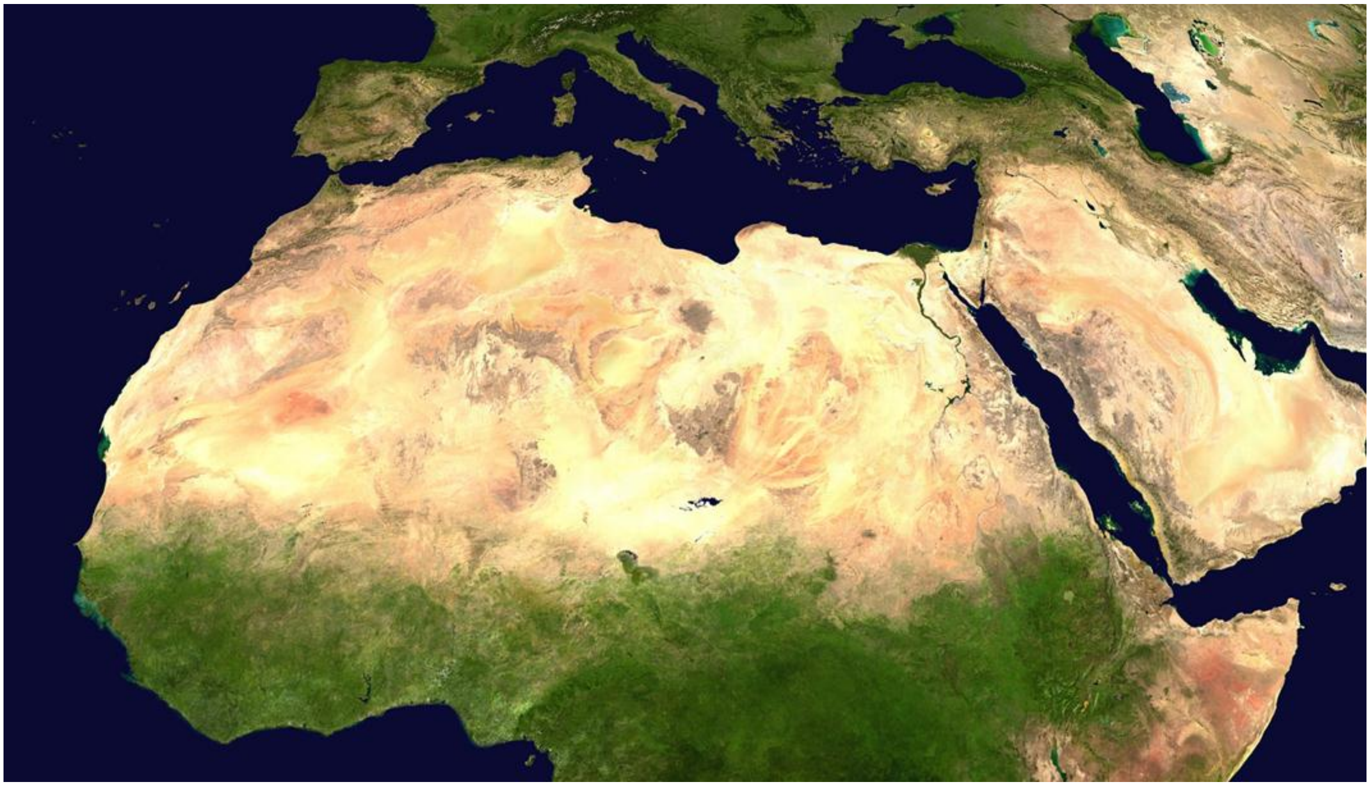
Regional Technical Cooperation Programme

Adaptation to Climate Change in the Water Sector in the MENA Region (ACCWaM)



Climate Change and Water in the Arab Region
Mapping of Knowledge and Institutions

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Executive Summary

1. MENA is the most water scarce region in the world, with 16 countries experiencing water scarcity (<1000 m^3 per capita per year) and 12 experiencing absolute water scarcity (<500 m^3 per capita per year). With rapidly growing and urbanising populations, water scarcity is increasing across the region on an annual basis.
2. This situation is already and will be further exacerbated by the impacts of climate change, with consensus opinion indicating mean temperature increases of 4C and mean precipitation reductions reaching -30% across the region by 2100. In addition to changes in means, daily, seasonal, and interannual variability in precipitation is also projected to increase.
3. The physical impacts of climate change are likely to include decreased river flows, increased water scarcity in rainfed areas, decreased recharge of groundwater, increased evapotranspiration, coastal change due to inundation and saltwater intrusion, increased frequency of heat-waves, and the possibility of increased flooding.
4. In Egypt key vulnerabilities are related to future Nile flows, the impacts of sea level rise in the Delta coast, and tensions between plans for expanding agriculture and needs to reduce agricultural water consumption.
5. In Jordan key vulnerabilities relate to reduced Jordan river flows, disproportionate water consumption in irrigated agriculture, impacts on rainfed agriculture, and limited opportunity for water savings efficiencies.
6. The least water scarce country surveyed, Lebanon has vulnerabilities related to the human geography, infrastructural, and institutional legacies of the civil war, with poor water networks, dysfunctional governance systems, and an absence of data.
7. Developing climate projections and assessing physical impacts in MENA is hampered by deficits in long-term data series, the complex interactions between climate, geography and hydrogeology, and the sensitivity of precipitation changes in arid areas.
8. There is a lack of capacity for and rigorous studies of climate vulnerability assessments across the region, particularly in terms of social vulnerability, gender and the impacts of climate change on human health.
9. There is a lack of evidence and experience on adaptation to climate change in the region. There are also capacity gaps on community based adaptation, and adaptation planning, policy, and economics.
10. There are growing national activities in planned adaptation by international donors and state organisations, climate research by academic and government institutions, and climate activism by NGOs.
11. At the regional level activity is less well developed, although dominated by UNDP and the World Bank. Several networks exist on related issues that could be exploited for mainstreaming adaptation in the water sector.
12. There are needs for individual, institutional and regional capacity building and knowledge provision which ACCWAM is well positioned to fulfil, although careful positioning is needed to avoid duplication of efforts.
13. The development of National Communications, National Adaptation Strategies, and updating National Water Strategies appear to the key national policy processes for ACCWAM to engage in.

