

wastewater are used for agriculture and industrial applications. As of 2011, about half the water supply was provided by desalinated water (Kuwait's Initial National Communications, 2012). On a per capita basis, Kuwait has one of the highest water usage rates in the world at 907 litres/day (Kuwait's Initial National Communications, 2012). This is added to the overall agricultural production that has increased nearly threefold from 1994 to 2010, thanks in part to a government policy of protecting agriculture (Al-Nasser and Bhat, 1995). This gave Kuwait few options for meeting socio-economic development needs. In fact, households and agriculture sectors dominate Kuwait's total water demand, with only a small share devoted to industrial applications.

REACTIVE RESPONSE TYPE

The increasing demand for drinking water has led the government to build six large desalination plants. However, the consumption of freshwater has grown significantly. In 2002, the total annual drinking water was 400.5 million m^3, while it had increased to 563.8 million m^3 by 2012 (Aquastat, 2008; CSB, 2014). This is due to the expansion of new cities, wastage, and the use of drinking water for agricultural purposes instead of brackish water.

Besides the desalination plants, Kuwait has two areas with natural fresh groundwater including Rawadatin and Umm Al-Aish. Their capacity is about 22 000 m^3/d and it could be increased to 50 000 m^3/d (MEW, 2002). However, this water is being used mainly for bottling.

Brackish groundwater wells, which are located in the south and southwest have salinity concentrations ranging between 3000 and 8000mg/l. This is used mainly for agriculture (Orner, *et al*., 1981). Wells in the north and central areas have salinity ranging between 10 000 and 100 000 mg/l which makes it unsuitable for agricultural irrigation.

Kuwait has four main sewage treatment plants in Jahra, Rekka, Urn AI·Haman, and Sulibiya. These produce more than 600 000 m^3/d of treated wastewater. Part of the tertiary treated wastewater effluent is directed to the farms areas, while the remaining effluents are discharged to the coastal seaside through the sea outfalls (Al-Humoud, 2003).

Abusada (1988) reported that brackish groundwater found in large quantities is mainly used for irrigation of public gardens and farms and is mixed with distilled water to make it drinkable. However, the production of brackish water from the existing and future water well fields will not be sufficient to cope with the increasing demand (MEW, 2010). Both electricity and water are heavily subsidised (about 95 percent) by the government (Wood and Alsayegh, 2010).

DROUGHT RISK MANAGEMENT POLICIES AND PLANS

Numerous efforts are underway to identify appropriate strategies for reducing water use (Al-Otaibi and Mukhopadhyay, 2005; Fadlelmawla A., 2009). The Ministry of Electricity and Water is coordinating programmes with the Ministry of Commerce to conserve water, such as the promotion of import regulations mandating high efficiency water faucets (Arab Times, 2012).

Currently, municipal wastewater reuse is widely used for growing crops rather than using fresh water. Treated wastewater is used for forestry, landscaping, and growing root crops and cereals which are not directly consumed by people and require processing.

INSTITUTIONS INVOLVED IN WATER MANAGEMENT

There is duplication and overlap in water agencies, as well as inadequate institutional capacity development and community participation. The situation is pressing Kuwait to begin to realise the necessity and urgency of instituting water policy reforms. This includes water management, policies, and legislation related to water use in agriculture (Aquastat, 2008).

The main institutions involved in water resources management are:

The Public Authority for Agricultural Affairs and Fish Resources (PAAFR), established in 1983 which is responsible for managing agricultural economic development and enhancing food security. Administratively, the PAAFR is organised into five main sectors: animal resources; fisheries resources; plant resources; landscaping; and finance and administration (Aquastat, 2008).

The Soil and Water Division is responsible for the design and evaluation of farm irrigation systems, testing irrigation equipment, crop water requirement research, monitoring groundwater quality and quantity and water resources planning. The Landscape and Greenery Department is responsible for irrigation designs for highways and forestry areas.

The Ministry of Electricity and Water (MEW), established in 1962 is responsible for studies, development, exploration, monitoring and giving licenses for drilling and using groundwater.

The Ministry of Public Works (MPW), established in 1962 is responsible for sewage water networks and collection reservoirs, wastewater treatment and utilisation and water quality monitoring laboratories. Also responsible for the delivery of treated sewage effluent to farms and public gardens.

The Kuwait Institute for Scientific Research (KISR) is in charge of research related to water resources with the Water Resources Division and Environment and the Urban Development Division.

The Environmental Public Authority (EPA) is in charge of monitoring water quality, with water analysis laboratories, a research and studies centre and a soil and arid land division.

The Ministry of Health (MOH).

In addition to government institutions, several farmers' associations and cooperatives are active in the agricultural and fisheries sector, including the two agricultural cooperative societies.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

New legislation is aiming at the rationalisation of water use, and increasing the level of public awareness of water scarcity and the need for downscaling water demand. This is expected to yield positive results.

With very vulnerable groundwater resources, Kuwait should protect it by using best practices; and adopt a friendly-ecosystems approach in integrated water resources management.

Water demand management should become a driving force in water resources management

7.2.4 Vulnerability to drought

The vulnerable sectors include agriculture, livestock (indigenous animals), rangeland, and municipalities. Among the vulnerable people are rural dwellers and urban foreigners (expatriate work force). Most farm owners are investors and have also other sources of income. Kuwait's revenues rely significantly on oil, and Kuwaiti nationals are wealthy and have other sources of income that allow them to import almost all food and feed.

AGRICULTURE SECTOR

Agriculture has seen minimal development. Kuwait's desert climate sustains little vegetation. Economic growth and welfare measures since World War II drew workers away from historical jobs and lessened the role of agriculture. In the late 1980s, less than 10 000 people were employed in agriculture (U.S. Library of Congress, 2014).

The expatriate work force has grown rapidly over the period 1994-2011 by about 4.6 percent per year and account for 63-68 percent of total population.

The potential for agricultural development is very limited, as less than1 percent of the land area is considered arable (Kuwait's Initial National Communications, 2012). Most crops are grown in greenhouses and a wide variety of vegetable crops are produced. Some are also grown hydroponically for export. There are many large-scale dairy farms where milk production has an average annual growth rate of about 4 percent. Indigenous meat production showed similar trends, reaching an average annual growth rate of about 5 percent per year. Moreover, Kuwait relies heavily on food imports. Such heavy dependence coupled with possible world food shortages in the future, creates concern about national food security (Kuwait's Initial National Communications, 2012).

LIVESTOCK AND ANIMAL HUSBANDRY

Livestock production is still an important component of the agricultural sector and contributes about 67 percent to total agricultural GDP, as compared to 23 percent for plant production and 10 percent for fisheries. When the desert is green (from the middle of March to the end of April), about one-fourth of Kuwait's meat supply is provided locally, by only a small number of Bedouins that are still raising camels, goats, and sheep for meat and milk (Bourn, 2003). Given the population growth and wealth of its citizens and limited livestock resources, it is not surprising that Kuwait depends heavily on food imports, including live animals. Following the Gulf War, Kuwait's imports of live sheep from Australia have steadily increased over the past decade to exceed 1.5 million in 2001, surpassed only by Saudi imports of 2.1 million. Kuwait thus appears to import 2.5 times as many sheep from Australia than graze in its arid plains.

7.2.5 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

The demand for fresh water is projected to increase substantially during 2005-2025 (Qadir *et al*., 2010). Developing and maintaining a continuous and secure supply of water is a vital pre-requisite for the country's socio-economic development plans.

In response to this and the expected increase in demand, Kuwait has resorted to building water desalination plants and wastewater treatment plants. The existing reserves of water resources are gradually dwindling with consumption rates increasingly surpassing replenishment rates (Darwish and Al Awadhi, 2009).

The government has established a strategy to use all treated wastewater, especially for agriculture and landscaping, to reduce the demand on fresh water supply. This is less costly than desalination. Such a strategy, if successfully executed, could significantly reduce the demand on water supply and could convert the treated wastewater into a new source for water supply. This concept of water reuse to alleviate scarcity is gradually being integrated into water resources management. The amount of water reuse has been steadily increasing over the past years, since the first project was implemented and operated in 1978.

In order to locally produce food for the population and feed for livestock, Kuwait is planning to reclaim more land for irrigated cropping. This will increase demand for water. Faced with these conditions, it is imperative to rationalise the water use efficiency of the existing water resources and to increase the supply as much as possible.

Desalinated water can be used, but because of its high cost only high-value cash crops produced under intensive conditions are cost-effective today (AQUASTAT, 2008).

7.2.6 Measures to build resilience to drought

The water policies of Kuwait are in need of major reform in order to cope with the increasing demand for water. Instead of the simple approach of increasing desalination capacities and groundwater withdrawal to meet demand the potential alternatives include mandating water collecting devices; restructuring water tariffs; reallocating resources; establishing awareness programmes; penalising wasteful practices; water auditing; groundwater protection; reducing leakage in the main network; tighter immigration laws; alternative desalination technology; artificial recharge using water harvesting. See also Appendix 14.

7.2.7 Issues

A long-term monitoring programme is needed to observe the positive and negative impacts on the environment; the risk of groundwater pollution and soil pollution if only treated wastewater is used; health risk evaluation from using treated wastewater; the impact of desalination plants on coastal water quality and marine life (production of concentrated brine); ways of reducing per capita water use (metering and price); the impact of water efficiency and conservation on future water consumption through water tariff systems, greater use of water conservation technologies, and a combination of both measures; revised water subsidies; and the need for integrated water management.

7.2.8 References

See Annex

7.3 BAHRAIN

7.3.1 Background

The Kingdom of Bahrain is an archipelago consisting of 33 low-lying islands, situated in a shallow bay in the Arabian Gulf known as the Gulf of Salwa, approximately halfway between Saudi Arabia in the west and Qatar Peninsula in the east. It occupies an area of about 710.9 km^2, with a population of 650,604 (CSO, 2002). This gives a population density of about 916 inhabitants per km^2, making it one of the most densely populated countries in the world (Al-Noaimi, 2004). Bahrain has experienced high rates of urbanisation since the early 1960s following the sudden increase in the country's oil revenues, which led to a fast increase in economic growth and improved standard of living. Only 10 percent of the population live in rural areas (Tollner, 2007).

Bahrain is arid and characterised by high summer temperatures, scant and irregular rainfall, high evaporation, and high relative humidity levels due to the surrounding Gulf waters and persistent winds from the northwest. The rainy season runs from November to April, with an annual average of 72 mm (Basheer and Bu Rashid, 2001).

Annual surface water runoff is only about 4 million m^3, so Bahrain depends on lateral flow from the Damman aquifer that forms part of the extensive regional aquifer system (the Eastern Arabian Aquifer). This extends from central Saudi Arabia where its main recharge area is located to eastern Saudi Arabia and Bahrain, which are considered the discharge areas. The annual rate of groundwater inflow is estimated at 112 million m^3 under steady-state conditions (before 1965), and this figure is considered to be the safe groundwater yield in Bahrain.

Rapidly increasing urbanisation, high population growth, extensive economic and social development, and improved standards of living during the last four decades have substantially increased the demand for water, causing over-exploitation of the already scarce renewable groundwater resources well in excess of their safe yield. This has led to a significant decline in groundwater levels, drastic storage depletion, and serious deterioration in groundwater quality.

7.3.2 Drought history

Prior to 1925, the main source of water supply was from natural springs and shallow hand-dug wells. This was used for both municipal and agricultural requirements. As demand increased following crude oil and gas developments in 1946, spring flows stopped and groundwater pumping began from the Dammam aquifer. In the 1970s, in order to conserve scarce water resources, the government directed its efforts toward building a desalination plant (UNU, 1995).

Water demand in the domestic sector increased threefold between 1976 and 1986, due to the rise in the standard of living. Further increases followed at a rate of 6 percent annually to reach 92 million m^3 by 2000. Demand was expected to reach 174 million m^3/year in 2010. Agriculture is the greatest water consumer in 1998, consuming 204 million m^3 from the Dammam aquifer – well above the safe yield. The deteriorating quality of groundwater, caused by over-extraction, poses further limitations on its use (Basheer and Bu Rashid, 2001).

Water use during 2003 for the three principal categories was 357.4 million m^3. Of this quantity, municipal uses had the largest share of 177.9 million m^3 (49.8 percent). About 159.2 million m^3 (44.5 percent), was used for agriculture. Industrial users consumed about 20.3 million m^3 (5.7 percent). Table 18 presents the total water use for 2003. This shows a water deficit of 65.5 million m^3 (24 percent) (Al-Noaimi (2004).

7.3.3 Government policy on drought

Excessive pumping of groundwater has caused a sharp decrease in groundwater storage and a reduction in potentiometric levels of about 4m between 1965 and 1992. As a

TABLE 18

Water uses in Bahrain by sources and categories of use for the year 2003 in million m^3

Source	Municipal	Agriculture	Industrial	Total uses
Groundwater	83.6	143.7	12.2	239.5
Desalinated water	94.3	---	8.1	102.4
Treated sewage effluent	---	15.5	---	15.5
Total	177.9	159.2	20.3	357.4

Source: Al-Noaimi (2005)

result, more than half the original groundwater reservoir has been completely degraded due to seawater intrusion and saline water up-flow from the deeper zones (Tollner, 2007). The annual extraction is almost twice the annual recharge, leading to an ever-increasing groundwater deficit.

It is neither economical nor practical to replace the Dammam aquifer as a major water source for agriculture, and so withdrawal from the aquifer for domestic and industrial purposes will continue. However, additional supplies must come from desalination plants, fed either by seawater or brackish water from the Umm Er Radhuma aquifer.

The government has also taken a number of actions to alleviate pressures on groundwater resources including strictly enforcing laws to reduce groundwater abstraction for agriculture and increasing its efficiency use; expanding the use of recycled wastewater in watering forage crops and landscapes; and continuing public awareness campaigns to reduce water consumptions.

REACTIVE RESPONSE TYPE

In response to this acute water shortage, the government has embarked on a major water supply augmentation programme through the development of non-conventional water resources.

The introduction of treated wastewater plants in the 1990s has made an alternate source of water for agriculture available to help in reducing withdrawal from the Dammam aquifer. The present contribution is 14 million m^3. With the expansion of the existing sewage treatment plant, this was expected to reach 60 million m^3 by 2005, and 72 million m^3 by 2008.

The industrial sector relies mainly on desalinated water. The total requirement does not exceed 10 million m^3/year and is not expected to increase substantially in the coming years.

DROUGHT RISK MANAGEMENT POLICIES/PLANS

Institutional weakness and fragmentation of responsibilities are the major reasons for water policy failure. Responsibilities for water development, use, and management are distributed among several water authorities. In1982, the government established the High Water Council, a ministerial body responsible for drawing up the country's water policy, and coordinating among the concerned authorities in all aspects related to water resources development and management (FAO, 2008a). However, the Council does not seem very active, and responsibilities are still fragmented with a lack of proper coordination among the concerned water authorities.

There is no water law or legislation in place, only privately owned water use rights exist (FAO, 2008b). The general principle governing these rights is that groundwater is the property of the landowners and, therefore, they have an exclusive right to extract and use this water as much as they wish and for any purpose they want without being liable for any damage caused to their neighbours or to the groundwater in general.

At present, abstraction for agriculture is not subjected to any licencing system nor controlled by a pricing system. However, from the mid-1980s onwards, agricultural wells were metered and the government is in the process of passing a law that would make it compulsory for all well owners to install meters on their wells. The total number of wells metered at present is about 1,670 (86 percent of total). The final objective is to observe irrigation water requirements, and subsequently to set up a licencing system for groundwater withdrawal and design an appropriate pricing system for excess water utilisation.

The government has issued numerous laws and legislation to regulate, administer, and control groundwater use; the most important of which is the Decree No. 12 of 1980 which was amended and substantially improved by the Decree No. 12 of 1997 (Tollner, 2007). Several ministerial orders and legislative decrees were issued at different stages to enhance enforcement of these laws. Human resources and capacity building are the institutional issues that have been given little importance; the result is inadequate technical capabilities, especially in the areas of groundwater development and management (Al-Noaimi, 2005).

At present there is no well-defined National Master Water Plan (NMWP) for sustainable water resources development and management (Al-Noaimi, 2005). There were a number of fragmented water policies and water conservation measures initiated over the last three decades to solve the escalating water shortage problems. Supply augmentation policies have also been considered through the implementation of some artificial groundwater recharge projects. In addition, the government is also adopting a number of demand oriented measures and management policies to improve water use efficiency and encourage conservation.

INSTITUTIONS INVOLVED IN WATER MANAGEMENT

Two principal entities are responsible for governing the water and wastewater (FAO, 2008; GWI- Bahrain, 2010):

The Electricity and Water Authority (EWA). In addition to electricity assets and production, the EWA is responsible for water production, transmission, distribution networks, bill collection and metering.

The Ministry of Works (MOW), which is responsible for all public work undertakings including roads, drainage, and wastewater. The MOW has a specific Sanitary Affairs Directorate in charge of coordinating nationwide treatment and re-use of wastewater.

The main Integrated Water Resources Management (IWRM) administration is composed of the Ministry of Works (MOW), Ministry of Water Electricity and Water Authority (EWA) and Ministry of Municipalities Affairs, Urban Planning and Agriculture. The Ministry of Municipalities, Urban Affairs (FAO, 2008) is the irrigation management institution and responsible for groundwater resources development, management, and use. This ministry also manages the treated sewage effluent in agriculture.

The current organisational structure and staff shortages in the Directorates of the ministries and the services dealing with water development and use are a major constraint to the efficient performance of irrigation (lack human resources and updated know-how). The High Council for Water Resources, created in 1982, is the highest authority on water resources, under the chairmanship of the Prime Minister. The main duties of the Council are to draw up the country's water policies; protect and develop water resources; regulate and coordinate water use among competing sectors; and take the necessary measures to solve any problems that might arise during the implementation of water policies.

STATE OF MONITORING AND INFORMATION SYSTEMS

Lately, the WRD has established a well-designed country-wide observation network for monitoring wells and groundwater levels. All data are already stored electronically and can easily be retrieved for analysis. Data on groundwater quality are also collected on an ad-hoc basis, although the Ministry of Electricity and Water carries out somewhat systematic salinity surveys. Efforts are being made to design a regular and more reliable groundwater quality observation network to monitor the salinity of the Dammam aquifer. Long-term metrological data are available from the Bahrain International Airport Metrological Station. Reliable short-term metrological data are also available from Shiekh Isa Air Base Station and, to a less extent, from other minor metrological stations (Al-Noaimi, 2004).

There is a need to establish a comprehensive computerised groundwater resources database that can be accessed by researchers and water resources planners to enable better understanding and enhancing decision-making processes. Active involvement of stakeholders and the public is necessary for effective water management. Legal reforms, including enforcement of water laws and legislation should be considered.

Capacity building should keep pace with the progress in research and escalating water problems. Policy instruments for water allocation and charging for water use for agriculture should be put into practice. Despite the major investment programmes in non-conventional water resources, considerable water deficits will be facing the Kingdom in the future.