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List of Abbreviations

ACCWAM	Adaptation to Climate Change in the Water Sector of the MENA Region
ACSAD	Arab Center for the Study of Arid Zones and Dry Lands
AR4	Fourth Assessment Report of the IPCC
AUB	American University of Beirut
BGR	Federal Institute for Geosciences and Natural Resources, Germany
Bm^3	Billion cubic metres, cubic kilometre
CDA	Community development association
CGIAR	Consultative Group on International Agricultural Research
ESCWA	UN Regional Economic and Social Development Commission in Western Asia
FAO	United Nations Food and Agriculture Organisation
FoEME	Friends of the Earth Middle East
FP7	Seventh Program Framework for Research of the European Commission
GCM	Global climate model
GEF	Global Environment Facility
GIZ	Gesellschaft für Internationale Zusammenarbeit, Germany
ha	Hectare
ICARDA	International Centre for Agricultural Research in the Dry Areas
IDRC	International Development Research Centre, Canada
IFAD	International Fund for Agricultural Development
IMWI	International Water Management Institute
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature and Natural Resources
JICA	Japanese International Cooperation Agency
KFW	KFW Banking Group, Germany
LAS	League of Arab States
MALR	Ministry of Agriculture and Land Reclamation, Egypt
MDG	Millennium Development Goals
MENA	Middle East and North Africa
MEW	Ministry of Energy and Water, Lebanon
Mm^3	Million cubic metres
MWI	Ministry of Water and Irrigation, Jordan
MWRI	Ministry of Water Resources and Irrigation, Egypt
NASA	National Aeronautics and Space Administration, USA
NBI	Nile Basin Initiative
NGO	Non-governmental organisation
NWRC	National Water Research Centre, Egypt
PET	Potential evapotranspiration
RCM	Regional climate model
RSDSC	Red Sea Dead Sea Conveyance Project, Jordan
SLR	Sea level rise
SNC	Second National Communication to the UNFCCC
TNC	Third National Communication to the UNFCCC
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
WHO	World Health Organisation
WUA	Water user associations

1. Introduction

1.1 Context of this study

This study was commissioned by the Adaptation to Climate Change in the Water Sector in the MENA Region Programme (ACCWAM). ACCWAM is a regional project of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) working in cooperation with the Arab League's (LAS) Ministerial Water Council (AMWC), the Economic and Social Commission for Western Asia (ESCWA), and the Arab Centre for the Study of Arid Zones and Dry Lands (ACSAD). ACCWAM is initially concentrating on activities in Egypt, Lebanon, and Jordan. The first phase of ACCWAM has a commitment of €3 million between 2011 and 2014, whilst phase 2 has a projected commitment of €4 million between 2014 and 2017.

ACCWAM's overall objective is 'to boost the capacity of water management institutions in the MENA region to adapt to climate change'. The project supports capacity development in regional and national water institutions, and the implementation of local innovation projects. ACCWAM's strategy is to promote alignment between the Arab Water Strategy and national water policies by working with key regional actors, supporting the development of national adaptation strategies, and trialling innovative adaptation measures with potential for replication. ACCWAM is also intended to invest in regional networks and intermediaries, particularly in the civil sector.

This study was commissioned to provide ACCWAM's project management unit with an assessment of current knowledge and institutions working on climate change and water in the target countries (Egypt, Jordan and Lebanon), and identifying areas for the program to contribute knowledge and add value.

1.2 Climate change and water in the MENA region

The Middle East and North Africa is regularly cited as being the most water precarious region in the world. The Food and Agriculture Organisation's (FAO) AQUASTAT database shows that in 2011, 16 of the 22 countries in the Arab region had less that 1000 m^3 of annual renewable water resources per capita, a standard index of water scarcity. 13 of these countries have annual renewable water resources of less than 500 m^3 per capita, an index of absolute scarcity representing a significant challenge to human development (see Figure 1.1.). In 2001 it was predicted that, due to rising populations, by 2025 the average annual renewable water resources for the Middle East would have fallen to 667 m^3 per capita compared to a world average of 4,780 m^3 per capita (El-Fadel, & Bou-Zeid 2001). Current indications are that this prediction will be realised sooner than 2025.

Water stress results from complex interactions between a number of factors including an arid environment, rapidly increasing demands from growing, urbanising and industrialising populations, human alterations of landscapes, and the infrastructural and institutional aspects of water collection, distribution, and treatment. Some of the most water stressed countries in the region are comparatively wealthy, and have developed additional sources from desalination. However, the majority of countries in the region meet deficits between water supply and demand by unsustainable exploitation of non-renewable groundwater, recycling of wastewaters, and rationing supply (Sowers et al 2011). The importance of transboundary rivers and aquifers, and the increasing scarcity of water, has contributed to concerns over the potential for political and institutional water conflicts becoming militarised.

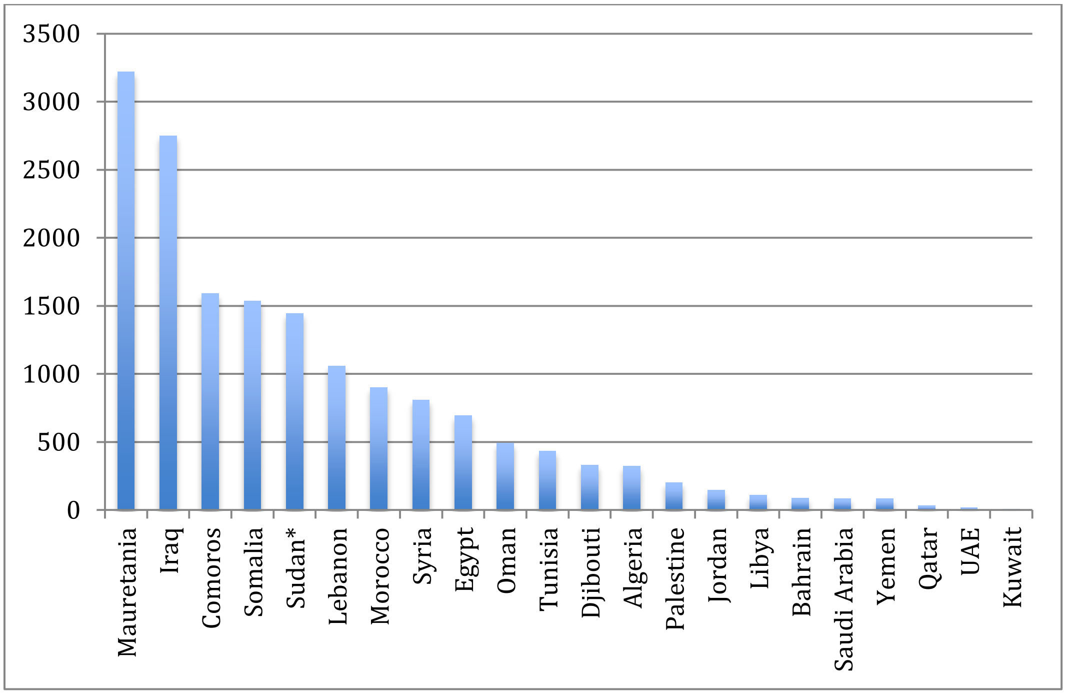

Figure 1.1 Total Renewable Water Resources per year per capita (m^3) reported to FAO. (Source: Aquastat, 2012. All dates are 2011. *Sudan includes South Sudan.)

The aridity and complex geography of the region creates an environment in which precipitation exhibits high spatial, seasonal and interannual variability. Precipitation is generally higher in coastal and mountain areas and declines towards interiors. The majority of precipitation falls during winter months, and across the region water supplies are generally lowest during the hot months of summer when irrigation needs are highest. Drought years can have significant impacts both on rainfed agriculture and overall water supplies. These aspects of variability and uncertainty in supply further stress a situation of general scarcity.

Projected Climate Change

Some have argued that, due to the low precipitation found in the region, the impacts of climate change are likely be negligible. However, the context of extreme and growing water scarcity means that any reduction in precipitation due to climate change would have significant impacts (El-Fadel, & Bou-Zeid 2001). Analysis of climate trends indicate that temperature has increased across the region since the 1950s, including daily minimum and maximum temperatures and the frequency of extreme high temperatures (Zhang et al 2005). However, less coherence is found in precipitation trends, mostly due to the complex drivers of precipitation in the region.

Similar results are found in the outputs of global climate models (GCMs) and regional climate models (RCMs), which generally struggle to cope with the region's high spatial, seasonal and interannual variability in precipitation (Evans et al 2004). The region's aridity and complex geography create major uncertainties in the representation of processes such as large-scale and convective rainfall and their feedback with surface conditions (Hemming et al 2010). Other key obstacles to climate modelling in the region are the lack of reliable historical station data, which hampers attempts to develop downscaled models, and the uncertainty of projecting rainfall over arid areas (El-Fadel, & Bou-Zeid 2001; 2007).

Recent studies using combinations of GCMs and downscaled RCMs have projected generally decreased precipitation over the region by 2100 (e.g. Evans 2009; Black et al 2011), with some studies projecting declines in winter precipitation between 28 and 33% in Iraq, Jordan, Lebanon, and Syria by 2100 (Oenol 2009), decreased precipitation between 5-25% in coastal Turkey and parts of Lebanon and Syria and consistent run-off and drought index changes by 2050 (Hemming et al 2010), and declines of precipitation between 30 and 40% in specific regions by 2100 (Kunstmann et al 2007; Suppan et al 2008). Meanwhile temperatures are generally expected to rise up to 4C by 2100, and precipitation is also expected to become more spatially and temporally variable (Kunstmann et al 2007; Evans 2009; Hemming et al 2010; Black et al 2011).

Using 21 GCMs the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) found that by 2099 under the A1B scenario Southern Europe and the Mediterranean (incorporating parts of MENA) would see annual mean warming of 2.2 to 5.1C, with the largest increase in summer months, and declines of -4 to -27% in mean precipitation. Over the same period and under the same scenario the Saharan region (incorporating North Africa) would see temperature increases of 3 to 4C and average decreases of -20% in precipitation along Africa's Mediterranean coast, whilst noting the considerable uncertainty in these projections (Christensen et al 2007). The IPCC's Fifth Assessment Report, due 2014, is likely to conclude that climate change is likely to result in increased streamflow drought and the number of days without rain by the end of the 21st Century.

Likely Impacts and Vulnerabilities

Across the region the impacts of climate change are likely to exacerbate existing water deficits and challenges. One study has predicted that rainfed agriculture in the Eastern Mediterranean will decline more than 170 000 km^2 due to declining means and increasing variability of precipitation (Evans 2009). Climate change will also exacerbate desertification in the region, with longer dry periods degrading soil quality and reducing the length of time rangelands can be grazed. Irrigated agriculture will experience both increased demand from evapotranspiration as well as potential shortfalls in supply. Riverflow is expected to decrease by 20% in the Euphrates (Issar 2008) and up to 23% in the Jordan (Suppan et al 2008), whilst the impacts on Nile streamflow are complex and uncertain (see Section 2). Indications for impacts on groundwater recharge vary greatly across the region depending on geology and climatology, but have been estimated at declines of 20-30% by 2100 for Jordan (Margane et al 2008). Waterborne diseases such as cholera and dysentery, already present in Syria, Jordan, and the Palestinian Authority, are likely to increase water quality declines and temperatures increase (El-Fadel et al 2003).

In terms of socioeconomic vulnerabilities, climate driven reductions in mean water supply coupled with increased variability is likely to disproportionately affect the poorest members of society, and exacerbate existing water inequalities. Inequalities are expected to be most severe for rural populations that rely on agricultural production and on small-scale water management networks, leading to significant impacts particularly in Syria, Iraq, Jordan, the Palestinian Authority, Morocco, and Yemen (El-Fadel, & Bou-Zeid 2001). The rise in the region's temperatures and decrease in precipitation rates will have a negative impact on transboundary water resources in MENA, potentially increasing the risk of conflict over aquifers such as the Disi and rivers such as the Jordan and the Nile (Zawahri 2010).

What is increasingly understood from climate adaptation and vulnerability research is that different social, economic, and livelihood groups will experience specific impacts differently. This means that assessments at the regional scale can only be done in the broadest sense, and that specific social vulnerability assessments are required before developing adaptation responses.

1.3 Summary

This introductory section has given a general outline of the ACCWAM project and the regional context of climate change and water. The majority of countries in the region are water scarce, and climate change threatens to worsen existing water deficits and related social and economic vulnerabilities.

The following three sections focus on Egypt, Jordan and Lebanon in turn. Section 5 draws some aggregate conclusions and observations based on these three countries, and makes some recommendations for ACCWAM.

2. Egypt

2.1 Climate change, vulnerabilities & adaptation in the water thematic

2.1.1 Climate change and water resources situation

With an average annual precipitation of just 51mm (from 180 mm yr^{-1} on the north coast falling to trace precipitation south of Cairo), approximately 97% of Egypt's water supply is sourced from the River Nile. Egypt's annual share of Nile waters is fixed at 55.5 billion cubic metres (Bm^3) per year according the 1959 agreement with Sudan, although the Egyptian-Sudanese hegemony of the river is increasingly challenged by Ethiopia and the other riparian states e.g. (e.g. Cascao 2008). Groundwater resources and limited rainfall form the majority Egypt's remaining water resources.

National population growth estimates range from 1.8 to 2% per year, with total population growing from 68 million in 2000 to between 81 and 85 million in 2012. As a consequence, Egypt's water security has dropped precipitously in recent decades: from 1900 m^3 per capita in 1960 to 713 m^3 per capita in 2009, passing through the Falkenmark water scarcity index of 1000 m^3 per capita in 1997 (Ministry of Water Resources and Irrigation 2005; AQUASTAT ; Abdel-Dayem 2011).

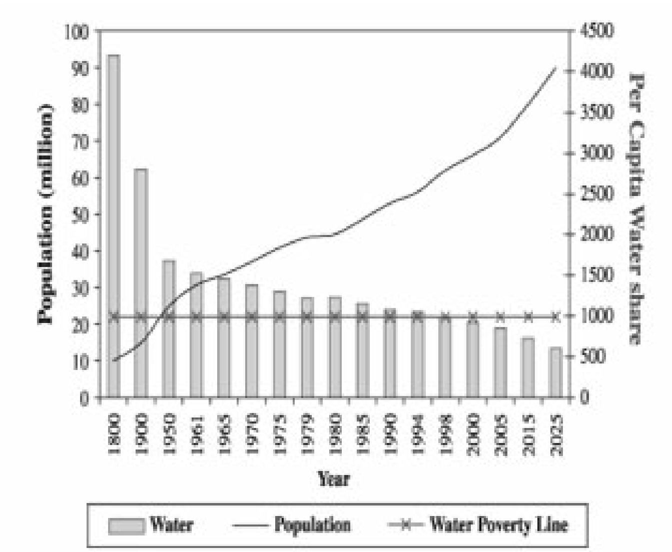

Figure 2.1. Annual per capita water share in Egypt, 1800-2025 (Source: http://www.idrc.ca)

Current national water demand has been estimated at 72 Bm^3 per year, with the 14 Bm^3 shortfall between resources and demand largely met through recycling of agricultural drainage and municipal wastewaters (Information and Decision Support Center 2011). In addition to a rapidly growing population, fragmentation of agricultural land, poverty, pollution, lack of state resources, and poorly coordinated policies are widely regarded as being the key challenges facing Egypt in developing sustainable water policies.