7.3.4 Vulnerability to drought

Agriculture is the highest water-consuming sector. It is mainly dependent on groundwater as the average rainfall is less than 80mm/year. This poses an enormous burden on the quality of the aquifer. Furthermore, soil salinisation resulting from deterioration in the quality of the groundwater used in irrigation has led to a general reduction in the cultivated area. This sector provides many job opportunities for Bahraini nationals.

The domestic sector, which includes drinking, food preparation, washing, cleaning, and watering gardens, accounts for a large portion of total use in the country. Bahrain has been experiencing high population growth and urbanisation since the early 1960s following the sudden increase in the country's oil revenues leading to rapid economic growth. There was also a large influx of guest workers needed to sustain the developments. Rapid urbanisation hinders the development of adequate infrastructure, such as effective distribution methods, sewage systems, and regulatory mechanisms. In 2001, nearly 88 percent of Bahrain’s population estimated at 700 000 live in urban areas (Roudi-Fahimi, 2002).

The community groups most vulnerable are foreign workers that constitute about 55 percent of the Bahrain's total labour force, estimated at 160 000 in 1992; urban and agricultural workers, and the Bedouin.

Agricultural land and groundwater aquifers are vulnerable to salinity.

7.3.5 Practices to alleviate drought impacts

Several water conservation and regulatory measures have been applied in practice since the beginning of this century. Some are reactive while others are more proactive.

In the municipal sector, there have been considerable efforts to reduce water consumption through an ambitious water conservation programme that includes the introduction of water-saving and flow limiting devices, supply ceiling and rationing system policies, leak detection and pressure control programmes, economic incentives, and the launch of public awareness campaigns.

Agriculture is seen as a wasteful and inefficient in water use. The government, through a subsidy programme, promoted the use of modern irrigation techniques as well as improving the traditional irrigation practices to increase irrigation efficiency and minimise water losses. Among the demand modification policies in this sector, measures such as improving the agricultural drainage systems and farming practices, as well as changing the crop patterns (particularly alfalfa) to less water consuming crops, have also been considered.

In 1990, the government imposed increasing the price of water to promote water conservation in the municipal sector, with different rates set for domestic and non-domestic consumers, and blended and brackish groundwater supplies. This tariff structure was modified and significantly reduced in 1992. An incremental tariff structure for agricultural, industrial, and tourism sectors has been proposed but is yet to be implemented. Between 1990 and 2002, the per capita water consumption decreased from 579 to 511 liters/day after some demand control measures were introduced (water metering and a progressive tariff system since 1990).

7.3.6 Measures to build resilience to drought

See Appendix 15 for details.

7.3.7 Issues

Although water is a non-renewable resource in Bahrain, not only is it is being consumed in a most irresponsible way but also the limited supply is being polluted by industrial waste from the production of oil.

7.3.8 References

See Annex.

7.4 QATAR

7.4.1 Background

The State of Qatar is a desert country with a harsh and fragile environment characterised by its arid climate, high summer temperature (more than 40 °C), and high evaporation rate (annual average of 2,200mm).

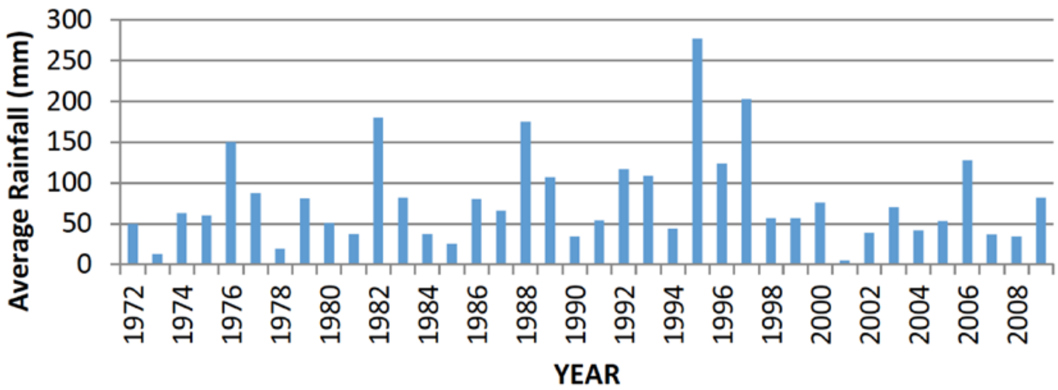
The fast economic development has led to increased population growth, improved standards of living, and industrial growth. This is putting immense pressure and demand on water sustainability. Potable water supplies are being met using desalinated water, which has reduced stress on groundwater supplies. However, this is changing as the population grows. The expansion of existing wastewater treatment facilities is providing quality treated wastewater for irrigating fodder crops and landscape needs. Poor and unpredictable rainfall with an annual average of 80mm (Figure 15) means there are no permanent rivers and so agriculture is sustained by irrigation using groundwater, which is recharged from rainfall (Aquastat, 2008).

7.4.2 Drought history

In 2013, the annual available water resource was estimated to be only 27 m^3/capita (World Bank, 2013), far below the water poverty line of 500 m^3/capita. This classifies Bahrain as a country experiencing "absolute scarcity". Climate change will aggravate this situation. In 2005 (Table 19), the annual water withdrawal was 444 million m^3 – 59 percent for agriculture, 2 percent for industry, and 39 percent for municipalities (Aquastat, 2008). This annual withdrawal includes renewable groundwater resources and fossil groundwater, desalinated water, and treated wastewater. Groundwater is being overexploited and withdrawals exceed recharge rates making water use unsustainable.

The north groundwater basin is the largest source with acceptable quality suitable for agriculture. It covers about 19 percent of the total land area. The southern basin extends to about half the land area. The water is saline and not suitable for agriculture (UN-Qatar National Vision 2030, 2009).

FIGURE 15
Average annual rainfall in Qatar 1972-2009



Source: Adopted from Amer, 2008; DAWR, 2009

TABLE 19
Annual water withdrawals by different sectors in Qatar (2005)

	Agriculture Million m^3	%	Domestic Million m^3	%	Industry million m^3	%	Total million m^3	%
Groundwater	218.3	83.5	2.4	1.4	n.a.	n.a	220.7	49.7
Treated sewage water	43.2	16.5	n.a	n.a	n.a	n.a	43.2	9.7
Desalinated water	n.a	n.a	171.8	98.6	8.4	100	180.2	40.6
total	261.5	100	174.2	100	8.4	100	444.1	100
% by sector	58.9		39.2		1.9		100	

The absence of perennial rivers, the deficiency of renewable aquifer water, and the severe scarcity of freshwater has forced the State to look for another solution to water security. Qatar now relies on solar desalination technologies, which compensate for depleting water levels in the aquifers. The state now produces 3.5 million m^3 annually. To ensure food security, 90 percent of food needs are imported (Al-Attiya, 2012). In 2009, the desalinated water provided almost 99 percent of Qatar's municipal water demand and some commercial uses (Kahramaa, 2010).

7.4.3 Vulnerability to drought

It is evident that the sector most vulnerable to drought and climate change is agriculture (farmers and livestock) since it depends almost entirely on fossil groundwater. Agricultural areas are scattered where the groundwater is suitable for farming, which is mainly from the centre to the north of the country. However, Qatar has now chosen to depend almost exclusively on imports to meet food requirements.

The potable water demand is mainly satisfied by desalting seawater (99 %), using the multi-stage flash desalting system. This is energy inefficient, very costly, and needs to be replaced with a more energy efficient reverse osmosis system.

Treated wastewater is another resource that should be used. It costs less than desalinated water. As the population and consumption increases there will be more wastewater for use in agriculture and for other purposes.

7.4.4 Governments' policy on drought

REACTIVE RESPONSE TYPE

Qatar has experienced rapid economic growth due to the discovery and production of fuel oil and natural gas. The country imports all its needs of food and feed; thus, it does not have any emergency programme for drought relief.

INSTITUTIONS INVOLVED IN WATER RESOURCE MANAGEMENT

Qatar is actively working towards re-organising its institutional set-up to create an enabling environment for enhanced and integrated water resource management. The main ministries and institutions responsible for water development, planning and management in Qatar are as follows:

The Qatar General Electricity and Water Corporation is responsible for providing desalinated water for drinking and industrial uses (Coordinator of water resource management).

The Permanent Water Resources Committee (PWRC) was established in April 2004 to develop a long-term water strategy for Qatar. The PWRC launched a long-term program for integrated water resource management in Qatar, which involves the formulation of a comprehensive National Water Resources Management and Development Strategy with a planning vision up to the year 2050.

The Ministry of Municipal Affairs and Urban Planning is responsible for the management of groundwater use in agriculture, The Public Works Authority is responsible for the collection of wastewater, waste treatment and the distribution of treated wastewater to the farms and for landscaping.

Water production and management also involves the close coordination of various agencies including: Ministry of Energy & Industry, Permanent Water Resources Committee, Water & Electricity Producers, Public Works Authority (sewage/drainage), Ministry of Municipal Affairs & Urban Planning (agricultural & water research), and Qatar General Electricity & Water Corporation (water networks).

DROUGHT RISK MANAGEMENT POLICIES/PLANS

Based on the recommendations of the Department of Agriculture and Water Research (DAWR), an Ameri Decree (No.1 of 1988) was issued governing the drilling of wells and use of groundwater. The Ministry of Municipal Affairs and Agriculture (MMAA) formed the "Permanent Committee for farms, wells and organising farmers' affairs" which is responsible, in addition to other duties, for implementing the groundwater laws. Unfortunately, the only articles which have been implemented are those connected with granting permits for drilling, altering and modifying wells. What is required is to put into action the articles concerning water use, protection, and conservation.

This situation has driven the Department of Water Management (MoE) to adopt the concept of Integrated Water Resources Management (IWRM). This includes maximising water resources by exploring the groundwater of deep aquifers; improving and increasing desalinated plants; injecting treated wastewater to replenish groundwater aquifers; optimising per capita consumption; educating consumers about the need to reduce water use; reducing water wastage; reducing distribution losses; preventing leakage, replacing old distribution piping; promoting water reuse for washing and sanitation; wastewater and sewage treatment and use for service and non-potable use; exploring alternative sources or mechanisms for water production; exploring renewable options and methods for water desalination; solar based water desalination; and increasing the efficiency of thermal-based desalination.

7.4.5 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS

Public awareness of water issues could be one of the most effective measures for mitigating water-related hazards and alleviating drought impacts. Proper education and training programmes could result in considerable water saving and consequently lead to cancelling some of the expensive water enhancement projects or at least postpone their implementation.

Qatar has launched several public awareness, training and education programmes on conserving water resources and combating desertification. The programmes have been carried out by the DAWR, the SCENR (Supreme Council for Environment and Natural Reserves) and the Qatar Electricity and Water Company.

Qatar has carried out a number of programmes and studies, issued water laws, and established committees for the consolidation of IWRM, the most important of which are the following (Aquastat, 2008):

Increasing natural recharge: The drilling of wells in depressions to depths that reach the water bearing formations will accelerate the natural recharge of floodwater. The project started in 1986 and 341 recharge wells have been drilled since then (DAWR, Groundwater Unit, 2006). Continuation of this project will make rapid recharge possible from the occasional storm runoff that accumulates in depressions before its loss through evaporation.

Development of water monitoring and irrigation scheduling: The water monitoring development program has been promoted through a telemetry system at 3 automatic agro-meteorological stations, 25 hydro meteorological stations and 48 hydro-geological stations.

Artificial recharge of groundwater: The Rus and upper Umm er Radhuma aquifers in northern Qatar have been heavily exploited for agricultural purposes. The total abstraction is far in excess of the average natural recharge. To solve this problem, artificial recharge of freshwater in the aquifer system was conducted.

Development of deep aquifers: the development of the aquifer is constrained by several factors including, depth of occurrence (450-650 m), low well production levels of up to 15 l/s and salinity within the range of 4 000 to 6 000 mg/l.

Increasing treatment and reuse of wastewater: The Drainage Affairs increased the volume of treated sewage effluent through the connection of more residential areas to the public sewer and extension to Doha South and Doha West treatment plants. The amount of TSE increased from 46 million m^3 in 2004 to 58 million m^3 in 2006, and the amount reused in forage production and irrigation of landscape increased from 39 million m^3 to 44 million m^3 during the same period.

Irrigation research and studies over the last ten years have included crop water requirements of the major crops in Qatar, irrigation with saline water, optimising the use of treated wastewater for forage production, the economics of protected agriculture when using desalinated water, optimum use of water resources in agriculture and modernizing irrigation in the Qatari farms.

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

The 'Environmental-Friends Centre', an NGO, has also participated in increasing public awareness especially among students and young people. The salient features of these programmes include: organising field days and exhibitions; conducting specialised lectures, seminars, conferences, symposiums and workshops; issuing technical bulletins, folders and posters; displaying films, presenting TV and radio programmes and publishing articles in newspapers; running campaigns; arranging competitions among school children.

Develop the Aflaj system for irrigation.

7.4.6 Measures to build resilience to drought

Measures to be adopted for improving water resources include:

Formulating IWRM

Capacity building and institutional strengthening

Developing a monitor system to control water resources from rainfall and aquifers

Promote the use of TWW for agricultural use

Water pricing: Water pricing needs to reflect the scarcity value of water, so that governments do not end up subsidising the depletion of an essential natural resource and polluting the environment

Developing a strategy to manage the demand and ensure the efficiency of use in agriculture sectors adopting advanced and appropriate technology

Raising farmer awareness to implement water conservation measures

Increasing natural recharge of aquifer by the drilling of wells to accelerate the natural water recharge from occasional storm tor floodwater.

7.5 UNITED ARAB EMIRATES (UAE)

7.5.1 Background

The UAE is located in the south-eastern part of the Arabian Peninsula. It covers an area of 83,600 km^2 and includes mountains, gravel plains, sand dunes, costal zones and drainage basins (Boer, 1997). More than 75 percent of the area is desert and is one of the hottest countries in the world (DWRS, 2002). The temperatures in summer months often reach 45-50oC and the mean annual temperature is 28oC, while in the winter it can be as low as 3oC (Alsharhan and Kendall, 2002). Rainfall is sporadic ranging between 80 and 130 mm annually. Evapotranspiration rates reach 8mm/day. The United Nations Environment Programme (UNEP) classifies the whole of Abu-Dhabi Emirates and most of the surrounding area as hyper-arid, belonging to one of the most inhospitable regions on earth (Middleton and Thomas, 1997).

Fully four-fifths of the land area is desert with fragile ecosystems including vast loose sandy deserts, oases, long coastlines, islands, and rangelands (Ministry of Energy of UAE, 2006).

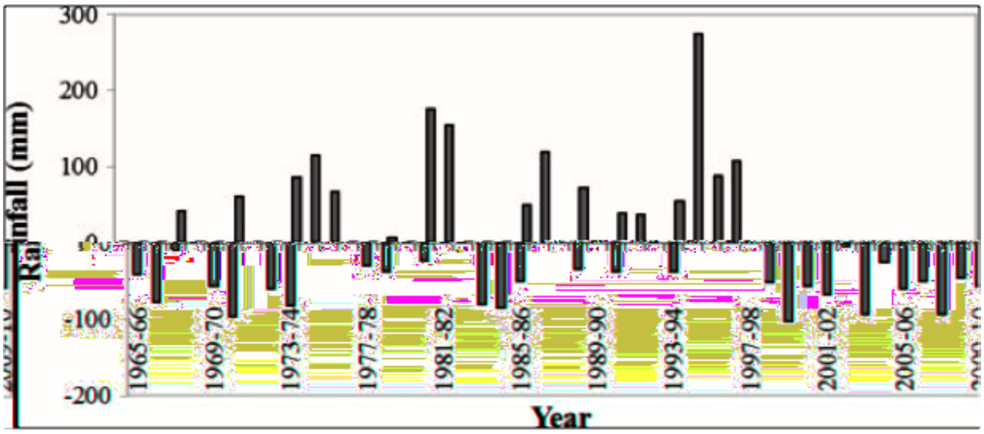
7.5.2 Drought history

The entire region is mostly dry throughout the year but with some surface runoff during rainy seasons. Water resources management is significantly constrained by limited, unreliable rainfall. The spatial temporal variability of rainfall affects the overall hydro-climatic conditions, such as drought and groundwater recharge. Sherif *et al.* (2009, 2011) concluded from their investigation on rainfall characterisation that rainfall events have average drought duration of 2.6 years. Rainfall and runoff deficits have been observed in the UAE over the last couple of decades (Figure 16) and consequently drought persisted for various lengths of years (Al-Rashed and Sherif, 2000). The annual rainfall in the region has reduced significantly since 1998 (Sherif *et al.*, 2009).

In arid regions such as the UAE, groundwater recharge from the ephemeral wadi beds and subsurface flow from mountainous valley beds play an important role in water management and water systems. Current demands in Abu-Dhabi are about 26 times greater than the volume of water which is naturally recharged within the hydrological system (Environmental Agency of Abu-Dhaby, 2007).

FIGURE 16

Departure of average annual rainfall with respect to their long-term mean value in the UAE



Source: Adopted from Amer, 2008; DAWR, 2009

Relatively high average annual rainfall was observed for the period 1995-1998; annual rainfall exceeded the normal rainfall (long-term average) once in 2 or 3 years. However, after 1998, rainfall has decreased. The range varies from 273 to 103mm. The highest rainfall occurred in 1995-1996 and lowest in 1999-2000. The UAE is successively experiencing rainfall deficits since 1999; drought conditions prevailed during the period 1999-2004.

The average annual rainfall varies in magnitude among the regions. The lowest is in the desert foreland and highest in the mountains and east coast regions (Table 20).

Drought is a normal and recurrent feature of this arid climate. Droughts and water deficit have major influences on society, mainly urban economic activities, agriculture, and livestock.

The prevailing drought characteristics in all regions of the UAE (Sherif *et al.*, 2013) based on the conceptual model of Ponce *et al.* (2000) are shown in Table 21. The Drought Severity Indicator (DSI) ranges from 1.4 to 1.5, and the average drought duration ranges from 2.7 to 2.9 years between 1 to 12 years maximum. The average frequency of drought is 4.5 years. Over a period of 45 years, drought was experienced in 28 of them.

Grazing in the Dubai inland desert has changed substantially over the last three decades. Camels are given supplementary feed, so their population is not limited by seasonal availability of vegetation. Desert plants face longer periods of heavy grazing from a larger camel population, and shorter periods for recovery.

TABLE 20

Average, maximum, and minimum annual rainfalls in UAE (1995–1998)

Parameter	East Coast	Mountain	Gravel Plain	Desert Foreland	UAE average
Mean (mm)	124.0	131.9	107.7	74.9	109.6
Maximum (mm)	531.5	418.3	349.7	231.7	382.8
Minimum (mm)	6.4	6.7	10.6	1.8	7.0

TABLE 21
Characteristics of droughts in different regions in the UAE.