Future climate projections for Egypt generally conform with regional simulations (see Section 1), with an increase ranging between 3 - 3.5C by 2100 suggested by one recent study based on 21 models (UK Met Office 2012). Precipitation projections have less consensus, although this is not surprising in such arid conditions. As the vast majority of Egypt's water is sourced from the Nile, the most significant impacts of climate change on water resources are likely to occur indirectly, either through climate and hydrological changes upstream, or through higher temperatures resulting in greater evaporation and transpiration losses within Egypt.

2.1.2 Climate impacts and vulnerabilities

2.1.2.1 The Nile

The vast majority of Egypt's water resources system is concentrated around the River Nile, which feeds an extensive system of domestic and industrial supply, and in particular networks of irrigation canals feeding agriculture. Return flows through wastewater treatment, agricultural drainage and recharge of the Nile Aquifer keep significant quantities within the river system. Past the Aswan High Dam the Nile is essentially a closed system until waters reach the sea or sinks in the desert. Questions of the impacts of climate change on water resources therefore focus on i) the supply of water through the River Nile at Lake Nasser, and ii) impacts on demand, use efficiency and water quality within the national water system.

National Water Supply

With 97% of Egypt's water supply arising from the River Nile, the consistency of future flows arriving in Lake Nasser is of concern. Approximately 86% of the water reaching Lake Nasser flows from the Ethiopian Highlands, principally through the Blue Nile, but also through the Atbarah and Sobat rivers. These rivers exhibit considerable seasonal and interannual variability, with 80% of flows in the Blue Nile and Atbarah following rainfall in Ethiopia during between July and October (Soliman et al 2009). The Nile Forecast Centre in the Planning Sector of the Ministry of Water Resources and Irrigation monitors the summer rains over the Ethiopian Highlands each summer to predict the expected flow into Lake Nasser and guide decision-making on the release of excess waters.

The Blue Nile has historically displayed decadal variability, with wet and dry periods (Conway et al 2009). Some climate studies, although limited by the number of scenarios and models included, have predicted an increase in seasonality of Blue Nile flows, with increasing flows in summer months (Soliman et al 2009; Beyene et al 2010). The White Nile is the other main tributary, and historically has had relatively consistent and stable flows.

Considerable uncertainty remains over the consequences of climate change on Nile river flows, and there is a substantial body of work on developing projections that have found no clear consensus on the direction or magnitude of change (e.g. Conway 1996; Strzepek et al 1996; Conway 2000). More recently Kingston and Taylor (2010) found no consensus in direction of change in streamflow between 7 Global Circulation Models (GCMs) at a catchment of the White Nile. Elshamy *et al.* (2009) found no consensus for 17 GCMs on the direction of change in precipitation around the upper Blue Nile, but increases in potential evapotranspiration (PET) led to an ensemble mean reduction in flow of 15% by 2081-2098. Taye et al. (2011) found no consensus in 17 GCMs under the A1B and B1 scenarios for outflows in the Lake Tana (Blue Nile) catchment by 2050, although outflows at Lake Nyando were expected to increase by 2050.

Beyenne et al. (2010), applied 11 GCMs to the whole Nile Basin for the A2 and B1 scenarios against a baseline of 1950-99 to generate flows reaching the Aswan High Dam Lake. They reported that ensemble mean flows between 2010-2039 were +11% for the A2 scenario and +14% for the B1 scenario, but that flows would decline by the period 2079-2090 by -16% for A2 and -13% for B1. However, although the general trend of decline over time was consistent, there was considerable variation in magnitude of change between models.

Much of this uncertainty is due to challenges in integrating climatological and hydrological models (e.g. Kingston, & Taylor 2010), complex relationships between rainfall and runoff (e.g. Conway et al 2009), PET and river flow (e.g. Elshamy et al 2009), ecology, seasonality and land-use, all of which vary across the Nile basin. The coarse resolution and crude description of land-surface climate feedbacks in current models also contribute to uncertainty (Elshamy et al 2009; Taye et al 2011). Beyene et al. (2010) also note that the timing and magnitude of changes will be critical to hydrological responses of the Nile Basin.

The discourse of Egyptian water officials reflects this uncertainty. The common assessment is that climate change may lead to small declines in flows, but that flows may also increase slightly. Set against current and anticipated increasing demographic and economic demand for water in Egypt and the upstream nations, a 16% (following Beyene et al 2010) or less reduction in river flows due to climate change is comparatively minor. (However, the prognosis of Beyene et al. implies a more severe relative decline between mid-century and 2090 of 25%, compared to 16% between 1999 and 2090).

The consensus opinion amongst water and environmental officials is that Egypt needs to continue adapting to increasing water scarcity due primarily to increased demographic and economic demand, and to potential uncertainties regarding increased use of river waters by upstream countries (Egyptian Environmental Affairs Agency 2010). However, there is sustained interest in developing integrated hydrological and climatological models for the whole Nile basin to reduce the uncertainty regarding the impacts of climate change on Nile River flows and support planning.

Impacts Within Egypt

Little research has been conducted on the impacts of climate change on Egypt's internal water system. The Second National Communication's section on vulnerability in water resources does not consider it, focusing instead on Nile Basin supply-side issues (Egyptian Environmental Affairs Agency 2010). The draft National Adaptation Strategy's section on water resources offers some speculations, but no evidence of substantial research or literature on the subject (Information and Decision Support Center 2011). The National Water Resources Plan mostly ignores the effects of climate change, which is reasonable as it is medium term plan to 2017 (Ministry of Water Resources and Irrigation 2005).

Attention has been given to the expected water demand increases from agriculture, but no research could be found on increased demands from industry or municipal water use due to climate change. Proportionately, the water share of agriculture is expected to decline from its current level (78%) as domestic and industrial demand increases. Although less significant than agricultural demand, understanding the potential municipal and domestic demand increases due to climate change would appear to be an important topic for research. Potential pathways for impacts might include increased household and industrial consumption of water in hot periods, increased evaporation and leakage from distribution networks, and reductions of biological water quality during hot periods.

The vast majority of available knowledge focuses on the potential impacts of climate change on agricultural water use, specifically on increased evapotranspiration rates in fields. For example, (Khalil et al 2009) modelled 6 scenarios for two wheat strains in 2038 and found that water use efficiency declined by up to 45%, with wheat yields declining around 35%. Eid et al. (2006) found that IPCC scenarios of 3.5C increases led to increases of up to 11.4% in water consumption by wheat, maize and cotton, also with reductions in yields. Based on Agricultural Research Centre studies, the Second National Communication anticipates increased evapotranspiration demand of 5-13% during the 2100s, a figure repeated in the

National Adaptation Strategy (Egyptian Environmental Affairs Agency 2010; Information and Decision Support Center 2011).

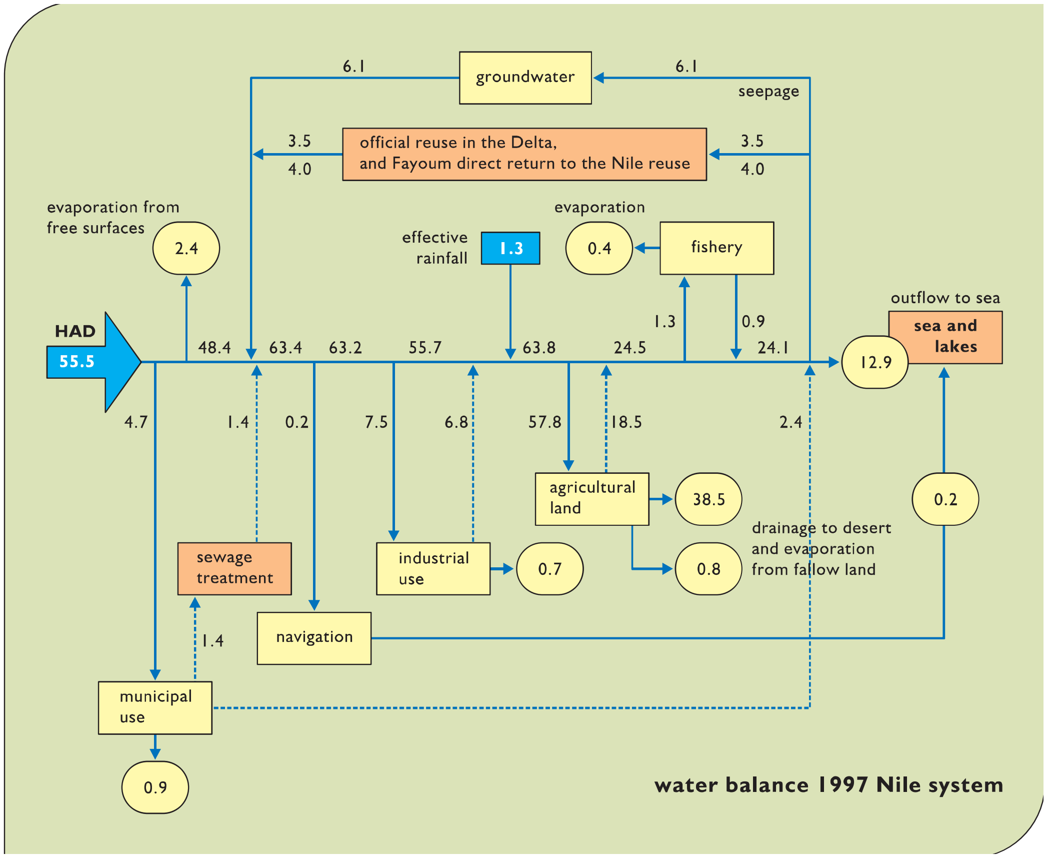

Figure 2.2. A schema of the Egyptian Nile system after the Aswan High Dam (HAD). Figures are in Bm³. (Source: Ministry of Water Resources and Irrigation 2005)

The agricultural water distribution network, with canals for irrigation supply and drainage, is also vulnerable to increased evaporation losses although these have not been quantified with any reliability. However, current efficiencies are known to be low due to evaporation and leakage, with some authors reporting losses of over 50% (El-Agha et al 2011). The National Adaptation Strategy reported that 2007 data indicated that agricultural water usage has become less efficient. Without giving a baseline year, it claims a 30% reduction in water transport efficiency, and 50% reduction in field irrigation efficiency (Information and Decision Support Center 2011). It is generally accepted that on-farm irrigation losses are unacceptably high, partly due to flood irrigation practices, the small size of plots, lack of incentives for water conservation by individual farmers, and declining infrastructure e.g. (e.g. Egyptian Environmental Affairs Agency 2010). However, the work of (El-Agha et al 2011) indicates that the biggest savings can be made at the level of main canals and main drains rather than by focusing on on-farm irrigation and tertiary canals. Similar work should be conducted with a climate change dimension, as the potential losses from increased evaporation have not been quantified. Again, however, the consensus opinion is that with irrigation water inefficiencies of 50% in current operations, increases of 1-2% from increased climate change-induced evaporation is fairly marginal, and there are significant gains to made from reducing water losses anyway.

Within the irrigation network, return flows to groundwater and drainage are significant, and Egypt already recycles 14 Bm^3 per year, mainly from agricultural drainage waters (Ministry of Water Resources and Irrigation 2005). However, water pumped from main drains pumped into main canals has led to deteriorating water quality, particularly in drainage canals polluted from municipal and industrial sources (Abdel-Dayem 2011). No work was identified on the impacts of climate change on water quality, however.

2.1.2.2 Rainfed areas

Egypt relies little on precipitation. It is significant only in areas of the North Coast, Eastern Desert and Red Sea Coast and the Sinai that have limited groundwater resources and access to Nile waters. Some communities in these regions cultivate rainfed arid crops such as barley, and rain also supports forage for pastoralism. Water harvesting from flash floods is a common feature in these areas.

Multiple studies agree that total precipitation and the frequency of wet days will decline across North Africa (Born et al 2008; Driouech et al 2010; Abouabdillah et al 2010; García-Ruiz et al 2011). Garcia-Ruiz and colleagues (2011) projected a decrease in annual precipitation of approximately 15% for MENA for 2040-2070 compared to 1960-1990. In particular they noted a marked decrease in winter precipitation of between 20 & 30%.

A contrary analysis of drought frequency in the Mediterranean region under A2 and B2 scenarios for 2070 found no evidence for increased drought frequency in much of North Africa (Weiß et al 2007). Rather, they found that precipitation would increase slightly, increasing water availability and decreasing drought frequency. However, the authors acknowledged that the high aridity means that there is more uncertainty over projections – a change in drought frequency is less meaningful in desert areas.

Less attention has been paid to the impacts of climate change on rainfed areas in Egypt due to their lesser national significance. However, the uncertainties are lower that pressures faced by dependent communities will become more intense. As communities reliant on precipitation in Egypt already experience poverty and marginalisation more acutely than the national average, this is a significant source of vulnerability and inequality.

2.1.2.3 Groundwater

Groundwater resources in Egypt can be separated into the non-renewable or marginally renewable aquifers of the Western and Eastern Deserts, the northwest coast and Sinai, and the productive renewable aquifers of the Nile Valley and the Delta. Groundwater resources in Egypt are under increasing abstraction pressure. In rural areas of the Nile valley and Delta, groundwater resources are used for domestic supply in those areas not covered by mains networks. Particularly in areas not well supplied by irrigation canals, such as the northern Delta and those in reclaimed lands to the east of the Delta, water is abstracted for supplementary irrigation. Poor sanitation networks, industrial wastewater, and recharge from agricultural wastewater also mean that the Nile aquifer experiences problems with degradation of water quality, particularly north of Cairo (Abdel-Dayem 2011). The Delta aquifer is also impacted by changes in the river's hydrology following the construction of the High Dam in Aswan, although increasing rates of abstraction for supplemental irrigation is also problematic

The large Nubian aquifer of the Western Desert is fossil water, and studies on the recharge of other aquifers have been limited. Aquifer recharge from rainfall is known to occur in Sinai and the North Coast. However, the highly sensitive relationships between temperature, rainfall, runoff, recharge mean that projecting the impacts of climate change on groundwater is complex and uncertain (e.g. Kingston, & Taylor 2010; Green et al 2011).