Region	Drought events	Drought duration (year)	Drought severity index	Average DSI	Average duration (year)	Frequency (year)	Drought years (%)
East Coast	10	1–7	0.16–3.36	1.40	2.9	4.5	64
Mountain	10	1–12	0.16–7.02	1.49	2.8	4.5	62
Gravel Plain	10	1–12	0.07–6.57	1.42	2.8	4.5	62
Desert Foreland	10	1–7	0.16–4.61	1.50	2.7	4.5	60
UAE as a whole	10	1–12	0.21–6.46	1.41	2.8	4.5	62

Source: Sherif et al. (2013)

Following unification of the UAE in 1971, the government instituted policies to increase agricultural production and to establish permanent settlements and income for nomadic people. The density of wells was dramatically increased, and semi-permanent farms or occasionally used areas became permanent year-round farms. Camel numbers after unification steadily increased to 250 000 (FAOSTAT, 2004). Most camels are allowed to graze the desert on an 'open access' basis that is common throughout West Asia (Ferguson *et al.*, 1998). People would move camp throughout the season each time feed supply for camels dwindled. Wells were dug in frequented places, enabling people to extend their nomadic range. In some places permanent settlements were established, such as Liwa (Abu Dhabi emirate), which has been continuously occupied since at least the 16th century (Heard-Bey, 2001). By these mechanisms, the entire inland sand desert became exposed to camel grazing, though it was not evenly distributed. Land surrounding permanent settlements was more heavily grazed, while land surrounding semi-permanent settlements were periodically grazed and then given time to recover. Other areas were labeled as restricted (Arabic: harim), and only accessed during drought periods when no other feed was available (Aspinall, 2001). Tribes used these areas to survive and to cope with irregular weather patterns that could produce a drought for several years at a time.

Ecological degradation frequently ocurs during overgrazing, but existing shrub and perennial grass species recovered substantially during five years of drought. This indicates that species are adapted for survival under heavy grazing, as would have occurred during the frequent multiple-year droughts. Significant ecological decline has occurred, but most is reversible by changing land management. During winter if the feed was good, camels could obtain most of their water requirements by eating plants. Their herders could also survive temporarily without fresh water by drinking camel milk (Heard-Bey, 2001).

7.5.3 Government policy on drought

Water resources in UAE are from conventional (surface runoff, groundwater, Falajes and springs) and from non-conventional (desalinated water, treated wastewater). The total annual renewable freshwater resources are estimated to be less than 150 million m^3.

Some 80 percent of water consumption is used for different greening projects (both agriculture and parks) and only 13 percent for domestic needs (Nunes *et al.*, 2011). This high rate of water consumption is exacerbated by increasing population, urbanisation and greening projects in the country. Rainfall is not enough to meet the excessive and growing demands. As a consequence, the extremely high demand is one of today's main environmental problems in the UAE and one of the most important threats for the future (Environmental Agency of Abu-Dhaby, 2007). Estimates by the National Drilling Company and the United States Geological Survey (NDC-USGS) in 1996 estimated that if abstraction at that time continued, brackish groundwater might only last another 250 years. But new abstraction figures now suggest that groundwater will only last for another 50 years.

The UAE has been able to develop a prosperous agricultural industry despite its highly arid condition. Since 2002, the "Greening the Desert" programme has been implementing different projects in order to combat desertification. Modern irrigation techniques and water from groundwater aquifers, wastewater treatment plants, and from desalination plants have made it possible to cultivate large areas. There are currently more than 100 000 hectares of cultivated land producing a range of crops including vegetables, fruit, and fodder. However, most farms irrigate with brackish water that will eventually render the land saline.

The UAE total water demand in 2009 was estimated to be 4.5 billion m^3 (Table 22). Assuming current demand patterns and rates continue, the UAE's total annual water demand is expected to double by 2030.

The predicted greatest increase in demand is in the urban sector (household, industrial, commercial). Conversely, water demand for agriculture and forestry is expected to decrease relative to current values as a result of depleting groundwater resources, unless treated wastewater or desalinated water resources are used as substitutes.

The vulnerability of water resources will likely worsen. Given climate projections suggesting the future possibility of lower rainfall, surface runoff could decrease, further reducing both surface and groundwater availability. UAE has undertaken a regional climatic modelling analysis, as well as vulnerability and adaptation studies for water resources. A key finding is the combination of future population growth, irrigation requirements, and economic activity and business-as-usual, will mean that water resource management will lead to future water demand far in excess of current supplies. The essential recommendation was to develop a strategy to reduce per capita water consumption by about 50 percent from current levels, and maintaining this through 2050.

The institutions involved in water management in the United Arab Emirates are presented in table 23.

TABLE 22
Water demand (million m^3)

	Demand	Groundwater	Desalination	Treated wastewater
Agric	1754	1687	67	-
Domestic	1789	87	1600	102
Forestry	456	456	-	-
Amenity	478	60	131	287
Total	4477	2290	1798	389

TABLE 23
Institutions Involved in water management in the United Arab Emirates FAO (1997)

Issue	Institutions involved	Source
Legislation	No comprehensive water law (several federal laws as part of environment and aquatic resources federal laws); Law 17 of 2005 for wastewater; a new water resources law is under final review	
Main WRM administration	Ministry of Energy; Ministry of Environment and Water	
Drinking water supply institution	Federal Water and Electricity Authority; Abu Dhabi Water and Electricity Authority; Dubai Electricity and Water Authority; Sharjah Electricity and Water Authority	Italian Trade Promotion Agency (2012)
Sanitation institution	Ministry of Environment and Water	
Irrigation management institution	Ministry of Environment and Water	
Inter-sectoral coordination	Water and Electricity Council	United Arab Emirates Cabinet
Territorial water management	General Water Resources Authority	

Source: Adapted from Chbouki (1992) by Amesiane and Ouassou (2000)

7.5.4 Vulnerability to drought

Deserts in the UAE are important ecosystems for traditional grazing by domestic animals. As a result of changes in nomadic practices, these regions have shown vulnerability to chronic overgrazing (Ministry of Energy, 2006). The pressure of overgrazing is mainly concentrated on the rangelands, resulting in a loss or reduction in plant cover beyond its bearing capacity (Soebisch and DePauw, 2004).

Rangelands and forests overgrazing are the main causes for flora degradation and accelerated erosion (Mousavi, 2006). Future trends in human and livestock practices may have more impact on desert systems than climate change (Al Shindagah, 2001).

El-Keblawy (2003), shows the difference in the number of species, species diversity, and plant cover density, when comparing in and outside limits of the recently designated protected site in the Al Ain-Dubai road region. The dominant species within the reserve boundaries were the most edible. Outside the reserve boundaries these were absent, which indicates that they were preferential and overgrazed.

Agriculture is becoming vulnerable with the overexploitation of saline groundwater.

7.5.5 Practices to alleviate drought impacts

The 1999-2004 drought, the worst in decades that impacted the whole MENA region, led to the establishment of regional drought networks, such as NEMEDCA "Drought management network for the Middle East, Mediterranean Region and Central Asia" set up in 2001 by CIHEAM, ICARDA, and FAO. NEMEDCA's main purpose is to promote cooperation between countries in the Middle Eastern, Mediterranean, and Central Asian regions, and to service all its members, among them the UEA. In addition, a "Drought Monitoring and Early Warning Centre Middle East" (RDMEC) was set up with the help of WMO, and is located in Saudi Arabia to serve and assist all Arab States to reduce the effects of drought by monitoring. This includes studying the climatic variables, as well as, their environmental; economic and social impacts; issuing seasonal predictions; issuing warnings on severe seasonal climatic events that may become extreme events; analysing the state of vegetation cover and desertification; and developing databases for climate information and climate numerical statistical models.

The West Asian countries are developing preliminary proposals for several networks to implement the UNCCD, including a Network on Drought Preparedness and Mitigation as part of the sub-Regional Action Programme (SRAP) to Combat Desertification and Drought in Western Asia. Two major activities are underway:

The Inventory Studies on Water Resources in West Asia and the Pilot Areas Project. A document presenting a framework for the selection of representative pilot project sites in the different member countries of the UNCCD Sub Regional Action Programme (SRAP) has been finalised.

The West Asian countries have developed their own SRAPs to strengthen cooperation at sub-regional level. Using an integrated natural resource management approach, the pilot areas will serve as sites for the participatory implementation of successful measures to combat land degradation as well as for the monitoring of land degradation and rehabilitation.

The project document will cover three thematic areas: mountain Agriculture (Lebanon, Oman, and Yemen); salt-affected areas (Bahrain, Kuwait, Syria, and the United Arab Emirates); and rangelands (Jordan, Palestine, Syria, and Saudi Arabia). The sustainable management of vegetation cover network will provide catalytic support to member countries to develop and implement national strategies for sustainable management of their land and vegetation cover to increase the income and food security. Activities will promote institutional mechanisms to deal with issues related to the development and management of rangeland, cropland and mountainous areas. Technical and institutional innovation for the management of land resources will be developed and tested. As a result, support and assistance will be provided to selected programmes and partnerships. A successful implementation of UNCCD supposes complementary activities implemented within the SRAP framework and sharing information and technical expertise.

AFLAJ WATER SYSTEM

This is an ancient technique by which underground tunnels are dug to channel water from distant sources to villages where it is needed. It is a tested method that helps conserve water and is still in use around the world today. Aflaj are still widespread in Oman, where there are currently more than 4000 channels with an annual flow of 680 million m^3.

The first aflaj built in the UAE was discovered in 1985 in Al Ain, and dates back to the Iron Age. Whilst some Gulf States may believe they have resolved their water scarcity problems through desalination, there is still a lot to learn from the ancient aflaj system, which not only supplies clean water, cheaply and effectively, but also transports and conserves large masses of scarce, existing water in arid environments (Aburawa, 2011).

7.5.6 Measures to build resilience to drought

The UAE Water Conservation Strategy is a major achievement in the realisation of the government's vision to secure sustainable water resource development for future generations. Among the proactive measures taken to enhance water security are:

A National Water Conservation Strategy was launched in 2010 focusing on water demand management measures in all water consumption sectors, by the establishment of a strategic water reserve (Aquifer Storage and Recovery) that will supply Abu Dhabi city and the surrounding area for up to 90 days at a daily rate of up to 151,400 m^3/day, and by investments in new water desalination, wastewater, and dam construction projects.

An improvement in Water Resources Information System using the Hydro-Geo-analyst and Manager software to gather in a central database all water resources-related data (geology, geomorphology, topography, climate, soil types, hydrogeology, groundwater salinity, water table levels, land use, economical activities, desalination plants, and treated wastewater) necessary for water management and reporting awareness at all levels of stakeholders and society.

Water Demand Management that will be sustained through close coordination between all water sector related partners by:

- Providing an updated and integrated assessment of UAE's water resources and their use
- Providing an understanding of what governs water demand, allocation and use
- Identifying options to improve the efficiency of water use, reduce costs and improve the environment
- Making recommendations to strengthen Federal policy, laws and capacity to comprehensively oversee sound water resources management and use; and
- Enhancing water security and protect surface and groundwater resources, marine, and the environment.

In order to implement the strategy, the following eight initiatives should be implemented:

Develop legislation, standards and Federal mechanisms for integrated water resources management

Better manage natural water resources and enhance strategic reserves

Develop national agricultural policy aimed at water conservation and increasing value to the economy

Manage desalinated water efficiently from a comprehensive and national perspective

Rationalise water consumption to be within the global daily per capita water consumption rate

Review and develop water pricing and subsidy policies

Better manage effluent and reclaimed water

Build capacity and strengthen local expertise on the concepts of IWRM.

7.5.7 Issues

Despite the above measures, there is still not a broad awareness of drought and its impacts, as well as the capacity to mitigate drought. All the effort targets water scarcity management and neglects drought management and water demand-supply management. Having a water management strategy (or policy) in place can help mitigate the impact of water scarcity and improve its management among the society. If a proper policy is not put in place to allow monitoring activities in different sectors, the situation may continue to deteriorate.

7.5.8 References

See Annex.

7.6 OMAN

7.6.1 Background

The Sultanate of Oman is located in the south-eastern part of the Arabian Peninsula. The total area is approximately 309 500 km^2 and it is the third largest country in the region. In 2010, Oman's population was nearly 2.8 million with an estimated average annual growth rate of 2.5 per cent annually. Only 5.9 percent of the land area is considered suitable for agricultural production activities. The 70,434 hectares of cropping is wholly dependent on irrigation (UNCCD, 2005; 2013).

Oman has an arid desert climate with an average annual rainfall of less than 100mm. Bare rock outcrop and very shallow soils are dominant on sloping terrain, whereas very gravelly soils occur in the valleys and alluvial fans. With summits nearing 3 000m above sea level in Jabal Lakhdar, the Hajar Mountains intercept moist air masses, hence receiving relatively higher rainfall than surrounding areas. A dense network of wadis conveys drainage water north to the Batinah plain, and south to the interior of Oman. A large number of scattered oases, mostly using falaj irrigation systems, tap local springs or wadis underflow, to grow mostly date palm, limes, alfalfa, and vegetables (Al-Hashmi, 2013).

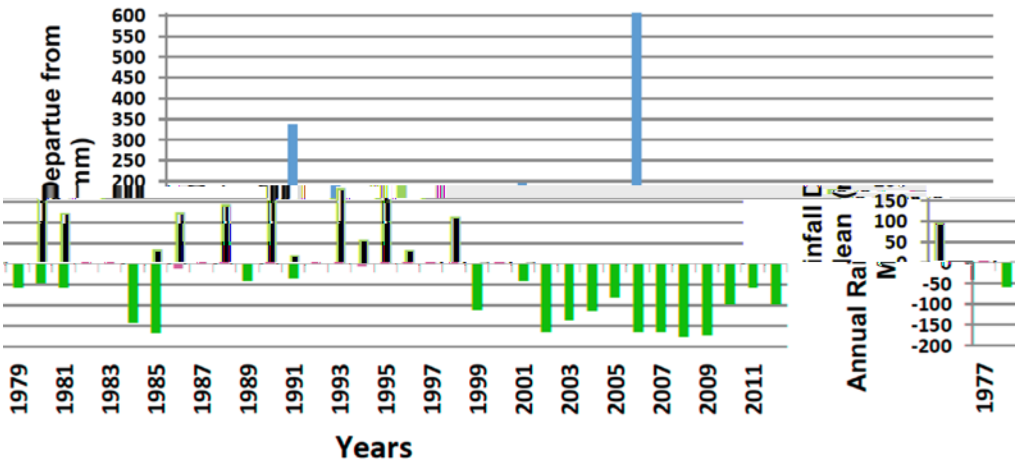
A large part of the southern coast is both arid and semi-arid except for the southern part, which is mainly dependent on the Indian summer monsoon for rainfall. More than 80 percent of total annual rainfall falls during this summer monsoon. Sometimes a heavy storm will deliver all the annual rainfall at one time and cause violent floods. Mean annual rainfall is less than 50 mm in the interior which covers two thirds of the country, and 100 mm along coastal areas. In the mountains, rainfall ranges between 100 mm to about 350 mm. During September to November, very little rainfall is observed (MRME, 2005; Al-Hatrushi *et al*., 2010).

7.6.2 Drought history

Oman has limited freshwater resources. Like most arid countries, it suffers from drought; low rainfall combined with extremely high summer temperatures, and high evaporation rates ranging from 2000 to 3000mm. The amount of rainfall received over Southern Oman during the four months June-September (summer monsoon) plays a vital role in the country’s GDP.

The limited water from rainfall shows inter-annual variability (Figure 17).

FIGURE 17
Inter-annual variability of rainfall anomaly over Oman for period 1977-2012



Source: Ouassou adopted from MRME (2005), Al-Hatrushi, (2011); and Varikoden, (2013)

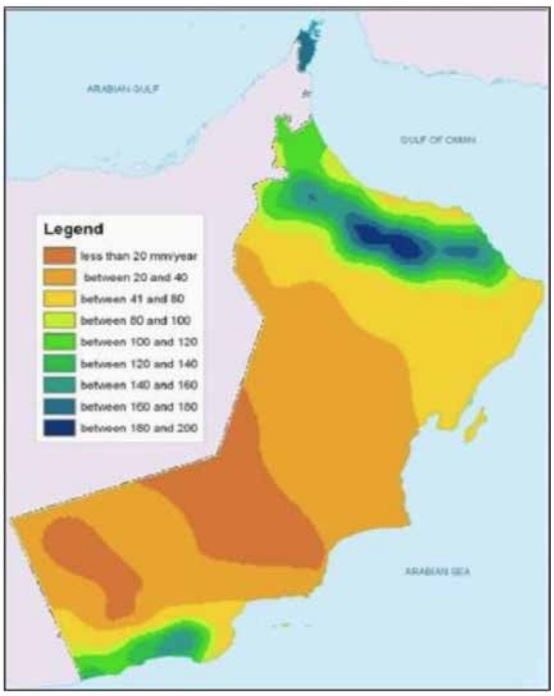
Rapid development during the past 40 years has brought an increase in urbanisation with a high demand for quality water supplies for agriculture, population increase, and rapid industrial and commercial growth. This has created a lot of stress on water resources. The quality of water is continuously deteriorating due to seawater intrusion into aquifers. Consequently, a number of agricultural farms have been abandoned and many others are facing salinity. Renewable water resources have primarily been developed for irrigated agriculture and consumption now exceeds the water availability (MWR, 2000).

Some of the reported drought periods are listed in Table 24.

Rainfall in arid areas tends generally to be very localized and intense with a short duration. It falls on land with limited or sparse vegetative cover, generating flash floods. Figure 18 shows the spatio-temporal variability of rainfall. Some 64 percent of the countrywide annual rainfall occurs during the winter season, and 36 percent in summer (Charabi, 2010).

In 1974-75 in the Western Hajar in the north of Oman, although the adjacent wadis were well-watered, the Upper Wadi al Kabir had received little rain. Although the Upper al Kabir received no rain in July and August in 1973, a length of the Upper Wadi Hawasina, only a few kilometres to the north, was twice deluged with enough rainfall to provide substantial wadi flows which reached the coastal plain some 45 kilometres away.

FIGURE 18
Spatio-temporal variability of the average annual rainfall (1984–2007)



Source: Al Barwani (2010)

TABLE 24
Reported drought periods in Oman

Month	Mean
October	28.0
November	27.5
December	26.9
January	26.5
February	26.5
March	26.9
April	27.7
May	28.2

Source: CIMH

Each shower was torrential with approximately 20mm of rain falling in about two hours (Durham University, 1977).

RAINFALL VARIABILITY

Oman has tried to enhance aquifer recharge by constructing several dams. The objectives are to reduce saline intrusion and to maintain a strategic reserve of fresh water resources, which can be used in case of emergency. According to climate projections of the Intergovernmental Panel on Climate change (IPCC, 2007), droughts in this part of the world will increase in the future.

WATER RESOURCES

The total water availability in 2007 was about 3,517 million m^3.

Groundwater represents 78 percent of the total water supply and recharged annually by rainfall and through surface water infiltration. Nonrenewable groundwater is in the interior regions of the country shared with riparian countries. The southern section (Rub' al Khali) of Umm er Radhuma-Dammam Aquifer System extends across parts of Oman, Saudi Arabia, the United Arab Emirates and Yemen.

Desalinated water accounts for the next highest share of water supply, representing about 15 percent

Surface water accounts for about 6 percent of total water supply. The annual average wadi flow is estimated at 211 million m^3.

Treated wastewater accounts for the remaining 1 percent of total water supply (MRMWR, 2012).

7.6.3 Vulnerability to drought

Agriculture, which is totally irrigated, is the most vulnerable sector. The coastal plains have some of the best soils and relatively important water resources. Nearly half the cultivated area in Oman is in the Batinah coastal plain. Excessive expansion of the cultivated land has led to seawater intrusion and salinisation of the groundwater and the soils. Groundwater remains the main source of water across the country. Almost 44 000 pumped wells irrigate 69 percent of the cultivated land and some 3000 Aflaj (or earth tunnel) serve the remaining 31 percent. However, some 80 percent of the area is still irrigated using traditional surface flooding methods which tend to be wasteful for water (Al Hattaly *et al*., 2010).

In 2005, 13 percent of Oman's population of 2.4 million was economically active in the agricultural sector and it provided permanent employment for the 226 500 people of whom 170 000 were Omani (Central Bank of Sultanate of Oman, 2011). In 2010, the population reached nearly 2.8 million.

An important part of the population irrigate using Aflaj. This source is 43 percent of the total renewable water resources available (Almamary, 2002). Aflaj oases provide the basic income for thousands of farmers in the rural areas. Changes in the reliability of

Aflaj as a consequence of drought and climate change could have serious consequences for the Aflaj oases communities.

In 2010, drought impacted livestock and herders' wellbeing as it affected 20,480 hectares of perennial forage crops used to feed over 2.5 million animals (MRMEWR, 2001).

The vulnerable sectors after agriculture are the industrial and tourism sectors.

7.6.4 Government policy on drought

Actions taken by the government to alleviate the impacts of drought and desertification include:

Preparation of the National Conservation strategy (NCS) of Oman, which laid the basis for future environmental policies

Preparation of plans for the survey and development of Regional water resources

Preparation of the National Plan to Combat Desertification (NPCD) as cooperative efforts of UNEP, ESCWA, and FAO

Study of water resources development and preparation of National Water Master Plan (NWMP)

Preparation of Master plan for ground water pollution protection (MPGWPP) (Al-Balooshi, 2003).

REACTION TO WATER SCARCITY

Since the 1970s, the government reacted to complement water from conventional water resources (surface water and groundwater), by focusing on non-conventional water resources, such as desalinated water and treated wastewater (Al Khabouri, 2007; UNCCD, 2013).

Desalinated water: Desalination is making an important contribution to water supplies. The majority of the desalination plants are installed on the coastal regions using sea water as the feed water. There are however, many small plants in the interior treating brackish groundwater (MRMWR, 2000). Desalinated water about 15 percent of total supply. By the end of 2007, there were 94 desalination plants. Of these, 47 used seawater as the feedstock and the rest used brackish water (UNCCD, 2013).

Treated wastewater: Wastewater collection, treatment and reuse. There are collection and treatment systems for some 25 percent of the Muscat municipal population. A treatment plant has been constructed at Salalah with a collection system. Additional facilities are being installed and commissioned in other main cities. The principal reuse of wastewater is for municipal greening in Muscat and Samail. Treated wastewater accounts for 1 percent of total water supply. The first project was completed in 2003 for reinjection of 20 000 m^3/day in the coastal wells in the Salalah plain to prevent seawater intrusion. In the Muscat Governorate, the current treatment capacity is 25million m^3/year.

PROACTIVE WATER MANAGEMENT

Several water conservation initiatives have been developed, such as leakage control in municipal water supply schemes and the improvement of irrigation methods through subsidy programmes. Public awareness of water resource issues has created a general and focused understanding of the overall situation and of the specific contribution each citizen can make. A number of national priorities and strategies related to water resources developed including:

Protection of the groundwater resources in qualitative as well as quantitative terms

Expanding water use monitoring

Control of saline water intrusion by reducing abstraction to below the long-term recharge rate

Construction of recharge dams and other hydrological structures

Increase the use of desalinated water for domestic purposes

Conservation of water for the agricultural sector through

- Moving high water consuming crops to brackish water areas
- Limiting cultivation of perennial grasses and high water consuming crops
- Promoting seasonal crops and limiting perennial cultivation
- Promoting modern irrigation techniques
- Promoting the use of brackish water for agricultural use.

The decentralisation of water management using a participatory approach is practiced in the system of Aflaj. User associations determine water allocations.

POLICIES AND LEGISLATION

Oman has embarked on institutional reforms for IWRM. Policy-makers have now shifted from entirely supplying solutions to demand management, highlighting the importance of using a combination of measures to ensure adequate supplies of water for different sectors. Oman has several laws on water resources, among them is the new Royal Decree defining water as a national asset to be protected, regulating activities related to wells and aflaj, and preventing water pollution. Measures being taken include management and conservation of water; control over well drilling; stopping the expansion of irrigation; and providing financial subsidy for the application of modern irrigation systems with the intention of rationalising water use for agricultural production (MRMEWR, 2005).

DROUGHT MONITORING AND EARLY WARNING SYSTEM

The government also intends to setup a monitoring and early warning system for drought management, and coordinate the dispersed water monitoring capabilities presents in different ministers and institutions, prepare drought and water plans and revise policy to integrate drought and water scarcity management.

But at present, there are no such systems in place. Each ministry follows water independently. The lack of an early warning system is a limiting factor in effective management of water resources. The Ministry of Environment & Climate Affairs (MECA) strongly believes that monitoring will be the key for drought management's success. The Ministry of Regional Municipalities and Water Resources operates 464 rainfall stations, 15 of them working via satellite and 18 are telemetry stations with a database having records going back over 100 years.

Improved information delivery systems would provide reliable, timely, and transparent information for decision-making, and project implementation. While the Ministry of Environment & Climate Affairs and other government organisations, like Ministry of Agriculture and Fisheries, have monitoring programmes, they are currently not integrated. A comprehensive integrated approach is needed to connect various monitoring efforts and to fill information gaps (MECA, 2012).

INSTITUTIONS INVOLVED IN DROUGHT AND WATER SCARCITY

The Ministry of Regional Municipalities and water Resources (water resources); the Ministry of Environment and Climate Affairs; the Ministry of Agriculture and Fisheries (irrigation management); the Ministry of Transport & Communication/ Directorate General of Meteorology; Public Authority for Electricity and Water (water supply); Oman Waste Water Company (collection, treatment & reuse of treated water); Municipalities; Public Authority for Stores and Food Reserve; and other government and private entities play a prominent role in securing adequate water in drought prone areas with limited resources of water and commodities.

7.6.5 Practices to alleviate drought impacts

While a vulnerability assessment has not been undertaken of water resources, the government outlined the current framework for IWRM to alleviate drought impacts. Decision-makers consider IWRM as fundamental to organising a framework to identify potential adaptation strategies for water resources in which water demand is increasing due to accelerated socioeconomic development while freshwater supply is decreasing and deteriorating.

Actions include ensuring a balance between water use and renewable water supply in order to preserve water resources, limit pollution, and support ecosystem functions; pursuing water security especially during drought periods through enhancement of public awareness of water scarcity through campaigns as an initial measure to reduce water use in domestic, industrial and agricultural sectors; increasing the efficiency of water supply by reducing losses through transmission and distribution pipes; using more treated wastewater; enhancing water supply by freshwater exploration/discovery, groundwater recharge initiatives, surface dam construction, rainfall harvesting techniques, and greater use of non-conventional water resources such as desalination, and use of treated wastewater or brackish water; promoting sustainable resource use by balancing water consumption by agricultural, industrial, commercial, and tourist activities with water resource constraints; and preserving water quality through new legislation and institutional reform at the national and regional levels.

7.6.6 Measures to build resilience to drought

With less future rainfall, groundwater recharge and surface water flow are expected to also decrease. When combined with continued socioeconomic growth, current challenges in balancing water supply and demand will be more difficult, as will the capacity to maintain water quality standards. Even without climate change occurring, water availability and groundwater deterioration have been identified as major development constraints, with absolute water scarcity predicted as early as 2020 (MRMWR, 2012). Alternative non-conventional resources are the only realistic option to maintain adequate supplies together with on-demand management. See Appendix 16 for more details.

7.6.7 Issues

In areas where the status of land ownership is not clear, practitioners may be reluctant to make long-term investments and would not be able to access credit. Sorting out the land ownership issue would be the main measure required for the plan to succeed.

Demand management should include further measures to make people more conscious of using water efficiently, and encourage those who fall into the high use group to cut back on use. These could include applying and increasing water tariffs to cover the true cost of water; reducing fuel and agricultural subsidies, including those on irrigation equipment; metering groundwater wells; and public awareness campaigns.

Cooperation with riparian countries would help the sustainability of aquifers and coordinate their management at sub-regional level such as the "GCC Water Cooperation Committee" established in 2002.

Coordinate research and development to help reduce the unit production costs of desalination and treatment of wastewater, and the use of solar energy.

Food self-sufficiency policies have not been successful and are not sustainable. The concept of "virtual water" holds immense relevance. By assessing how much water can be saved through importing certain food items (particularly those that consume high amounts of water such as alfalfa for dairy production of wheat), a huge amount of water can be saved and more appropriately used. Analysis of "virtual water" should be included in development plans as a means of relieving pressure on scarce water resources. Oman estimated that "virtual water" imports into the country in 1998 were approximately 3,860 million m^3, which is similar in amount to the whole natural renewable water resources available in Oman. This provides strong insights as to how much water could be saved by importing food and possibly shifting the saved water to other economic purposes or conservation for future generations.

7.6.8 References

See Annex.

7.7 YEMEN

7.7.1 Background

Yemen is one of the poorest countries in terms of water resources – 120 m^3/capita/year, which is well below the critical water scarcity level of 500 m^3 (USAID, 2012). Yemen's population in 2013 was 24 million and is growing at 2.3 per cent a year making it one of the fastest-growing according to the World Bank. Rainfall is highly erratic in time, quantity, and location, and falls in two main seasons: March to May (Seif), and July to September (Kharif), the latter being wetter (Van Der Gun and Ahmed, 1995).

Yemen can be divided into four main geographical regions: the coastal plains in the west, the western highlands, the eastern highlands, and the Rub al Khali in the east. The total land area is 55 million hectares, most of which is barren mountains and deserts with wadis. About 2 million hectares is potentially cultivable (CSO, 2007). However, due to the scarcity and variability of the water resources, the average annual total cultivated area is not more than 1.5 million hectares. In wet years with well-distributed rainfall, the total cultivated area reaches 3.5 million hectares.

Agriculture is the largest sector of the economy. In 1998-99, it accounted for 30 percent of GDP and employed 58 percent of the total working population. Some 77 percent of the population derive their livelihoods from agriculture and related activities (IMF, 2001). Numerous environmental problems hamper growth in this sector, such as soil erosion, sand dune encroachment, and deforestation. But the greatest problem by far is water scarcity. Agriculture relies heavily on groundwater but water tables are falling by approximately 2 meters annually. Irrigation has made fruit and vegetables primary cash crops. Traditional rainfed crops such as cereals have declined. According to the World Bank, cultivation of the narcotic plant "qat" plays a dominant role in Yemen's agricultural economy, constituting 10 percent of GDP and employing an estimated 150 000 people and displacing land areas that could otherwise be used for exportable coffee, fruits, and vegetables.

7.7.2 Drought history

The annual rainfall is between 346mm and 876mm with an average of 584mm. Mean potential evaporation is 1640mm (Bruggeman, 1997). To identify the dry or drought years, Demuth and Stahl (2001) suggest the 80 percent percentile (P80) as a threshold for a meteorological drought, which corresponds to an annual rainfall of 446 mm. Rappold, (2004) examined the annual rainfall data available from Ta'is located on the foot of Jabal Sabir in Yemen (Figure 19) for trends of wet and dry years for the period 1944-1995. The result was 9 out of 41 years were considered dry – 1945, 1961, 1983 to 1986, 1988, 1991, and 1994, indicating the increase in frequency and severity of drought from the beginning of 1980s. Recent drought events were observed in 1990-91 and 1998-99 (IMF, 2001); and 2007 to 2009 (IRIN, 2009). Thus from 1980 to 2009, 14 dry years out of 29 years or 48 percent almost twice the percentage observed during the whole period 1944-1995, indicating an increase in the number of dry years during the last two decades.

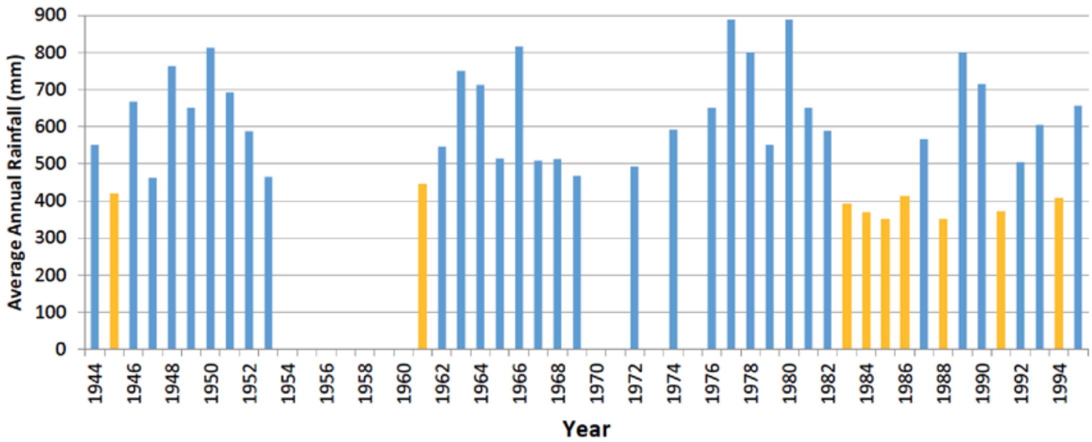
Due to the uncertainty of present climate predictions for the highlands of Yemen, the impacts of climate change on agriculture range from more rainfall and greater floods to less precipitation and longer drought periods (IPCC, 2007).

7.7.3 Impact of drought

Yemen has a semi-arid to arid climate. Annual rainfall is less than 50 mm along the Red Sea and Gulf of Aden coasts to a maximum of 500-800 mm in the Western Highlands. It is below 50mm inland. Drought has its hardest impacts in the months February and March. The combination of high population growth and over-stretched water resources has contributed to a severe water crisis that may be one of the most catastrophic in the world.

Yemen's total annual renewable water resource amounts to 2,100 million m^3 while the total demand is estimated to be 3,400 million m^3. 1,300 million m^3 comes from deep

FIGURE 19
Annual rainfall of Ta'is region in Yemen for the period 1944-1995



Source: Ouassou adopted from Rappold, 2004

aquifers, which are declining at 1 to 7m annually (Al-Asbahi, 2005). Groundwater resources are running out and some areas could be depleted in just a few years. It is a crisis that threatens the very survival of this arid, overpopulated country.

The government now supplies water once every 4-5 days in some urban areas, and in much of the country there is no public water supply at all. The market price of water has quadrupled in the past four years. The lack of water is fuelling tribal conflicts and insurgencies (Worth, 2009).

Since the 1970s, Yemenis turned swiftly from rainfed farming to irrigation using water pumped from new tube wells, encouraged by the government and foreign donors keen to expand production. But at the same time this helped "qat" cultivation (Ward, 2000). The narcotic leaf "qat" has become the cash crop of choice as it commands the highest price in local markets, and as much as 40 per cent of available water resources are used for the irrigating "qat" alone (World Bank, 2007).

Groundwater is not just for agriculture and livestock, it is also the main source of water for the major cities. In 2006, 59 per cent of the urban population and 38 per cent of the rural population were covered by government-run water supply. This leaves the majority of the population at the mercy of unregulated businessmen who pump water from aquifers and wells and transport it to markets by truck. According to the FAO, in 2008 there were 52 000–55 000 wells in active use, with 800 drilling and production rigs in use across the country. Only 1000 wells and 70 drilling rigs were registered and licensed for use (Erian, 2013).

The yields of irrigated crops by spate irrigation vary widely and are influenced by floods and years with less than normal rainfall. As a result of drought in Tihama wadis, yields varied from 600 to 3 500 kg/hectare for sorghum, 600 to 1,200 kg/hectare for millet, 350 to 700 kg/hectare for sesame, 5000 to 14 100 kg/hectare for melon, and 650 to 1,600 kg/hectare for cotton. Some households have installed wells to have access to pumped irrigation, in order to reduce the risk of crop failure, and obtained net annual revenues that are at least twice as much as for households depending exclusively on spate irrigation (Noaman, 2009).

During a severe drought in 1990-91, cereal production declined sharply (IMF, 2001).

IRIN (2009) reported that near the capital, Sanaa, from 2007 to 2009, severe drought forced local herders to sell some of their sheep to buy fodder for the rest, but fodder prices have increased threefold over the past two years. The selling price for a breeding ewe fell from US$89 in early 2008 to $54 in 2009.

Malnutrition resulting from drought was to blame for the fall in dairy production, high abortion rates, and the spread of blood parasites and epidemics among ruminants. Many thousands of sheep and goats died. Drought causes also the terms of trade to turn against producers. The price of essential grains rise while the sale value of their stock falls since many other producers are also trying to sell their animals in order to survive. This is accompanied by deterioration in the quality and size of the animals on sale. Herders may also sell classes of animals, such as pregnant females, which they would normally retain (IRIN, 2009).

7.7.4 Vulnerability to drought

Yemen is highly vulnerable to drought impacts. According to the Yemen Environment Authority, more than 75 percent of the population is rural-based and engaged in farming and pastoralism, and hence highly reliant on climatic conditions for their livelihoods. Yemen's economy largely depends on its rural natural resources. Recently, Yemen suffered from increased drought frequency, increased temperatures, and changes in precipitation patterns leading to degradation of agricultural lands, soils and terraces. Livestock farming while constituting only 2.5 percent of Yemen's GDP in 2008, according to Deputy Minister of Agriculture and Irrigation, it is the main income source for over 3 million people in the southeast. Families who are entirely dependent on herding for their livelihoods are the most affected by drought, as they have no alternative sources of income. Thousands of herders were forced to move with their livestock to faraway areas in search of pasture and water. They relied only on underground cisterns filled by rainwater or trucked in water sold at a higher price in remote villages (IRIN, 2009).

Yemen has no perennial rivers, and depends on rainfall from water run-off and groundwater recharge. The drought had serious repercussions on the food security of a large segment of the population (ESCWA & DESA, 2013).

WATER RESOURCE VULNERABILITY

Water is available from wadis, springs, shallow wells, boreholes, and traditional cisterns that collect run-off. Groundwater constitutes the majority of total renewable water resources, while rainfall is the major source of all water in the country. The distribution of water is erratic, with 90 per cent of the population having less than a minimum standard of domestic supply; access to water has become a survival issue (ESCWA2, 2007). Yemen's poverty and lawlessness make the problem more serious. Unlike some other arid countries in the region, Yemen lacks the money to invest in desalination plants. Even wastewater treatment has proved difficult. Oil production has passed its peak and output is declining (Bennett, 2010). Yemen has limited water desalination capacity to compensate for water shortages. The quantity of desalinated water was estimated at 10 million m^3/year in 1989, contributing to the water supply of Aden (UNFPA &Yemen, 2012). As a result of very high population growth, expansion of irrigated areas, and rapid industrial growth, Yemen's water resources are being pumped and are diminishing at alarming rates. This vulnerability is magnified by the poor management of scarce and overexploited water resources. The agriculture sector is by far the major consumer of water and, since it is not priced, water use efficiency in the agricultural sector is very low. Outdated and poorly maintained irrigation systems have allowed for significant water losses and mismanagement.