The Nile aquifer accounts for approximately 87% of national groundwater abstractions (Ministry of Water Resources and Irrigation 2005). However, as it is primarily recharged by excess irrigation water and the river itself, it is not considered to be a distinct water resource. Salinity levels in the aquifer are generally around ten times higher than in the river due to recharge from agriculture. The Moghra aquifer east of the delta is known to be recharged by rainfall and inflow from the Nile aquifer, although flows have not been quantified.

The situation of the Delta aquifer merits special attention. This complex aquifer is recharged mainly by water flowing within the Nile River, seepage from Nile groundwater, and the extensive irrigation and drainage canal network. As mentioned above, increasing infrastructural control of river flow and accompanying land-use changes have induced hydrological changes affecting the Delta's saltwater balance and groundwater levels. On the one hand, the annual flood no longer flushes the groundwater and soils, increasing demographic and economic demands for water have reduced the recharge quantities reaching the Delta, and increased abstraction of groundwater in the Delta for supplementary irrigation have contributed to increases in salinization and reductions of recharge. On the other hand, the annual flood was replaced by a more regularised steady flow, and agricultural drainage water became an important source of recharge, although this has also contributed to declining groundwater quality and waterlogging of soils. A lack of regular monitoring has meant that the actual changes are not known from observation. For example, during the1980s some hypothesised that increased recharge from agricultural drainage water might have improved the Delta aquifer's saltwater balance (e.g. Kashef 1983), although the general consensus is that the saltwater balance has been negatively affected by these changes (e.g. Ebraheem et al 1997).

Extensive agricultural reclamation of the Delta during the 1970s and 1980s was encouraged by optimistic assumptions about the volume of groundwater that could be exploited. However, groundwater surveys revealed that saltwater intrusion had occurred up to 130km inland (Kashef 1983). A survey during the 1990s established that the freshwater zone, whilst thick in the south, decreased northward to less than 10m at its maximum extent south of Kafr el-Sheikh City near the town of Qutur, whilst the saline water zone rose rapidly from a depth of 140m just south of Kafr el-Sheikh City to less than 10m near Burullus Lake (Ebraheem et al 1997). The same survey found that a thin and shallow brackish water zone in the southern and middle Delta, formed by leaching from agriculture and human waste, became a thick transitional zone between Qutur and Kafr el-Sheikh City, where it mixed with saline groundwater from the north. North of Qutur, salinity values for water above 30m ranged from 2 500 to 77 681 ppm (the standard reference of seawater is 35 000 ppm), with chemical analysis indicating hypersaline waters were formed during the Pleistocene and Holocene. In some areas a thin lens of freshwater, recharged by rainfall, floats on top of brackish or saline water, and is used as a fragile but crucial water source by local populations (Ministry of Water Resources and Irrigation 2005).

This complex picture has raised questions about the vulnerabilities of the Delta's groundwater to the impacts of sea level rise (SLR). In principle, increased sea levels imply increased seaward hydrostatic pressures, creating additional saline water heads and increased saltwater intrusion (Werner, & Simmons 2009). These impacts are expected to synergise with other SLR impacts such as increased coastal erosion and direct inundation, meaning that effective intrusion could be greater (e.g. El-Raey et al 1995; El-Raey 1997; El-

Raey et al 1999b; El-Raey et al 1999a; El-Nahry, & Doluschitz 2010; El Sayed Frihy et al 2010). Sherif and Singh (1999) modelled the impacts of SLR in the Nile Delta, and concluded that a 50cm SLR could force additional saltwater intrusion of up to 9 km. Using their parameters but a more simplistic modelling approach, Werner and Simmons (2009) concurred that intrusion of up to 5 km in the Nile Delta was conceivable due to surface works and abstraction inhibiting compensation by a rise in the water table.

A recent study by the Research Institute for Groundwater in the area of Ras el-Bar and Gamarsa (near Damietta) modelled the impacts of SLR on two groundwater layers extending 40km inland. The shallow layer lay between 0 and 3 metres above mean sea level (MSL), and the deeper layer was between -7.5 and -11m below MSL. Observed salinities were between 5 000 and 35 000 ppm for the shallow layer and 40 000 and 60 000 for the deeper layer, and they observed that the coastal balance was not stable. They calculated that in the absence of SLR, limited saline intrusion would continue over 30 years, whilst a 0.5m SLR would cause additional intrusion of 7 km after 30 years (Research Institute for Groundwater 2011). A study for the same project by the Drainage Research Institute highlighted the potential for SLR to force rising groundwater levels in areas within 15km of the coastline, with consequent impacts on agriculture and infrastructure through waterlogged soils (Drainage Research Institute 2011).

Although the direct impacts of SLR on the Delta coast have yet to be fully quantified, there is some evidence that initial projections based on low-resolution maps have over-estimated likely losses of land area. There is increasing confidence that judicious engineering works, strengthening of natural protection systems, and adaptations to planning and building codes will be able to cope with the majority of flood threats (Elshinnawy et al 2012). However, the potential for climate-driven increases in saltwater intrusion and groundwater levels is a major concern to the authorities. This is particularly so given current vulnerabilities of farmers in the nearshore area, who already experiences challenge with the supply of irrigation water of sufficient quality and quantity. The potential for groundwater and increased salinization to degrade urban infrastructure has also drawn notice.

2.1.2.4 Institutional vulnerabilities

The physical vulnerabilities and impacts outlined above need to be set against institutional vulnerabilities relating to water management in Egypt. A vulnerability assessment by Hamouda et al. (2009) concluded that geopolitical and institutional factors were as important as biophysical issues in Egypt, with ineffective government, management and enforcement, and limited budgets and expenditure on research all contributing to vulnerability. The political economy of water, in terms of the layers, institutions and networks of interests and political and technical decision-making over water in Egypt are not well documented or analysed, although work is on-going by researchers such as Samuel Luzi. The work of Luzi (2010) analyses water policy at a national level and concludes that stakeholder interests are frequently more significant than rational or technical considerations in water allocations. Qualitative institutional analyses by Jeannie Sowers portray an under-funded and over-staffed water ministry struggling to sustainably implement and manage action and reform (Sowers 2012). Funding from donor agencies, and accompanying technical assistance, is crucial to keeping the system going and infrastructure functioning, as the state is under-resourced and there are insufficient incentives for the private sector to engage.

Together, these assessments indicate the politicisation of water, as well as the fragmented nature of water governance. In particular Sowers draws attention to the fragmented mandate, authority and resources of the water ministry in the context of central policy versus local action, and the difficulties of adopting community-based participatory approaches in the context of an authoritarian regime (Sowers 2012). In the context of climate change, these institutional challenges have the potential to become significant hurdles to successful adaptation.

2.1.2.5 Summary – key vulnerabilities

- Potential reduction in national water share due to increased upstream abstraction
- Continued decline of per capita water resources due to population growth
- Increased demand from industry and an urbanising population
- Lack of certainty regarding direction and magnitude of climate impacts on Nile river flows
- Inefficiencies in water distribution, recycling and treatment networks, both for irrigation and domestic supply
- Increased water demand from, and evapotranspiration in, agriculture
- Declining water quality, particularly in the Delta
- Communities dependent on rainfed systems subject to reduction in precipitation and increased variability
- Overexploitation of groundwater resources in the western desert, eastern desert, Sinai, New Lands, and the Nile Delta
- Salt water intrusion into coastal groundwater and increased groundwater levels driven by sea level rise
- Institutional challenges related to resources, mandate and effectiveness of water authorities
- Institutional challenges related to co-governance between the state, private sector, and communities and water users

2.1.3 Adaptation

Egypt has neither a single institution responsible for coordinating adaptation action, nor a significant body of practical experience in adaptation to climate change. Few climate adaptation pilots have been implemented, and studies have focused on opportunities for exploration rather than empirical demonstration.