Farmers supplement spate irrigation with groundwater withdrawals, leading to the rapid increase in aquifer depletion, combined with declining rates of recharge during drought periods (ESCWA1).

AGRICULTURAL VULNERABILITY

Drought can be highly detrimental to the agricultural sector and Yemen's food security. Given its high level of food aid dependence, which peaked at 6.1 per cent in 2002, Yemen is particularly vulnerable to drought-induced agricultural crises (ESCWA1, 2005).

Irrigated farming systems are still heavily dependent on rainfall, especially those under spate irrigation systems. Agricultural production and productivity in rainfed areas are extremely low averaging 1.2 tons/hectare. Expansion of irrigation systems could decrease the risks associated with rainfed farming and increase yields, but there are no adequate water resources to expand irrigation at current water use rates.

The rangeland, occupying 75 per cent of Yemen's land area, is seriously vulnerable to drought. Reduced pasture and fodder production due to drought, leaves herders with insufficient feed for their livestock, thereby losing their livestock to malnutrition, disease and starvation, while others are forced to liquidate their livestock assets, by selling them for premature slaughter.

ENVIRONMENTAL VULNERABILITY

The degradation of watershed basins has serious economic, ecological, environmental, and social implications, which reduce Yemen's resilience to drought. Most watershed areas suffer from extensive soil erosion due to poor land use and recurrent droughts. It is estimated that 92.8 per cent of the country is at risk of desertification (Althawr, 1999) owing to drought that reduces plant cover and changes the micro-climate (Abu Hatim and Shawky, 2009).

SOCIO-ECONOMIC VULNERABILITY

Despite the availability of oil, Yemen remains one of the least developed countries in the world (UNDP Human Development Index, 2003; World Bank, 2005a). The high dependence on agriculture means there is low resilience to socio-economic drought. Yemen only grows a third of its food needs. The fast-growing population and limited agricultural growth means there is increasing reliance on food imports, which increased 48 per cent between 1961 and 1991, and 75 per cent in the period 1992-2002. Yemen is now one of the most food-aid dependent countries. Poor access to safe drinking water and sanitation are threats to public health (World Bank, 2005b). The growing water shortage and increasing pollution is leading to worsening environmental health. The incidence of diseases has in large part resulted from low connectivity to sewerage systems, erratic water supply, and water shortage during drought (ESCWA1, 2005).

7.7.5 Government policy on drought

Yemen's approach to managing drought is currently reactive, focused on post disaster relief and recovery activities. There are no sustainable drought management and strategies plan, even in the Yemen National Adaption Programme of Action (NAPA) planned measures (ESCWA & DESA, 2013).

However, the drought of 1990-1991 which affected the entire country, and was the worst in living memory forced the government to adopted serious actions. The government has taken steps to mitigate the water shortage situation since 1991, including:

Creating a single water resource management agency, the National Water Resources Authority

Institutionalising water conservation programmes such as fog collection, water harvesting, water treatment and reuse, dams, and water rationing

Improving access to sanitation with increased connectivity to sewerage infrastructure

Institutionalising food security programmes, such as the credit subsidy for wheat and flour, diesel fuel for water pumps, groundwater irrigation, and maintenance subsidy for spate irrigation

Institutionalising poverty alleviation strategies, including increased access to credit in rural areas.

Some of these measures form a base for moving from a reactive to a preventive approach to drought and water management. They had positive effects on poverty and water supply. But the water scarcity and drought-related problems have outpaced the Government's ability to mitigate their effects. The government response to drought is largely reactionary as there is no early warning system or national drought preparedness plan.

In 2003, Yemen became the first country in the ESCWA region to administer a Food Insecurity and Vulnerability Information and Mapping System (FIVIMS) survey, with FAO assistance, to identify food insecurities, their locations, coping mechanisms and consumption habits, and intra-household impacts. Because the issues of food insecurity and socio-economic drought are strongly linked, this initiative serves as a base for monitoring socio-economic drought. The survey and national water strategy are first steps towards drought preparedness.

In 2005, the government developed a national water strategy within the National Water Resources Authority (NWRA), which gives national water resource management a much needed focus. The government remains committed to addressing the issues of poverty and food insecurity, which are strongly linked to water shortage and drought (ESCWA1, 2005).

INSTITUTIONAL FRAMEWORK AROUND INTEGRATED WATER RESOURCE MANAGEMENT AND DROUGHT

The responsibility for IWRM, drought, and climate change (Wodon and Liverani, 2014) lies with:

The Ministry of Water and Environment (MWE), established in 2003, is responsible for water resource planning and monitoring, drafting legislation, and building public awareness. In practice the Ministry's authority extends only to urban areas. Subsectors of the Ministry include the National Water Resources Authority (NWASA), General Rural Water Authority, and Environmental Protection Authority (EPA).

The Ministry of Local Administration (MLA) is responsible for water supply and sanitation in rural areas.

The Ministry of Agriculture and Irrigation (MAI) is responsible for policies on irrigation, crops, livestock, and forestry (Al-Asbahi, 2005). Plans for ensuring the sustainability of the country's water resources, increasing the productivity of irrigated agricultural land, and reducing governmental involvement and relying more on user groups to manage the resource are all part of Yemen's National Water Strategy and National Irrigation Strategy (FAO 2008). The General Directorate of Forestry and Desertification Control, established in 1984 within the MAI, is responsible for forest supervision, formulation of forest policies and strategies, implementation of forest campaigns, and desertification control (FAO, 2008).

Despite the progress in establishing central water and agricultural management organisations, institutional arrangements for central drought monitoring and drought early warning are lacking. Therefore, significant changes in the institutional structures and water resources policies are needed to enable a more multi-disciplinary and integrated approach to drought preparedness.

Agriculture and water management institutions are relatively young, and institutional capacity and authority are still weak. Data are scant and not always comprehensive or reliable, which constitutes a significant obstacle to drought monitoring. Furthermore, in all these institutions, there is a shortage of trained scientists and information exchange is not a policy. In general, there is no baseline study that has been carried out on drought, and the current information on drought is ad hoc and without a focal institution.

7.7.6 Practices to alleviate drought impacts

MEASURES AND PRACTICES APPLIED BY GOVERNMENTS AND OTHER SUPPORTING INSTITUTIONS

Agricultural and poverty alleviation policies of the past included: low-interest loans, subsidised diesel pricing, free or below-cost priced water, uncontrolled groundwater drilling, banning the import of fruits and vegetables, and public investment in surface or spate irrigation. However, these actions have encouraged further depletion of groundwater, and many of these policies have since been reversed.

Most of the population and economic activity are concentrated in the water depleted western highlands, making it difficult to explore alternative sources of supply such as desalination as the sea is far away from where it is needed and the cost of water transfer would be prohibitive.

Post drought relief activities consist of emergency relief and recovery programmes, which involve various branches of technical ministries, and utility agencies at governorate level.

Some international relief agencies such as FAG, UNDP, GEF, and IUCN helped Yemen in developing a strategy on climate variability and biodiversity; others on food, health, rehabilitation and relief actions.

The World Food Programme is the most important food assistance organisation in the country.

The FAO Emergency Operations and Rehabilitation Division in the Technical Cooperation Department (TCE) included in the 2010 Yemen Humanitarian Response Plan (YHRP) to respond to a series of acute and chronic humanitarian needs which have been triggered. The three projects address problems of seed availability through the distribution of improved, drought-tolerant wheat, sorghum and millet seeds for small and medium scale cereal farmers, as well as of feed provision to small-scale livestock owners, with special attention to IDPs in Sa'dah.

The EMOP to support drought-affected families by high food prices, targeted in districts where more than two-thirds of the population is living below the poverty line.

The Country Programme (CP) serves as one of the few safety nets for vulnerable rural families in Yemen and consists of two activities. Health Nutritional support to mothers and children (and leprosy and TB patients). Patients are provided with take-home family rations.

MEASURES AND PRACTICES ADOPTED BY PRACTITIONERS

Measures used to counteract droughts impacts and floods include:

Adapting plant varieties and rain or flood water harvesting techniques, which were part of the traditional forms of land management in the highlands of Yemen.

Diversifying the household economy. Poorer households in spate-irrigated areas generally depend on multiple sources of income.

Many live animals are sold cheaply to fund emergency feeds to keep the rest of stock alive. When conditions improve, they often return the animals to the pastoralists to manage them.

Using different plots of land to increase the probabilities of the crop success

Saving surplus grains from one year to bridge the gap to the following year

Investing in easily disposable property, such as livestock, in good years with crop surplus to be sold in a lean year

Wage labour and off-farm income-generating activities

Exploiting locally available natural resources, in particular trees for the sale of timber, fuel wood and charcoal

Migrating male household members in search of labour in or outside the country

Borrowing money from relatives, suppliers and/or money lenders

Bee keeping.

Adopting low-value, drought-resistant subsistence crops, such as sorghum, wheat, millet

Producing fodder crops to support livestock

Moving from rainfed farming to irrigation using water for "qat" cultivation (Ward, 2000).

7.7.7 Measures to build resilience to drought

See Appendix 17 for details.

7.7.8 Issues

The supply-demand gap is widening alarmingly and cannot really be bridged without rationalising water use through appropriate water management and development policies.

Agriculture accounts for more than 90 per cent of the total water use mainly for 'qat' growing at the expense of potable water and leading to groundwater depletion. This problem has outpaced the government's ability to change.

7.7.9 References

See Annex.

Annex: Country References and Appendices

1. North Africa

1.1. MAURITANIA

1.1.1. References

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1.1.2. Appendix 1: Drought risk management options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U	Exploiting high-cost waters	U,A,I
	Treatment and reuse of wastewater	A,I	Over-drafting aquifers	U,A,I
	Water transfers	U,A,I,R	Diverting water from specific	U,A,I
	Locate potential new resources standby supplies	U,A,I	Decreasing transport and distribution losses	U,A,I
	Aqueducts and canals	U,A,I	Adjust legal and institutional framework	U,A,I,R
	Groundwater recharge; Artificial recharge using harvested water	U,A,I	Reallocation of resources	U,A,I,R
	Monitoring and forecasting	U,A,I,R	The risk of groundwater pollution and soil pollution is possible if only treated wastewater is used	A
	Alternative desalination technology	U,I	Health risk evaluation of using treated wastewater in agriculture	A
	Alternative desalination technology	U,I	Health risk evaluation of using treated wastewater in agriculture	A
	Artificial recharge using RO water	U,I	Labor migrating to earn an income and the move towards non-farm livelihood incomes. The role of migration as an adaptive measure, particularly as a response to drought is also well known.	A
	More research on the technology of desalination plants to deliver seawater into fresh water in a safe and reasonable price	U,A,I,R	Labor seasonal migration, providing a critical livelihood source. The role of remittances derived from migration provides a key coping mechanism in drought years	A
	More researches on the MFS technology compared with RO technology related to the reliability, quality and risk in reuse of treated sewage in agriculture and irrigation and environmental impact on both surface water and groundwater	U,I	Agricultural capital stock and extension advice can raise household welfare and strengthen resilience during non-drought years.	
	Adjust legal and institutional framework	U,I	a schedule of the various prophylactics for the most prevalent diseases of the different species, depending on systems of husbandry, eco-climatic conditions and categories of animal.	
Demand management	Improved early warning systems and their application may also reduce vulnerability to future risks associated with drought, climate variability and change.		Improvement of animal products through selection program and ensure effective participation of livestock herders.	
	Shift towards drought-tolerant crops		Improvement of local poultry farming conditions prevention of disease, housing, watering and feeding conditions.	
	Livestock farming sector focus on the reduction of risks related to the restriction of grazing land, and the development of animal health and production. To ensure that pastoral land is not partitioned, the establishment and the implementation of a pastoral code promoting free access to resources and mobility are essential.		Popularization of village poultry farming should be organized using women nominated by their respective communities	
			Disseminate adequate techniques to improve the nutritional and quantitative value of fodder, and provide animals with supplementary minerals small workshops for making salt-licks and multi-nutritional blocks.	
			Livestock herders' organizations should spread information, supply and stock supplementary feed for strategic periods	
			Promote an alternative source of energy to meet the needs of communities. The use of butane gas is the most promising form in the light of the experience of SOMAGAZ Mauritanian Gas Company. However, other new or renewable forms of energy could be envisaged: kerosene, wind and solar energy, peat, etc.	

Adopting supplementary and deficit-irrigation	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
Water saving irrigation techniques drip, sprinkler	A	Restricting municipal uses lawn irrigation, car washing, …	A,I,R
Incentives to invest in water saving technology	U,A,I	Water metering and pricing to reduced extremely high per capita water consumption	U,A,I
Water recycling	U	Restructuring the water tariff	U,I,A
Dual distribution networks for drinking water supply	U	Water rationing	U,A,I
Inventory private wells and negotiate their public use	U,I	Education and awareness creation	U,A,I
Assess vulnerability and advise water users	U,A,I	Provide permits to exploit additional resources	U
Elaborate alert procedures	U,A,I,R	Negotiate transfer between sectors	U,A
Carry-over storage	U,A,I	Mandating water collecting devices	U
Conjunctive use	A,I	penalizing wasteful practices	U,I,A
Adjust legal and institutional framework etc.	U,A,I,R	Water auditing and stakeholders participation	U,A,I,R
Groundwater protection	A	Reduction of leakage in the main network	U,I
Awareness programs	U,A,I,R	Awareness programs	U,A,I,R
	U,A,I,R	Adjust legal and institutional framework	U,I,A,R
		Revising water subsidies	U,I,A
		use in agriculture a combination of water tariff system and of water conservation technologies	A
Implementation of the Integrated Water Resource Management approach		For irrigated crops: intensification and the diversification of agriculture to promote crops with high yields and small-scale irrigation.	
Regular assessment of availability of water resources and requirements.		For rain-fed agriculture crops Improving agricultural methods in pluvial zones by introducing new drought-resistant, high-yield cereal species	
Establishment of a system of monitoring and mitigation of impacts related to the dynamics of sustainable socio-economic development which respecting the conservation of the environment.		For rain-fed agriculture crops: Promoting economical irrigation techniques in oasis areas drip irrigation pilot schemes	
Promote rapid dissemination and circulation of information among partners in an effort to organize periodic submission of results and to draft priority action plans.		Training and informing producers, their Socio-Professional Organizations SPO, and Community Educators CE	
Establishment of a schedule for division of water and management regulations to prevent conflict of use.		Diversification of livelihood activities	
Establishment legal and economic regulations to promote improved use of water resources.		building of stronger livelihoods to ensure resilience to future shocks	
Prior reinforcement of capacities to ensure the perfect implementation of Integrated Water Resource Management		cash transfers	
Putting an end to the causes of the degradation of the principal land ecosystems and measures for their restoration wood and charcoal, pasture-land and agricultural production and sustainable management of the various land ecosystem types wetlands, agricultural ecosystems, forests, pasture-land ecosystems.		school feeding schemes	
National grain reserves		food price subsidies	
Weather insurance		Promote collaboration between the different structures involved in collecting, analyzing, and monitoring pastoral and agricultural information, and the structure following up plant diseases.	

	Epidemiological studies should be carried out and broadened to enable the development of an epidemiological map
	The strengthening of marketing potential improving networks for marketing milk, red and white meat, leather and hides by taking action on conservation equipment, types of conservation, and collection systems
	Strengthened land ecosystems by reforestation for energy purposes agro-forestry projects and production wind-breaks, notably and assisted plantation of trees manual or aerial sowing of seed, hoeing.
	Develop forestry by integrating the concepts of management and control. The forests in Mauritania are under threat because they are being used without any form of renewal; the production activity should be limited to their capacity for regeneration

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

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1.2.2. Appendix 2: Drought risk management options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
	Increase water collection and storage opportunities reservoirs	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U	Exploiting high-cost waters	U,A,I
	Treatment and reuse of wastewater	A,I	Over-drafting aquifers	U,A,I
	Water transfers	U,A,I,R	Diverting water from specific	U,A,I
	Artificial precipitation	U,A,I,R	Decreasing transport and distribution losses	U,A,I
	Locate potential new resources standby supplies	U,A,I	Adjust legal and institutional framework	U,A,I,R
	Groundwater: Strengthening the control system and penalties in the case of overuse; Limiting groundwater pumping revision cost of water prices, elimination of incentivizing subsidies for overuse, rules prohibiting and restricting pumping, efficient technologies…	U,A,I	Aquifers recharge by re-injection of treated waste water 100 Mm3/year by 2030; substitution of groundwater used for potable water to surface water 85 Mm3/year by 2020; artificial regeneration groundwater storage of 180 Mm3/year	
	Groundwater recharge	U,A,I	Improved efficiency of water distribution networks by minimizing losses	
	Aqueducts and canals		Improvement of water use efficiency in industry and tourism units towards water reuse	
	Monitoring and forecasting	U,A,I,R	Maintain water pricing system which enables more rational use of water	
	Adjust legal and institutional framework	U,A,I,R	Awareness campaign for water saving and campaigns to minimize drought damages	
	Continuation of small and medium size dams program 1000 in 2030		Maximizing storage of rainwater more than 140 dams	
			Construction of 50 dams by 2030 1.7 BCM	
			Use of groundwater aquifer	
			Construction of earth dams in which rainfall runoff is stored several were built	
			Water transfers between several basins	
			Extension of the artificial cloud insemination	
			Water transfers between several basins	
			Desalination in extension 400 Mm3/year; yet a pre-treatment filtration and advanced reverse osmosis in construction in 2014 in Agadir to produce some 100 000 cubic meters of drinking water per day Andrew Burger, 2014	
			Waste water reuse very low but planned to increase 300 Mm3/year by 2020	
			Conservation and management of water resources; water harvesting techniques surface of roofs for domestic or others for agricultural uses	
Demand management	Adopting supplementary and deficit-irrigation	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
	Water saving irrigation techniques drip, sprinkler, …	A	Restricting municipal uses lawn irrigation, car washing, …	A,I,R
	Incentives to invest in water saving technology	U,A,I	Review operations of reservoirs	U,A,I
	Water recycling	U	Water metering and price scaling	U,A,I
	Dual distribution networks for drinking water supply	U	Water rationing	U,A,I
	Inventory private wells and negotiate their public use	U,I	Education and awareness creation	U,A,I
	Assess vulnerability and advise water users	U,A,I	Provide permits to exploit additional resources	U
	Elaborate alert procedures	U,A,I,R	Improved efficiency of water distribution networks by minimizing losses	

	Carry-over storage	U,A,I	Adjust legal and institutional framework	U,I,A,R
	Conjunctive use	A,I	Negotiate transfer between sectors	U,A
	Adjust legal and institutional framework	U,A,I,R	Generalizing tap water and sewage network in urban and rural areas	
			Strengthening the responsibility of the ABH's Agences de Bassin Hydrographique in groundwater management and generalization of groundwater contracts.	
			Improvement of water use efficiency in industry and tourism units towards water reuse	
			Popularization of village poultry farming should be organized using women nominated by their respective communities	
			Maintain water pricing system which enables more rational use of water	

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

Drought risk management options to address agriculture resilience

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Drought monitoring and early warning		Growing drought-tolerant crops, improved varieties tolerant to stress, and certified seeds	
	Introducing index-based weather insurance schemes		Direct seeding; change in seeding dates and/or seeding density	
	Scaling up financial and technical assistance drought relief and management plan		Supplemental irrigation	
	Strengthening regional and international cooperation		Good agronomic practices soil preparation	
			Improving the livelihoods of poor communities including small farmers and pastoralists herders	
			Enhancing the value of traditional knowledge in drought management	
			Storage of fodder and animal feed	
			Reduction of flock size and animals in distress to feed remaining flock; the number vary depending on drought impact, and selling of young lambs first then if needed reproductive ewes.	
			Provisional indebtedness with feed sellers or milk producers	
			Shifts in animal and also people diets to lower price / lower quality inputs	
			Reliance of subsidized feedstuffs	
			Multiplication and deepening of wells digging	
			Make best use of available feed resources, for animal health improvements	
			Implementing vaccination plans for maintaining animal health	
			Temporary migration	
			Sedentarization enhanced by the establishment of fodder subsidies	
Demand management	In 1995, Morocco established the water law, which emphasis on integrated water resources management through better water use efficiency, resource allocation practices, and protection of water quality.		Replacement of firewood in semiarid rangelands by developing saving wood stoves and solar power plants and home apparatus combines domestic economy and preservation of forest.	
	Creation of National Drought Observatory NDO in 2001		water saving by improving implementation of irrigation potential average amounts to be saved 2.4 BCM/year	
	Adoption of weather-insurance approach in cereal production Stoppa and Hess, 2003		Conversion to modern irrigation technique - a potential of 2 BCM/year, if 40 000 ha per year are upgraded	

Development of solar energy – preservation of forest and watershed ecosystems	Improvement of the adductions to the irrigated areas: potential of 400 MCM/year
Integrated Watershed Management by the Regional River Basin Agencies and HCEFLCD - conserving and developing degraded natural resources for the prevention of soil erosion, regeneration of natural vegetation, rain water harvesting and recharging of the ground water table.	Communication campaign and training for farmers to help them implement water-saving techniques
Adjust legal and institutional framework	Improved management and utilization of community forests
Monitoring and forecasting livestock and feed and rangeland forage availability	Development of shrub and bushes planting, soil rotation to leave part for grazing
	Shift in flock composition with continuous increase trend of goats
	Reorganization of transhumance schemes, with mechanized transport
	Collection of grass/hay during the rainy season and storage for use in dry periods
	Loan and credit schemes between private contractors, either of land, or of other production inputs
	Complementation of purchased animal feed
	Enactment of a volume-based pricing;
	Dry farming techniques - Direct seeding; seed rate; resistant varieties to biotic and abiotic stress; improving water harvest, storage at farm and plot levels
	Crop and plot diversification Income source diversification / off farm work
	Increase reliance on feed and grains storage capacities
	Diversification of income generation activities through migration of some household members
	Diversifying the source of income; and Sale of assets mostly livestock

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

1.3. ALGERIA

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1.3.2. Appendix 3: Drought risk management ons to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs	U,A,I,R	Exploiting high-cost waters	U,A,I
	Desalination of brackish and saline waters	U	Over-drafting aquifers	U,A,I
	Treatment and reuse of wastewater	A,I	Diverting water from specific	U,A,I
	Water transfers	U,A,I,R	Decreasing transport and distribution losses	U,A,I
	Artificial precipitation	U,A,I,R	Adjust legal and institutional framework	U,A,I,R
	Aqueducts and canals	U,A,I		
	Groundwater recharge			
	Monitoring and forecasting	U,A,I		
	Adjust legal and institutional framework	U,A,I,R		
		U,A,I,R		

Demand management	Adopting supplementary and deficit-irrigation; increased awareness programs	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
	Water saving irrigation techniques drip, sprinkler, …	A	Restricting municipal uses lawn irrigation, car washing, …	A,I,R
	Incentives to invest in water saving technology	U,A,I	- Review operations of reservoirs	U,A,I
	Assess vulnerability and advise water users	U	Water metering and pricing	U,A,I
	Water recycling	U,A,I	Water rationing	U,A,I
	Development and rehabilitation of poor state of wastewater treatment		Education and awareness creation	U,A,I
	Elaborate alert procedures; Early warning systems national and regional set up by the OSS		Provide permits to exploit additional resources	U
	Carry-over storage	U,A,I,R		
	Management of transboundary groundwater resources in a logic of sustainability	U,A,I	Adjust legal and institutional framework	U,I,A,R
	Conjunctive use	A,I	Negotiate transfer between sectors	U,A
	Adjust legal and institutional framework	U,A,I,R	Participation in the collective management of water resources	

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

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Category	Long-term

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1.5.2. Appendix 5: Drought risk management options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U	Exploiting high-cost waters	U,I
	Treatment and reuse of wastewater	A; I	Over drafting aquifers	U,A,I
	Water transfers	U,A,I	Diverting water from specific	U,A,I
	Artificial precipitation		Decreasing transport and distribution losses	U,A,I
	Locate potential new resources standby supplies	U,A,I	Adjust legal and institutional framework	U,A,I,R
	Aqueducts and canals	U,A,I	Etc.	
	Groundwater recharge	U,A,I		
	Monitoring and forecasting	U,A,I,R		
	Adjust legal and institutional framework	U,A,I,R		
Demand management	Adopting supplementary and deficit-irrigation	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
	Water saving irrigation techniques drip, sprinkler	A	Restricting municipal uses lawn irrigation, car washing, …	U,I,R
	Incentives to invest in water saving technology	U,A,I	Review operations of reservoirs	U,A,I
	Water recycling	U,I	Water metering and pricing	U,A,I
	Dual distribution networks for drinking water supply	U,I	Water rationing	U,A,I
	Inventory private wells and negotiate their public use	U,I,A	Education and awareness creation	U,A,I
	Assess vulnerability and advise water users	U,A,I	Provide permits to exploit additional resources	U,A,I
	Elaborate alert procedures	U,A,I,R	Negotiate transfer between sectors	U,A
	Carry-over storage	U,A,I	Adjust legal and institutional framework	U,I,A,R
	Conjunctive use	A,I		
	Adjust legal and institutional framework			
		U,A,I,R		

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

2. Egypt and Sudan

2.1. EGYPT

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2.1.2. Appendix 6: Drought risk management options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U	Exploiting high-cost waters	U,A,I
	Treatment and reuse of wastewater	A,I	Over-drafting aquifers	U,A,I
	Water transfers	U,A,I,R	Diverting water from specific	U,A,I
	Artificial precipitation	U,A,I,R	Decreasing transport and distribution losses	U,A,I
	Locate potential new resources standby supplies	U,A,I	Adjust legal and institutional framework	U,A,I,R
	Aqueducts and canals	U,A,I	Etc.	
	Groundwater recharge	U,A,I		
	Monitoring and forecasting	U,A,I,R		
	Adjust legal and institutional framework	U,A,I,R		
	Adopting supplementary and deficit-irrigation	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
	Water saving irrigation techniques drip, sprinkler, …	A	Restricting municipal uses lawn irrigation, car washing, …	A,I,R
	Incentives to invest in water saving technology	U,A,I	- Review operations of reservoirs	U,A,I
	Water recycling	U	Water metering and pricing	U,A,I
	Dual distribution networks for drinking water supply	U	Water rationing	U,A,I
	Inventory private wells and negotiate their public use	U,I	- Education and awareness creation	U,A,I
	Assess vulnerability and advise water users	U,A,I	Provide permits to exploit additional resources	U
	Elaborate alert procedures	U,A,I,R	Provide drilling equipment	U
	Carry-over storage	U,A,I	Adjust legal and institutional framework	U,I,A,R
	Conjunctive use	A,I	Negotiate transfer between sectors	U,A
	Adjust legal and institutional framework Etc.	U,A,I,R	- Etc.	
R1.a Reduced Water supply				
	-Resolve conflicts with Nile Basin countries	W R	-Reduce water disposal to the Mediterranean	W N
	-Increase regional-level rainfall harvesting	W R	-Optimize operating rules of the HAD	W N
R3.a Decreased water availability for agriculture				
			-Reduce irrigated areas & seasons	A N
R1.a Reduced Water supply				
	-Development of deep groundwater	W L	-Increased Agricultural Drainage water re-use	A N
	- Research &applications on Demand Management	AUI L	-Construct & encourage Desalination plants	W L
	-Local use of Treated Waste Water	A L	-Regional cooperation & enhance prediction tools	R
	-Enhance research to develop new resources	W R		
	-Enhance research on saline & sea water usage	A L		
	-Reduce evaporation losses from Lake Nasser	W L		
R1.b Conflicts among competing users & sectors on scarce resources				
	-Distribute water on Volumetric Basis	U		

	-Activate Role & Laws of Water User Associations	A		
	-Issue new Rules and standards for Water Rights	A		
	-Efficient Awareness programs	UAI		
R1.c Increased pollution in streams				
	-Effective Monitoring & treatment systems	UAI	-Strict Environmental Regulation	UAI R/E
	-Efficient Awareness programs same as above	UAI		
	-Active role of Communities and participation	UAI		
R1.d Cross cutting issues				
	i. Public health deterioration	H		
	ii. Soil salinity & land use changes	A		
	iii. Less hydropower generation	En		
	iv. Less inland navigation activities	Tr		
R3.a Decreased water availability for agriculture				
	-Investment in efficient irrigation equipment piped mesqas-marwas,& trickle irrigation….	M N A	-Reduce Water Duty for irrigated lands	M A
	-Develop & Apply volumetric water quota system	L N A	-Efficient water quality protection programs	M A
	-Enhance role of water user associations	M R A	-Activate fair & social water tariff system	M A
	-Strict rules on high water consumption crops	M N		
	-Generalize controlled drainage in rice areas	I A		
	-Wide Use of drought and salt tolerant crops	M A		
	-Create incentives to conserve irrigation water	M A		
	-Efficient Awareness programs same as above	M A		
R3.bDecreased water availability for the municipal sector				
	-Effective Awareness & educational programs among users to use conservative practices	N U	-Develop tariffs leading to water conservation	N U
	-Reduce leakage from public networks	L U	-Apply conservative water regulations	N U
	-Install meters for all users	N U	-Construct & encourage Desalination plants	L U
R3.c Decreased water availability for industrial sector				
			Apply strict regulations for effluent quality	N I
			Enhance water recycling & offer incentives	L I

*H: Health; A: Agriculture; En: Energy; T: Transportation
U: Urban/Domestic; I: Industry; R/E: Recreation/Environment ; R: Nile Basin countries
Scale or size: adaptation measure implemented at regional level (R), national level (N), local/community level (L)

2.2. SUDAN

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2.2.2. Appendix 7: Adaptation measures for water management

Category	Long-term	Uses*	Short-term	Uses
Water supply	-Resolve conflicts with Nile Basin countries	W R	-Reduce water disposal to the Mediterranean	W N
	-Increase regional-level rainfall harvesting	W R	-Increased Agricultural drainage water re-use	A N
	-Development of deep groundwater	W L	Expanded rainwater harvesting	A
	-Construct & encourage Desalination plants	W L	Water storage and conservation techniques	A
	-Local use of Treated Waste Water	A L	Enhance water recycling & offer incentives	L I
	-Enhance research to develop new resources	W R	Introduction of new water harvesting/spreading techniques making use of intermediate technologies.	
	-Enhance research on saline & sea water usage	A L	Promotion of greater use of effective, traditional water conservation practices.	
	Rehabilitation of existing dams as well as improvements in water basin infrastructure for increased water storage capacity, particularly in central and western Sudan.		Improvement of access to groundwater supplies by humans and animals though installation of water pumps.	
	Construction of dams and water storage facilities in some of water valleys, particularly in western Sudan.			
Water Demand Management	Enhancement of capabilities of regional meteorological stations to monitor hydro-climatic variables.		Introduction of a revolving micro-credit fund to support implementation of small water harvesting projects.	
	Introduction of water-conserving agricultural land management practices.		Extension services in capacity strengthening in water capture and storage techniques for small-scale farmers.	
	- Research &applications on Demand Management	A U I L	-Distribute water on volumetric Basis	U
	-Issue new Rules and standards for Water Rights	A	Reduce irrigated areas & seasons	A N
	-Efficient Awareness programs	UAI	-Strict Environmental Regulation	UAI R/E
	-Effective Monitoring & treatment systems	UAI	Increased irrigation efficiency	A
	-Effective Awareness & educational programs among users to use conservative practices	N U	-Active role of Communities and participation	UAI
	-Regional cooperation & enhance prediction tools	R	-Activate Role & Laws of Water User Associations	A
	-Apply conservative water regulations	N U	-Efficient Awareness programs	UAI
			-Reduce Water Duty for irrigated lands	M A
			-Efficient water quality protection programs	M A
			-Activate fair & social water tariff system	M A
			-Investment in efficient irrigation equipment trickle irrigation….	M N A
			-Develop & Apply volumetric water quota system	L N A
			-Enhance role of water user associations	M R A
			-Strict rules on high water consumption crops	M N
			-Generalize controlled drainage in rice areas	I A
			-Wide Use of drought and salt tolerant crops	M A
			-Create incentives to conserve irrigation water	M A

		-Reduce leakage from public networks	L U
		-Install meters for all users	N U
		-Develop tariffs leading to water conservation	N U
		Adjustment of planting dates and crop variety Crop relocation	A

*H: Health; A: Agriculture; En: Energy; T: Transportation.
U: Urban/Domestic; I: Industry; R/E: Recreation/Environment ; R: Nile Basin countries
Scale or size: adaptation measure implemented at regional level (R), national level (N), local/community level (L)

Key adaptation actions by sector as identified in Sudan's NAPA

Sector	Adaptation Activities and Needs
Agriculture	• Community-based forest and rangeland management and rehabilitation. • Replacement of household goat herds with sheep herds to reduce pressure on fragile rangelands. • Lessening of pressure on local forests through use of mud brick building design and alternative energy sources. • Land use conversion from agriculture to livestock rising. • Strengthening of agricultural and veterinary extension services, including demonstration. • Introduction of drought-resistant seed varieties, poultry and fish production. • Improved land management through tree planting of areas denuded for soil protection and erosion control. • Drought early warning systems for disaster preparedness. • Extension services in agricultural capacity strengthening for small-scale farmers. • Protection and/or rehabilitation of rangelands, including construction of shelterbelts to reduce windstorm impacts.
Public Health	• Improve community sanitation and medical services. • Building of community awareness regarding preventative measures for malaria, etc. • Introduction of preventive measures to restrict malaria transmission. • Introduction of early disease diagnosis and treatment programs for malaria, etc. • Improvement of irrigation system management so as to reduce breeding sites. • Provision of alternative water supply systems for domestic use that do not involve open standing water areas. • Improved climate-sensitive disease surveillance and control Improved water supply and sanitation services
Tourism	•Diversification of tourism attractions and revenues

3. Iraq and Syria

3.1. IRAQ

3.1.1. References

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3.1.2. APPENDIX 8: DROUGHT RISK MANAGEMENT OPTIONS TO ADDRESS WATER SHORTAGE

Category	Long-term	Uses*	Short-term	Uses
	Prioritize the development of a master plan for Natural Resources and Drought Management	U,A,I,R	develop, coordinate, and implement the drought mitigation program	
	Establish an early warning system and improve the current meteorological system	U	The creation of an operational and sustainable task force central drought management unit or committee	
	Improve understanding of the definition of drought, how to monitor it, and how to predict it on a scientific basis in order to shape a proper drought management plan	A,I	protect the nutritional	
	Effectively use meteorological data and forecasts, through early warning systems	U,A,I,R	protect health,	
	Evaluate the impacts of drought and mitigate its effects on agricultural production and food security	U,A,I,R	Educational attainments of affected communities.	
	Implement adaptive measures to drought to reduce vulnerabilities and adverse consequences. Successful adaptive measures require actions to be taken at the national and community levels.	U,A,I	Establishment of appropriate social institutions and arrangements that discourage marginalization of vulnerable population and enhance collective/participatory decision-making process	
	Create public awareness about drought in Iraq and educate the public about the efficient use of water through media	U,A,I	Diversification of income sources and livelihood systems that reduce vulnerability and risks, especially for the poor	
	Adopt more efficient water management and irrigation practices such as drip irrigation, and develop crops more resistant to difficult weather conditions.			
	Water conservation and watershed management activities.	U,A,I	Introduction of collective security arrangements such as farmers' cooperatives and community based organizations CBOs	
	Agro-Ecological Characterization and Mapping of Drought Vulnerability would allow the establishment of drought vulnerability profiles, the drawing of drought risk maps, and the choice of adapted strategies of drought management techniques.	U,A,I,R	Building capacity of smallholder farmers and extension staff, including NGOs and civil society organizations CSOs, to adopt and promote integrated water management interventions	
	strengthen the joint dialogue between riparian countries on all levels, including political and technical	U,A,I,R	Provision of knowledge, technology, policy, institutional, and financial support, similar to credit facilities for the vulnerable communities	
	Shift to water conservation practices in the country: water is used more efficiently and demand for irrigation water is reduced.	A	Upgrading rainfed agriculture through on site rainwater harvesting systems and other farming practices that retain water in cropland terraces, contour bunds, ridges, tied ridges, planting pits, conservation agriculture, etc.	
	gradual shift to more sustainable agricultural practices such as changing cropping pattern in favor of less water intensive crops, introducing new irrigation systems, and other economic activities that are less vulnerable to drought like livestock and agro-industry.	A	Enhancing supplementary irrigation systems and farming practices that supply water to crops during critical growth stages	
	water conservation	U,A,I		
	Watershed management activities.	U	Rangelands: Need for more awareness campaigns on practices to assure resource conservation	

	Policies and Organization micro-finance strategy; micro-insurance; micro-credit	U	Rangelands: Need for more local know-how on market access
	Formulation of drought policy geared toward vulnerable sectors, with emphasis on poverty reduction and food security	U,I	
	Establishment of an integrated drought monitoring and information system, including an early warning system and farmer coping mechanisms	U,A,I	
	Development of policies and institutions that support adaptation at the community level and encourage private sector participation, allowing for greater dedication of resources to the development of adaptive technologies and innovations	U,A,I,R	
	Training of mid-level professionals working with different organizations and governmental departments and launching a regional training program with local universities about drought preparedness and adaptation	U,A,I	
	Resource allocation for the development of adaptive technologies and innovations to enhance sustainable economic growth	A,I	
	Formulation of drought policy geared toward vulnerable sectors, with emphasis on poverty reduction and food security		
	Establishment of an integrated drought monitoring and information system, including an early warning system and farmer coping mechanisms		
	Development of policies and institutions that support adaptation at the community level and encourage private sector participation, allowing for greater dedication of resources to the development of adaptive technologies and innovations		
	Training of mid-level professionals working with different organizations and governmental departments and launching a regional training program with local universities about drought preparedness and adaptation		
	Resource allocation for the development of adaptive technologies and innovations to enhance sustainable economic growth	U,A,I,R	
	Implementing a water management action plan.	U,A,I,R	Clean abandoned and degraded palm groves
	Deploying a wastewater reuse plan	U	Planting date palm trees to restitute palm groves in southern Iraq
	Decentralizing water management which should be more on a watershed or district basis, and followed by water users associations.	A,I	Establish an extension program targeting integrated pest management and the selection of high-value varieties of date palm responding to market need.
	Early Warning System is the most pertinent mitigation measure for drought	U,A,I,R	Establish a marketing strategy for Iraqi dates aiming at increasing exports.
	Undertake an institutional capacity building program on drought mitigation techniques for technicians of the ministry of agriculture and related ministries public, researchers, at both central and regional levels.	U,A,I,R	Establish field trials in central and southern Iraq for high yielding varieties of rice developed by the International Rice Research Institute IRRI adapted to salinity, high temperatures, or drought IRRI, 2013.
	Support research and development programs, by providing finances, required infrastructure and equipment for research aiming at investigations in fields of drought mitigation and related topics.	U,A,I	Promote high diversity of products and proper crop rotations to keep salinity under control: Rice/ chickpea, lentils, and cotton ; rice/ vetch, lentils, chickpea, sorghum, and mille in mixed farming raising water buffalo; wheat/ fodder legumes medics, vetch and barley and integrated with livestock production; barley / legumes.
	Develop a rangeland management plan for Iraq. Monitoring rangeland in Iraq should be based on a national inventory	U,A,I	Introduction adapted high yielding varieties and distribute high quality grain seeds i.e. wheat, barley, corn and legumes to farmers, especially after drought years.