Currently, three key governmental documents indicate intentions and directions of adaptation efforts in the water sector. These are the National Water Resources Plan for Egypt to 2017 which was funded by the Dutch Government (Ministry of Water Resources and Irrigation 2005), the Second National Communication to the United Nations Framework Convention on Climate Change (Egyptian Environmental Affairs Agency 2010) and the draft Egypt's National Strategy for Adaptation to Climate Change and Disaster Risk Reduction (Information and Decision Support Center 2011), both funded by UNDP. These last two documents indicate general ideas and approaches for adaptation rather than reporting on results of detailed or quantified prospective studies.

2.1.3.1 Supply side adaptations

With uncertainty over the direction of future Nile River flows, attempts have been made to identify adaptation options for both increasing and decreasing water flows, as well as specific responses to uncertainty in supply.

Adaptation to Uncertain Supply

With uncertainty over the future direction and magnitude of river flow changes, and with the possibility of increased annual and decadal variability in flows, these options focus on buffering capacity and storage.

The option of changing operating procedures for Aswan High Dam has been proposed. Currently the minimum operating level of the dam is set at 175m above sea level, with waters discharged in August each year to capture the arriving floods from the Ethiopian Highlands. Changing policy to permit minimums of 170m or 165m above sea level would slightly increase the risk of capturing less water in particular year, but would reduce losses from evaporation and the Toshka spillway, allow more capture in high flow years, and the excess water released could contribute to irrigation (Egyptian Environmental Affairs Agency 2010; Information and Decision Support Center 2011). This option was examined as part of the Lake Nasser Flood and Drought Control project between 2002 and 2005. The deepening and widening of the Toshka spillway to accommodate larger runoff, and widening the main Nile stream and larger canals has also been identified as a medium term priority to accommodate larger stream flows (Information and Decision Support Center 2011).

The preparation of alternative storage for use in emergency cases has also been proposed, with options including Toshka, the Qattara Depression, and the salty coastal lakes of Manzala, Burrulus, Idku and Mariout (Egyptian Environmental Affairs Agency 2010). However, the economic, environmental and other costs and benefits of such large-scale have not been examined in any detail.

Adaptation Measures for Managing Increased Flows

In general the concern here is to avoid unnecessary wastage through limitations in storage and distribution infrastructure, and to capitalize on additional flows. These options may contain risks if flows decline in the long term following medium term increases and expansion of infrastructure and demand.

In addition to the options of developing increased storage in Egypt, both the National Adaptation Strategy and the Second National Communication identify the potential for increased upstream storage as a possible adaptation to increased river flows (Egyptian Environmental Affairs Agency 2010; Information and Decision Support Center 2011). They refer to the Nile Basin Initiative as the appropriate vehicle for pursuing such options, and point to the possibility for reservoirs in upstream countries to have mutual benefits in flood protection and hydroelectric power generation.

Adaptation Measures to Increase Supply

These measure focus on developing new water resources. Inevitably this area has received considerable attention, as the accompanying measures also respond to anticipated increased water scarcity due to demographic pressures.

Options for increasing Nile flows are focused on improved water management in riparian countries, which are the focus of Nile Basin Initiative activities. Given that the 55 Bm^3 per year received by Egypt is equivalent to 2.8% of the water budget for the whole Nile basin, Egyptian officials feel that more can be done in terms of managing greenwater in upstream countries. However, existing projects need to be re-evaluated to assess the impacts of climate change (Egyptian Environmental Affairs Agency 2010).

Additional deep groundwater resources have recently been identified, adding to Egypt's potential for increased exploitation which is thought to range between 36 and 130 Bm^3

(Macdonald 2012). However, policy documents to date indicate a preference for maintaining the majority of these resources as strategic storage for unforeseen developments (Egyptian Environmental Affairs Agency 2010). This may partly reflect the significant costs of drilling and transferring waters to areas of demand, an equation that may change in the future. The National Water Resources Plan anticipates future abstractions of up to 4 Bm^3 per year (Ministry of Water Resources and Irrigation 2005). There are concerns that shallow groundwater resources are already over exploited, particularly in the Delta. No significant increases in abstractions are anticipated, and particularly in coastal areas may be reduced, and priority will be given to abstractions for drinking water in the Nile aquifer (Ministry of Water Resources and Irrigation 2005).

Despite limited and variable precipitation, rainwater harvesting could make a contribution to water budgets along the coats and in the Sinai, as well as helping mitigate the impacts of flash floods (Egyptian Environmental Affairs Agency 2010). The National Water Plan estimated that 1.3 Bm^3 of rainfall is used each year (Ministry of Water Resources and Irrigation 2005). It has been estimated that this could be increased to 1.5 Bm^3 by constructing dams, reservoirs and sub-surface reservoirs for collection and storage (Information and Decision Support Center 2011). Whilst a crucial resource for local communities, the relatively minor impact this would have at a national level, high costs involved in constructing small dams, and limited capacity for engaging local communities to support small-scale retardation and recharge of groundwater imply that this is unlikely to be a significant sphere of action. The exception is likely to be in those areas where dams could reduce the impact of floods on important settlements, industry, and tourism infrastructure (Ministry of Water Resources and Irrigation 2005).

Desalination has been noted as another potential source of water, particularly if applied to brackish groundwater for supplementary irrigation (El-Kady, & El-Shibini 2001; Egyptian Environmental Affairs Agency 2010). The costs are currently prohibitive on a mass scale, although private hotel complexes as well as the municipal water supply in Sharm el Sheikh use desalination. However, hopes focus on reduced future costs of solar desalination.

Virtual water constitutes a specific form of supply-side solution, referring to water embedded in internationally traded goods, usually food (Allan 1998; Zeitoun et al 2012). Increasing food imports whilst decreasing food exports – particularly those that are water intensive – is therefore a means of meeting water demands without consuming national resources. Another study by Zeitoun et al. (2010)examined the virtual water trade within the Nile Basin between 1998 and 2004 and concluded that Egypt is a net importer of 'virtual' water embedded in foods, importing 372 Mm^3 per year from upstream Nile nations and approximately 30 000 Mm^3 per year from non-Nile Basin countries, chiefly in the form of soy and wheat. This represents more than half of Egypt's Nile waters allocation, and indicates the importance of global trade to achieving water security for Egypt. Others have calculated more conservative figures of a net import of virtual water for Egypt of 10 917 Mm^3 per year for Egypt between 1997 and 2001, including industrial trade (Chapagain, & Hoekstra 2008).