	Agriculture subsidies should be practice oriented rather than crop oriented for wheat for example, where the government focuses on releasing financial aids for more diverse crops, through proper agriculture practices including the use of drip irrigation, the import of selected seeds tolerant to drought, the import of equipment like seeders for conservation agriculture, etc..	U,A,I	Promote complementary irrigation according to plant requirements and climate demand through appropriate irrigation techniques i.e. sprinklers.
	Strengthen vulnerable community groups through their consolidation into associations, syndicates, and other similar entities according to their common interests.	U,A,I,R	Promote research to develop an efficient irrigation water management for irrigated crops including demonstration plots for different irrigation techniques, different varieties to control salinity, and different water application rates and frequencies.
	Enhance fair trade and other marketing strategies focusing on direct contact between farmers and consumers or the export market.	U,A,I,R	Install water points water reservoirs, tanks, wells, etc. for human and animal relieve in dry periods
	Promote the development of products specific labels based on geographical indication securing the sustainable use of natural resources, and a fair equitable trade; to alleviate poverty amongst vulnerable groups like farmers, herders, and fishermen.	A	Promote the establishment of water harvesting techniques, in streams and water catchments
	Facilitate access to credit for farmers in general, with a special focus on vulnerable community groups herders, fishermen, cereal growers, women head of households …, through appropriate legislative framework.	A	Conduct a sustainable program for fresh water fish to assess the potentials in rivers and marshlands, species
	Improve awareness and enforce Labor Law and female workers rights, and other laws related to the rights of community vulnerable groups like women and children, including the access to education.	U,A,I	Promote grain and fodder storage for animals feeding during dry periods, and establish financial facilities for them.
	Create an Iraqi Drought Management Fund, which could be part of a broader Disaster Risk Management Fund with the objective of ensuring the necessary budgetary needs for drought relieve and long term mitigation measures.	U	Promote the diversity of milk products by its process into different dairy products that are better preserved and sold with higher added-value.
	Rangelands: Need for means for improving income and government support	U	Facilitating linkage between farmers and shepherds; farmers to sell their crops and crop residues in years of drought to shepherds who are in a deficit of fodder for their herds through weekly market in their vicinity
	Marshlands: Need for International agreements on water which only apply to the marshlands as their waters are affected by regional neighbors	U,I	Assess vulnerable groups in rural and urban areas women head of households, poor families, farmers, shepherds, unemployed people, handicaps, etc. and prioritize them in all relieve actions after drought.
	Marshlands: Need for more scientific research on the marshlands	U,A,I	Impact alleviation through direct financial and in-kind aids, or micro-credit facilities to vulnerable community groups including farmers that are victim of crop failure in drought years, herders who liquidate their livestock in drought years, women head of households, families
	Marshlands: Need to assign protected areas in view of the international significance of the marshlands and their important biodiversity and potential allocation as a RAMSAR Wetland	U,A,I,R	Optimize water flow into the marshes and Increase the number of water control regulators for a better water management.
		U,A,I	Update the existing legislative and adopt legislations that guarantee an adequate annual supply of water to the marshes, especially during drought periods
		A,I	Update water pricing, define water policies and water allocation for the different crops.
		U,A,I,R	Support healthy river ecosystems by determining the quantity, timing, and quality of water flows required to sustain freshwater ecosystems and the human livelihoods and wellbeing.
			Emphasize to develop a transboundary water agreement between Iraq, Turkey, Syria, and Iran.

	Support and facilitate aquaculture in the marshes.
	Encourage civil society involvement and NGO's in protecting, restoring and preserving the marshlands and any other threatened natural ecosystem.
	Support education of vulnerable community groups using "food for education among the poorest areas

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

3.2. SYRIA

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3.2.2. Appendix 9: Drought risk management options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U	Exploiting high-cost waters	U,A,I
	Treatment and reuse of wastewater	A,I,R	Over-drafting aquifers	U,A,I
	Water transfers	U,A,I,R	Diverting water from specific	U,A,I
	Locate potential new resources standby supplies	U,A,I	Decreasing transport and distribution losses	U,A,I
	Aqueducts and canals	U,A,I	Adjust legal and institutional framework	U,A,I,R
	Groundwater recharge; Artificial recharge using harvested water	U,A,I	Reallocation of resources	U,A,I,R
	Climatic prediction and early warning systems, Monitoring and forecasting	U,A,I,R	The risk of groundwater pollution and soil pollution is possible if only treated wastewater is used	A
	Alternative desalination technology	U,I	Health risk evaluation of using treated wastewater in agriculture	A
	Artificial recharge using RO water	U,I	Labor migrating towards non-farm livelihood to earn an income	A
	More research on the technology of desalination plants to deliver seawater into fresh water in a safe and reasonable price	U, I	Improving water harvesting methods	A
	More researches on the MFS technology compared with RO technology related to the reliability, quality and risk in reuse of treated sewage in agriculture and irrigation and environmental impact on both surface water and groundwater	U,I	Labor seasonal migration, providing a critical livelihood source. The role of remittances derived from migration provides a key coping mechanism in drought years	A
	Adjust legal and institutional framework	U,A,I,R	Food-for-work or cash-for-work programs	U, Ru, A
	Establishment of emergency funds	U,A,I,R	Provision of food aid or fodder	U, Ru, A
	Establishment of a national grain reserves	A	School-feeding programs	U, Ru
	Development and sustainable management of natural rangelands	A	Support internally displaced persons until they return home	U, Ru
			Cash transfers	U, Ru
			Livestock restocking schemes by means of Government subsidies	A

Demand	Adopting supplementary and deficit-irrigation	A	Restricting municipal uses lawn irrigation, car washing, …	U,I,R
	Water saving irrigation techniques drip, sprinkler	A	Water metering and pricing to reduced extremely high per capita water consumption	U,I
	Incentives to invest in water saving technology	U,A,I	Restructuring the water tariff	U,I
	Water recycling	U	Water rationing	U,I
	Dual distribution networks for drinking water supply	U	Education and awareness creation	U,A,I,R
	Inventory private wells and negotiate their public use	U,I	Provide permits to exploit additional resources	U,A,I
	Assess vulnerability and advise water users	U,A,I	Negotiate transfer between sectors	U,A,I,R
	Elaborate alert procedures	U,A,I,R	Mandating water collecting devices	U,I
	Carry-over storage	U,A,I	Penalizing wasteful practices	U,A,I
	Conjunctive use	A,I	Water auditing and stakeholders participation	U,I
	Adjust legal and institutional framework	U,A,I,R	Reduction of leakage in the main network	U
	Groundwater protection	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
	Awareness programs	U,A,I,R	Use modern irrigation techniques using less water supplemental, drip and sprinkle irrigation	A
	Implementation of the Integrated Water Resource Management approach	U,A,I,R	Maximizing direct use of rainwater for food production and for replenishment of water tables	A
	Regular assessment of availability of water resources and requirements.	U,A,I,R	Use rainwater harvesting methods other then dams - permeable rock dams, contour ridges, runoff strips and semi-circular bunds slow down runoff water, improving soil moisture	A
	Establishment legal and economic regulations to promote improved use of water resources.	U,A,I,R	Revising water subsidies	U, A
	Promote rapid dissemination of information among partners in an effort to organize periodic submission of results and to draft priority action plans.	U,A,I	Improvement of animal products through selection program and ensure effective participation of livestock herders	A
	Establishment of a schedule for division of water and management regulations to prevent conflict of use	U,A,I,R	Food-for-work or cash-for work schemes involving local communities in a participatory manner	A, Ru
	Reinforcement of capacities to ensure the perfect implementation of Integrated Water Resource Management	U,A,I,R	Hedgerows and windbreaks to stabilize soil and provide fodder, while reducing evaporation	A,R
	Ensure that pastoral land is not cultivated, and establishment of a pastoral code promoting mobility and free access to rangeland resources	A	Disseminate adequate techniques to improve the nutritional and quantitative value of fodder, and provide animals with supplementary minerals	A
	Sustainable management of the various land ecosystem types wetlands, agricultural ecosystems, forests, pasture-land ecosystems.	A	Livestock herders' organizations should spread information, supply and stock supplementary feed for strategic periods	A
	Epidemiological studies should be carried out and broadened to enable the development of an epidemiological map	A	Intensification and the diversification of irrigated agriculture to promote crops with high yields and small-scale irrigation.	A
	Strengthening market potential improving networks for marketing milk, red and white meat, leather and hides by taking action on conservation equipment, types of conservation, and collection systems	A	Improving rain-fed agricultural methods in pluvial zones by introducing new drought-resistant, high-yield cereal species	A
	Establish National drought strategy to provide institutional and policy framework	U,A,I,R	Use in agriculture a combination of water tariff system and of water conservation technologies	A
	Improved management of rangelands	A	Diversification of livelihood activities	A
	Optimization of the use of available drought-tolerant breed livestock	A	Building of stronger livelihoods to ensure resilience to future shocks	U, Ru
	Institutional strengthening and capacity building Institutional collaboration; Capacity building and training; Establishment of emergency funds	U,A,I,R	Promote collaboration between the different structures involved in collecting, analyzing, and monitoring pastoral and agricultural information, and the structure following up plant diseases.	U,A,I,R

	Establishment of an insurance mechanism to compensate farmers in the event of crop failure and livestock losses- Weather insurance	A	Identifying useful food-for-work or cash-for-work programs for the community during the drought	U, A, Ru
	Appropriate use of rangelands to minimize the risks associated with drought must focus on three components: protection, rehabilitation, and proper management	A	Consider other livestock feed resources be used for animal- crop residues and agro-industrial by-products available in the region	A
	Participation of affected communities in district drought committees to specify real needs and know their rights and their role in drought response	A	Encouraging sale of animals at an early stage of the drought, before prices fall, to allow herders purchase fodder and save on stock rebuilding costs after the drought	A
	District drought committees should draw up plans of action for different stages of the drought	A	Identifying relevant support to be provided as provision of subsidized seed to farmers or re-stocking for herders	A
	Ensuring adequate representation of farmers and herders through the farmers union	A	Promote an alternative source of energy to meet the needs of communities. wind and solar energy, etc.	A
	Establishing drought committees at the district level	A	Conservation cropping techniques zero tillage to minimize fuel costs	A
	Agricultural capital stock and extension advice to raise household welfare and strengthen resilience during non-drought years	A	Provision of incentives to diversify crops and varieties	A
	Provision of drought- and salt-tolerant varieties	A	Improved access to drought forecast and monitoring information	U,I,A,R
	Use of the most adapted animal species and breeds	A	Improved management of livestock in rangelands	A
	Scheduling various prophylactics for the most prevalent diseases of the different species, depending on systems of husbandry, eco-climatic conditions and categories of animal	A	Improved utilization of crop residues and new feed resources	A
			School feeding schemes	U, Ru
			Food price subsidies	U,A
			Awareness programs	U,A,I,R
			Adjust legal and institutional framework	U,A,I,R

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment; Ru

4. Iran

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4.2. APPENDIX 10: DROUGHT RISK MANAGEMENT OPTIONS TO ADDRESS WATER SHORTAGE

Category	Long-term	Uses*	Short-term	Uses
	Developing Drought monitoring and early warning system	U,A,I,R	More cooperation between different stakeholders to develop drought solutions	U,A,I,R
	Drought policies and planning	U	Provide disaster assistance to affected people	U,A,I
	Investing on constructing water reservoirs as well as modern irrigation networks	A,I	Water harvest for floodwater storage	U,A,I
	Training and education of users and consumers on resource water use efficiency	U,A,I,R	Preserving the aquifers of the country	U,A,I
	Awareness on water use efficiency as part of the public educational programs	U,A,I,R	Use less water dependent plant species for landscaping, forest reclamation and other purposes.	U,A,I
	preparation of National Drought Mitigation Plan	U,A,I	Use Remote sensing technology for forecasting and drought assessment	U,A,I,R
	Maximizing water productivity in all sectors of economic activities, particularly in agriculture			
		U,A,I	Special fund to support the farmers who are willing to enhance their irrigational method;	

	Increasing above-ground and underground water storage capacities;			
		U,A,I	Training and education of users and consumers on resource water use efficiency;	
	Keeping the balance between aquifers discharge and recharge. In addition to 69 executed artificial recharge projects, 23 are under construction projects and 59 under study projects were considered	U,A,I,R	Provision of adequate storage facilities for better water quality, particularly in the remote residential districts;	
	Minimizing losses in the conveyance systems, particularly in the residential distribution networks	U,A,I,R	Implementing strict control measures for water pollution, especially in water scarce areas	
	Using spray and drip irrigating	A	Leveling of fields	A
	Improving water productivity	A	Using spray and drip irrigating	A,I,R
	Introducing resistance cultivars to drought	U,A,I	Using Mulch to decrease water consumption on farming	U,A,I
	Change farming pattern for less water usage	U	Collecting regional knowledge of farmers against drought	U,A,I
	Controlling allocation and water consumption metering, ..	U	Drinking water rationing	U,A,I
	Improve irrigation to increase product's output	U,I	Elimination or reduction of cultivated areas of crops such as summer vegetables or rice in certain locations	U,A,I
	Saving the genetic heritage and bio-diversity of the country and maintaining plants germplasm from drought prone areas	U,A,I	Keeping the balance between aquifers discharge and recharge, In addition to 69 executed artificial recharge projects, 23 are under construction projects	U
	crop and livestock insurance programs	U,A,I,R	Using surface water resources instead of underground water resources; limiting exploitation of underground water resources	U
	Continue Inter-basin water transfers from Persian Gulf Basins to Central Basin; from the Karoon and Dez to the Zayanderud basin; Zahidan, etc. …	U,A,I	Achieve better allocation of available water. Irrigation systems and farmers should be flexible enough to adapt to changing conditions.	U,I,A,R
		A,I	Substitute the maxim of "more crops per ha" with "more crops per drop."	U,A
		U,A,I,R	Prevent surface and groundwater pollution	
	Use appropriate irrigation methods and technologies surge, low energy sprinkler, trickle		Establish citizen participation and local management systems.	
	Practice the "reduce, reuse, and recycle" water-usage maxim in each sector		Providing continuous on the job training for managers, planners, and producers.	
	Substitute "crisis management" with "risk management."		Providing drought forecasts, monitoring and early warning systems for all stakeholders, particularly farmers in the most drought susceptible areas.	
	Establish a National Drought Commission.			
	Improve watershed and aquifer management. These measures have different benefits such as control and storage of flood flows, groundwater recharge, hay production, increasing vegetation cover, return of farmers to their villages, control of desertification, and employment possibilities.			
	Improve collaboration and communication between all stakeholders, institutions and ministries involved in drought and water management.			
	Develop local water-harvesting methods and soil moisture storage.			
	Conserve forests and rangelands, and prevent desertification.			

	Manage water consumption patterns. The percent of people living in urban and rural areas is 63 and 37 percent, respectively. About 32 percent of the water consumed comes from surface and 68 percent from groundwater sources.	
	Improve rural and tribal economies to prevent displaced people to urban areas.	
	Preparation of National Drought Mitigation Plan	
	Formation of a National Drought Committee, with members from all the ministries and organizations directly concerned with drought and water-related issues	

5. LEBANON JORDAN, AND PALESTINE

5.1. LEBANON

5.1.1. References

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5.1.2. APPENDIX 11: DROUGHT RISK MANAGEMENT OPTIONS TO ADDRESS WATER SHORTAGE

Category	Long-term	Uses*	Short-term	Uses
Water resources	Strategies to reduce water demand increasing water efficiency by minimizing losses in all uses of surface and groundwater sources and leakage control,	U I A	rainwater harvesting of surplus winter runoff Collectable runoff	A
	Conservation- water demand reduction Reform water tariff system to account for domestic consumption	U I A	Wastewater reclamation All collected wastewater can be reused	A
	Develop darns and hill lakes to store rainwater for use during the dry period		Seawater/brackish water desalination for water supply	U I
	Updating legislation, reviewing regulations and enhancing enforcement institutional and administrative reforms new approach to water rights	U I A	provide alternative sources of water supply to ensure future demand is met	U I
	Reform Government agencies responsible for the water sector and repair deteriorated infrastructure	U I A G	Reduce pollution of water resources through better wastewater management. build wastewater treatment plants and sewer networks	U I
	Investigating use of seawater for cooling machines	I	green building and green infrastructure requirements and design for espousing rainwater harvesting	U I
	Use of submarine springs Submarine springs with significant flows are located along Lebanese coastal waters	U I A G	Construction of small- and medium-sized urban collective storage ponds, filled by both monitored springs and groundwater Rather than build dams	U I A
	Agreements managing water-sharing arrangements water sharing programs	Trans-boundary water resources	Promoting water reuse at all levels: Reuse of grey water, water harvesting. Best Management Practices for storm water runoff management, collecting and storing storm wale, for reuse in irrigation, and reuse of treated sewage	A I G
	Groundwater management : Strengthening the capacity of water and wastewater establishments to monitor groundwater abstraction and developing a comprehensive database of groundwater wells.	G	Groundwater management : Assessing the feasibility of artificial groundwater recharge in major coastal areas for protection of groundwater from salinization in coastal areas	Aquifer recharge G
	Protect Groundwater through increased regulation and new legislation	G	Emphasize the importance of aquifer recharge in water sector plans and strategies. Establishing recharge dams and other structures to increase groundwater reserves	D I A Aquifer recharge G
	Develop watershed management plans: Prioritize watersheds and initiate development of management plans on the most vulnerable ones Assess water balance in each watershed Prepare a management plan that considers future uses	U I A G	Standards and guidelines: Implement plat rooftop water harvesting projects Storm-water re-use in agriculture Re-use of treated wastewater in agriculture Develop guidelines for grey water re-use Develop guidelines for aquifer recharge	
	Develop a water database : Develop and implement a long-term river and spring monitoring program Develop a comprehensive database of groundwater well Develop and implement a snow cover monitoring program	U I A G	Develop a water database : Assign one national institution to hold and Implement the water monitoring data	U I A G
Agriculture sector	Elaborate a national rangeland program	A	Select and introduce more drought and heat-resistant species and hybrids	A
	Enhance genetic selection of local breeds	A	change planting dates and cropping patterns	A
	Policy and legislation options, research topics for improved vulnerability assessment and monitoring, and adapted infrastructure	U I A G	adopt sustainable agricultural practices and integrated pest management techniques	A

	Shift to perennial crops apple, cherry, and to a lesser extent other stone fruits, olives and grapes with low chilling requirements in lower altitude areas of cultivation.	A	Promote mixed-use farming e.g., animal and vegetable production.	A
	Adopt sustainable agriculture practices such as conservation agriculture, adequate crop rotation including fodder species and organic farming.	A	Change planting dates and cropping patterns according to precipitation and temperature variations and irrigation water availability.	A
	Adopt integrated pest management techniques and good agricultural practices when organic farming is not an option to decrease chemical use and lower production costs.	A	In Bekaa: Shift to less water consuming crops, e.g., barley instead of wheat, snake cucumber instead of cucumber, figs instead of kaki, grapes instead of peaches; and to more drought and heat-tolerant crops such as industrial hemp, avocado and citrus as opposed to bananas.	A
	Livestock and rangeland management Elaborate a national rangeland program in collaboration with concerned actors that includes concise, specific management plans and specifications.	A	In coastal plains: Adopt plantation schemes and greenhouse systems to facilitate air circulation among plants	A
	Enhance genetic selection of local breeds so the livestock is adapted to local climate extremes and cross them with breeds that have a higher potential of milk or meat production.	A	In coastal zones: Introduce crops tolerant to higher levels of humidity and temperature i.e., citrus, tropical fruit trees, and to higher salinity concentrations i.e., legumes, cucurbits and solanaceous rootstocks,	A
			Shift to more efficient irrigation systems such as drip irrigation or sprinklers, and adjust irrigation schedules as well as water quantities according to the increasing crop water demand.	A
			Livestock and rangeland management Adjust livestock numbers to adapt to rangeland capacity.	A
			Diversify animal production by expanding into dairy products, meat, leather, and wool.	A
Public Health	enhancing the Early Warning Alert and Response System to improve the capacity of the current system to respond to unexpectedly occurring disasters	U A	strengthening the epidemiological surveillance system and surveillance for temperature-related mortality and morbidity	U A
			improving access to health care and proper sanitation;	U I A
Tourism	improving insurance coverage in the face of extreme events for high mountain areas and winter tourism destinations at risk;	U I	Developing and promoting alternative and sustainable types of tourism, supporting protected area management, and enhancing and restoring the forest cover in order to promote sustainable tourism for natural areas at risk.	U I A
			moving ski areas to higher altitudes or to colder north slopes;	I

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment; G: Groundwater aquifer

5.2. JORDAN

5.2.1. References

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5.2.2. Appendix 12: Drought risk management options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs; micro-catchments treatments	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U	Exploiting high-cost waters	U,A,I
	Treatment and reuse of wastewater	A,I	Over-drafting aquifers	U,A,I
	Water transfers	U,A,I,R	Diverting water from specific	U,A,I
	Artificial precipitation	U,A,I,R	Decreasing transport and distribution losses	U,A,I
	Locate potential new resources standby supplies	U,A,I	Adjust legal and institutional framework	U,A,I,R
	Aqueducts and canals	U,A,I	Etc.	
	Groundwater recharge	U,A,I		
	Monitoring and forecasting	U,A,I,R		
	Adjust legal and institutional framework	U,A,I,R		
	Adopting supplementary and deficit-irrigation	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
	Water saving irrigation techniques drip, sprinkler, micro irrigation, mulches, and protected agriculture;	A	Restricting municipal uses lawn irrigation, car washing, …	A,I,R
	Incentives to invest in water saving technology	U,A,I	Review operations of reservoirs	U,A,I

Demand management	Water recycling	U	Water metering and pricing	U,A,I
	Dual distribution networks for drinking water supply	U	Water rationing	U,A,I
	Inventory private wells and negotiate their public use	U,I	Education and awareness creation	U,A,I
	Assess vulnerability and advise water users	U,A,I	Provide permits to exploit additional resources	U
	Elaborate alert procedures	U,A,I,R	Provide drilling equipment	U
	Carry-over storage	U,A,I	Adjust legal and institutional framework	U,I,A,R
	Conjunctive use	A,I	Negotiate transfer between sectors	U,A
	Adjust legal and institutional framework , etc. ..	U,A,I,R	Enforcing conservation measures through the control of water wastes, spills and illegal uses.	
	Strengthening Infrastructure and Human Capital:			
	• Strengthen competence and communication across sectors and between levels of society			
	• Improve technical training and awareness			
	• Empower communities to take ownership of local water initiatives		The enhancement of water management at the farm level by promoting for example the application of irrigation water by night, the automation of farm irrigation networks, the monitoring of soil moisture, and examining crop water requirements for micro-climate zones	
	The promotion of the sustainable irrigated agriculture by protecting groundwater resources;		advanced irrigation technologies e.g., cloud seeding for increased rainfall with Thailand	
	The development of new sources of water, such as wastewater		Drought awareness, knowledge management and education	
	Improvement in management and administration through better operation and maintenance of irrigation facilities from sources e.g., reservoirs, rivers or springs to farm gate, the use of piped irrigation networks, the metering of water at the farm, and participatory irrigation management		The monitoring of the quality of irrigation water at the source and during conveyance, and of the distribution network, as well as improvement in the quality of wastewater allowing unrestricted irrigation and the testing of soil salinity	
	The use of modern technology, such as genetically engineered plant varieties to enhance agricultural yield		The introduction of better water pricing, so that prices can be differentiated according to water quality, and irrigation water managed as an economic commodity, with prices covering at least operation and maintenance costs, and, where possible, capital costs	
	Index-based weather insurance represents an emerging innovative market scheme for managing risks associated with drought		The introduction of regulation and controls to discourage crops with high water needs through economic and market forces	
	Pumping water from the Red Sea to the Dead Sea		Promote soil and water conservation measures and improve agricultural production	
	Pumping water from the Disi aquifer in the country's Deep South up to the capital		Community participation and political commitment, networks, resource availability, and emphasizing self-reliance and drought resilience	
	Encourage and strengthen the joint dialogue between riparian countries on all levels, political and technical to reduce the drought risk from trans-boundary water issues			
	Drought risk management / drought monitoring and early warning systems, plans, and policies			
	Vulnerability assessment, drought mitigation, response actions			
	Preparedness of plans to reduce drought impacts			

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

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5.3.2. Appendix 13: Drought risk management options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Agricultural sector	Enable the institutional and legal environment: Plans to develop the Agricultural Insurance service.		Enable the institutional and legal environment: Implement and activate the endorsed Law of Farmers Compensation Fund	
	Implement Early warning system Improve the quality and accessibility of data.		Implement Early warning system Improve public awareness to control water demand trough extension services and media	
	Early warning and forecasting for agricultural drought.		Installing a net of meteorological stations especially for the eastern slop and Jordan valley where condensed irrigated agriculture is practiced	
	Technical and institutional capacity building for drought management.		Providing alternative sources of income to impoverished fishers and farmers by helping develop aquaculture	
	A methodology to quantify drought impacts across all relevant sectors needs to be developed.		Move to greener economy to sustainable agricultural practices and increased use of renewable energy resources such as wind and solar energy.	
	Providing alternative sources of income impoverished fishers and farmers by safeguard the livelihoods of aquaculture producers			
Water Resources	6 Alternative Resources: purchased water, desalination, reuse of treated wastewater and reallocation management.		3 Water Harvesting by installing various water collectors ex. rooftop water harvesting systems.	
	7 Enhance innovative and indigenous practices.		4 Improving groundwater recharge through utilization of generated runoff.	
	8 Promoting respect for international humanitarian and human rights law.		5 Demand Management water losses reduction, conduct public awareness to control water demand awareness, changing crop patterns, and water use restrictions balancing demand with water supply sources, conservation agriculture, drought resistant crops, and save fresh water by use of nonconventional water.	
	Installing water collection ponds for irrigation and constructing small scale dams in wadis		Conduct public awareness to control water demand	

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

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6.2.2. APPENDIX 14: DROUGHT RISK MANAGEMENT OPTIONS TO ADDRESS WATER SHORTAGE

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U	Exploiting high-cost waters	U,A,I
	Treatment and reuse of wastewater	A,I	Over-drafting aquifers	U,A,I
	Water transfers	U,A,I,R	Diverting water from specific	U,A,I
	Locate potential new resources standby supplies	U,A,I	Decreasing transport and distribution losses	U,A,I
	Aqueducts and canals	U,A,I	Adjust legal and institutional framework	U,A,I,R
	Groundwater recharge; Artificial recharge using harvested water	U,A,I	Reallocation of resources	U,A,I,R
	Monitoring and forecasting			
		U,A,I,R	The risk of groundwater pollution and soil pollution is possible if only treated wastewater is used	A
	Alternative desalination technology	U,I	Health risk evaluation of using treated wastewater in agriculture	A
	Artificial recharge using RO water	U,I		
	Adjust legal and institutional framework	U,A,I,R		
	More research on the technology of desalination plants to deliver seawater into fresh water in a safe and reasonable price	U,I		
	More researches on the MFS technology compared with RO technology related to the reliability, quality and risk in reuse of treated sewage in agriculture and irrigation and environmental impact on both surface water and groundwater	U,I		
	Adopting supplementary and deficit-irrigation	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A

	Water saving irrigation techniques drip, sprinkler	A	Restricting municipal uses lawn irrigation, car washing, …	A,I,R
	Incentives to invest in water saving technology	U,A,I	Water metering and pricing to reduced extremely high per capita water consumption	U,A,I
Demand management	Water recycling	U	Restructuring the water tariff	U,I,A
	Dual distribution networks for drinking water supply	U	Water rationing	U,A,I
	Inventory private wells and negotiate their public use	U,I	Education and awareness creation	U,A,I
	Assess vulnerability and advise water users	U,A,I	Provide permits to exploit additional resources	U
	Elaborate alert procedures	U,A,I,R	Negotiate transfer between sectors	U,A
	Carry-over storage	U,A,I	Mandating water collecting devices	U
	Conjunctive use	A,I	penalizing wasteful practices	U,I,A
	Adjust legal and institutional framework etc.	U,A,I,R	Water auditing and stakeholders participation	U,A,I,R
	Groundwater protection			
		A	Reduction of leakage in the main network	U,I
	Awareness programs	U,A,I,R	Awareness programs	U,A,I,R
	There is a need for integrated water management in Kuwait.	U,A,I,R	Adjust legal and institutional framework	U,I,A,R
			Revising water subsidies	U,I,A

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

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6.3.2. Appendix 15: Drought risk management options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U,	Exploiting high-cost waters	U,A,I
	Treatment and reuse of wastewater	A,I	Over-drafting aquifers	U,A,I
	Groundwater recharge	U,A,I	Diverting water from specific	U,A,I
	Monitoring and forecasting	U,A,I,R	Decreasing transport and distribution losses	U,A,I
	Adjust legal and institutional framework	U,A,I,R	Adjust legal and institutional framework	U,A,I,R
Demand management	Adopting supplementary and deficit-irrigation	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
	Water saving irrigation techniques drip, sprinkler,	A	Restricting municipal uses lawn irrigation, …	A,I,R
	Incentives to invest in water saving technology	U,A,I	Water metering and pricing	U,A,I
	Water recycling	U	Water rationing	U,A,I
	Dual distribution networks for drinking water supply	U	Education and awareness creation	U,A,I
	Inventory private wells and negotiate their public use	U,I	Provide permits to exploit additional resources	U
	Assess vulnerability and advise water users	U,A,I	Adjust legal and institutional framework	U,I,A,R
	Elaborate alert procedures	U,A,I,R	Negotiate transfer between sectors	U,A
	Conjunctive use	A,I		
	Adjust legal and institutional framework	U,A,I,R		

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

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6.6.2. Appendix 16: Drought risk management options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U	Exploiting high-cost waters	U,A,I
	Treatment and reuse of wastewater	A,I	Over-drafting aquifers	U,A,I
	Water transfers	U,A,I,R	Diverting water from specific	U,A,I
	Artificial precipitation	U,A,I,R	Decreasing transport and distribution losses	U,A,I

	Locate potential new resources standby supplies	U,A,I	Adjust legal and institutional framework	U,A,I,R
	Aqueducts and canals	U,A,I	increase the use of desalinated water for domestic purposes	
	Groundwater recharge	U,A,I		
	Monitoring and forecasting	U,A,I,R		
	Adjust legal and institutional framework	U,A,I,R		
	protection of the groundwater resources in qualitative as well as quantitative terms			
	construction of recharge dams and other hydrological structures			
	Search for cooperation with riparian countries would help the sustainability of the aquifers			
Demand management	Adopt crop and livestock insurance			
	Adopting supplementary and deficit-irrigation	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
	Incentives to invest in water saving technology	U,A,I	- Review operations of reservoirs	U,A,I
	Water recycling	U	Water metering and pricing	U,A,I
	Dual distribution networks for drinking water supply	U	Water rationing	U,A,I
	Inventory private wells and negotiate their public use	U,I	- Education and awareness creation	U,A,I
	Assess vulnerability and advise water users	U,A,I	Provide permits to exploit additional resources	U
	Elaborate alert procedures	U,A,I,R	Provide drilling equipment	U
	Carry-over storage	U,A,I	Adjust legal and institutional framework	U,I,A,R
	Conjunctive use	A,I	Negotiate transfer between sectors	U,A
	Adjust legal and institutional framework	U,A,I,R	control of saline water intrusion by reducing abstraction to below the long-term recharge rate	
	expanding water use monitoring		moving high water consuming crops to brackish water areas	
	participatory approach through water user associations		limiting cultivation of perennial grasses and high water consuming crops	
	ensure a balance between water use and renewable water supply in order to preserve water resources, limit pollution, and support ecosystem functions		promoting seasonal crops and limiting perennial cultivation	
	pursue water security especially during drought periods through enhancement of public awareness of water scarcity through campaigns as an initial measure to reduce water use in domestic, industrial and agricultural sectors		promoting modern irrigation techniques	
	use more of treated wastewater		promoting the use of brackish water for agricultural use	
	Enhance water supply by freshwater exploration/discovery, groundwater recharge initiatives, surface dam construction, rainfall harvesting techniques, and greater use of non-conventional water resources such as desalination, use of treated wastewater or brackish water		increase the efficiency of water supply by reducing losses through transmission and distribution pipes	
	preserve water quality through new legislations and institutional reform at the national and regional levels		promote sustainable resource use by balancing water consumption by agricultural, industrial, commercial, and tourist activities with water resource constraints	
	Setup a monitoring and early warning system for drought management		preserve water quality through new legislations and institutional reform at the national and regional level	
	Coordinate the dispersed water monitoring capabilities presents in different ministers and institutions			

	prepare drought and water plans
	Revise policy to integrate drought and water scarcity management
	Use the concept of "virtual water" to hold immense relevance for water-scarcity

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

YEMEN

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6.6.4. Appendix 17: Drought risk management options to address water shortage options to address water shortage

Category	Long-term	Uses*	Short-term	Uses
Supply enhancement	Increase water collection and storage opportunities reservoirs	U,A,I,R	Mixing fresh and low quality waters	U,A,I,R
	Desalination of brackish and saline waters	U	Exploiting high-cost waters	U,A,I
	Treatment and reuse of wastewater	A,I	Over-drafting aquifers	U,A,I
	Water transfers	U,A,I,R	Diverting water from specific	U,A,I
	Artificial precipitation	U,A,I,R	Decreasing transport and distribution losses	U,A,I
	Locate potential new resources standby supplies	U,A,I	Adjust legal and institutional framework	U,A,I,R
	Aqueducts and canals	U,A,I		
	Groundwater recharge	U,A,I		
	Monitoring and forecasting	U,A,I,R		
	Adjust legal and institutional framework	U,A,I,R		
Demand management	Adopting supplementary and deficit-irrigation	A	Restricting agricultural uses rationing, subjecting certain crops to stress, …	A
	Water saving irrigation techniques drip, sprinkler, …	A	Restricting municipal uses lawn irrigation, car washing, …	A,I,R
	Incentives to invest in water saving technology	U,A,I	Review operations of reservoirs	U,A,I
	Water recycling	U	Water metering and pricing	U,A,I

	Dual distribution networks for drinking water supply	U	Water rationing	U,A,I
	Inventory private wells and negotiate their public use	U,I	Education and awareness creation	U,A,I
	Assess vulnerability and advise water users	U,A,I	Improve water resource management with increased stakeholder participation.	U
	Elaborate alert procedures	U,A,I,R		U
	Carry-over storage	U,A,I	Adjust legal and institutional framework	U,I,A,R
	Conjunctive use	A,I	Negotiate transfer between sectors	U,A
	Adjust legal and institutional framework	U,A,I,R	Creating a single water resource management agency, the National Water Resources Authority	
	Institutionalizing water conservation programs such as fog collection, water harvesting, water treatment and reuse, dams, and water rationing		Improving access to sanitation with increased connectivity to sewerage infrastructure	
	Institutionalizing food security programs, such as the credit subsidy for wheat and flour, diesel fuel for water pumps groundwater irrigation, and maintenance subsidy for spate irrigation		Intercropping of various cereals and pulses and staggered planting over time	
	Institutionalizing poverty alleviation strategies, including increased access to credit in rural areas		Use cereal production for a double purpose for grains, fodder, or both depending on rainfall of the season	
			Almost all households engages in other activities, such as : - livestock production, - agricultural labor, - salaried work, - migration for work to cities in Yemen or to neighboring countries Saudi Arabia, Kuwait, United Arab Emirates by adult males in the households is a common practice for money remittance	
			growing drought-resistant crops to mitigate the risks of low rainfall and water shortages	

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment

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The studies are carried out by FAO, in collaboration with the Water for Food Institute, University of Nebraska-Lincoln, USA, as a direct contribution to FAO's Strategic Objective "increasing the resilience of livelihoods to disasters" and Strategic Objective "make agriculture, forestry and fisheries more productive and sustainable".

ISBN 978-92-5-130683-3 ISSN 1020-1203
9 789251 306833
CA0034EN/1/06.18