Despite the discrepancies in figures, both studies indicate the significance to Egypt of virtual water flows, and the National Water Resources Plan estimates that 27% of agricultural water needs are met through virtual water (Ministry of Water Resources and Irrigation 2005). However, whilst some MWRI officials expect to see increasing reliance on virtual water, some agricultural experts and officials have argued that returning to food self-sufficiency, particularly in wheat, should be a high priority. This view gained some support following the 2011 Revolution, with some arguing that high global wheat prices placed unsustainable pressure on both the national and household economies. Regardless, of where this debate leads in the future, it is clear that although virtual water can help address global efficiencies in water consumption, water importers face increased political costs and dependency (El-Sadek 2010).

2.1.3.2 Demand side adaptations

Egypt faces increased water scarcity even in the absence of climate change, and considerable effort by the MWRI has been focused on identifying strategies for improving water use efficiency, reducing losses, and reducing water demand. The National Water Resources Plan adopts Integrated Watershed Management as the principle means for adaptation to water scarcity in general. Aside from highlighting the need to make rational water allocations, the plan focuses on increasing system efficiencies, in particular maximizing reuse of wastewaters (Ministry of Water Resources and Irrigation 2005; Loutfy 2010). There is also a focus on reducing losses from the Nile system to sinks away from the Nile Valley, such as desert and coastal areas, which without action would increase by 2017. As a consequence the reclamation of 250 000 feddans in the Middle Sinai Scheme has been postponed until groundwater or other alternatives can be found (Ministry of Water Resources and Irrigation 2005).

Identifying means for improving water use efficiency in agriculture has been a main concern due to its dominant consumptive role. In this context it is important to distinguish between potential adaptations in the direct control of the MWRI – flows in the primary and secondary branch canals – and those in the tertiary canals (*mesqa*) and on-farm adaptations, which are communally or privately controlled, and lie within the province of the Ministry of Agriculture.

Water Allocations to Agriculture

As discussed below, several policy documents and national programs intend to increase agricultural water use efficiency, mainly through improved irrigation practices and wastewater recycling. The National Adaptation Strategy and National Water Resources Plan also state that saved water will be used to expand irrigated agriculture into new lands, even though the same National Water Resources Plan states that an objective is to reduce losses to sinks outside the Nile Valley (Ministry of Water Resources and Irrigation 2005; Information and Decision Support Center 2011). Horizontal expansion of agriculture in new land developments are known from remote sensing observations to have significantly higher evapotranspiration losses than long-used lands in the centre of the Delta (Elhag et al 2011). Horizontal expansion of agricultural area will therefore increase the amount of water lost to sinks, and reduce return flows to groundwater and drainage waters available for recycling. The majority of the planned horizontal expansion, therefore, is focused using water from the periphery of the irrigation network that would otherwise be lost to the sea through drainage.

Based on projected streamflow analyses Beyene et al. (2010) concluded that Egypt would be able to satisfy historical irrigation requirements between 2010 and 2039, and also meet a 5% increase in irrigation water demand during the same period. However, their analysis also indicated that water releases would decline by between 13 and 15% by the period 2070-2099. Such analyses in conjunction with policies regarding horizontal expansion based on increased agricultural water efficiencies raise the potential of maladaptation, with increased water demand being generated through agricultural expansion prior to a longer-term reduction in flows. However, the economic and political realities of Egypt may lead policy makers to discount the long-term future sufficiently for that to be a rational option.

On-Farm Adaptations

Proposed adaptations in the agriculture sector proper focus on improving on-farm irrigation efficiency and reducing pesticide and fertilizer use as means of improving the quality of return flows (Egyptian Environmental Affairs Agency 2010).

Improvements in on-farm irrigation efficiencies are seen as an important counter to expected increases in water demand from evapotranspiration (Egyptian Environmental Affairs Agency 2010; Information and Decision Support Center 2011). A key part of the National Adaptation Strategy is to improve on-farm irrigation efficiency to 75% in 5 million feddans over the next ten years, although this is dependent on the necessary resources becoming available. Some of the proposed adaptations in this area include: the development of new crop varieties; improved agroecological situating of crops in areas maximizing their water use efficiency; earlier planting of crops to avoid higher temperatures; deficit irrigation to promote yields per unit water rather than yields per hectare; and increased deployment of improved irrigation technologies (Egyptian Environmental Affairs Agency 2010; Information and Decision Support Center 2011).

Although practical experimentation has yet to be reported on, Khalil et al. (2009) showed some of the potential practical complexities by simulating some outputs of interactions between different wheat strains, irrigation regimes and planting times under different scenarios of climate change in 2038. They found that it was possible to reduce yield losses and irrigation requirements under certain conditions for some strains, but the balance between maintaining yields and water use efficiency was dependent both on strain and planting time.

An assessment of proposed on-farm adaptations by Attaher et al. (2010; 2009) found that improving surface irrigation efficiency would be most effective in Old rather than Reclaimed Lands. Deficit irrigation was found to exacerbate yield loses to the extent it was only preferable under drought conditions, but that combinations of reduced surface irrigation and deficit irrigation could be optimal. They noted that whilst the costs of improvements to individual farmers could be barriers to adaptation, the overall costs to the irrigation network were likely to be cost efficient. However, as Jensen (2007) and others have shown, drip irrigation technologies are not necessarily more efficient in areas where precipitation does not leach salts, and poorly maintained systems may lead to no significant improvement in efficiency.

Jensen (2007) notes that the most significant water savings can be gained by timing irrigations to match the needs of crops, preferably by using computerized irrigation schedules. However, as farmers generally receive irrigation water on a time allocation, and the average farm size in Egypt is less than one feddan, Egypt's ability to implement or capitalize on this approach remains small without very significant investment in infrastructure and technology. There is also no investigation as yet into more radical approaches, such as vertical urban agriculture using aeroponic systems, for ensuring food security whilst improving water-use efficiency, potentially to dramatic effect.

However, the strategic purpose of increasing on-farm water efficiency and links to water scarcity adaptation is never clearly explained in the documents reviewed. At different points it is referred to in the context of adapting to additional on-farm evapotranspiration demands, improving equity between upstream and downstream farmers on tertiary canals, or creating new water for horizontal expansion of agriculture in to new areas. It is discussed more commonly simply as an objective in its own right.

Keller and Keller (1995) demonstrated that although local water use efficiency in Egyptian agriculture is quite low (approximately 42%), the overall efficiency of the system is above 90% due to return flows through drainage and groundwater. This implies limited opportunity for water savings in real terms (Jensen 2007).

The value of return flows from drainage and groundwater is clear, and adaptations to reduce agricultural pollution from fertilisers and pesticides could have significant cost, health and water quality benefits downstream. By contrast, the benefits from reduced on-farm inefficiencies are less obvious when placed in context.

Adaptations in the Irrigation Network

The National Water Resources Plan identifies several potential adaptations in the primary and secondary canal network, including reducing leakage through improvement of infrastructure and reducing evaporation by redesigning canal cross-sections, as well as improving the drainage network (Egyptian Environmental Affairs Agency 2010).

An analysis by (El-Agha et al 2011) indicated that on-farm and tertiary canal improvements would not significantly reduce water losses, with the majority of losses occurring in main canals and drains. They suggest that a focus on improving the main canal, accompanied by more precise water delivery practices at branch and tertiary levels, would have the largest impact on reducing inefficiencies. For implementation they suggest prioritising the lower Delta canals, where farmers are more likely to rely on polluted wastewater or saline water in supplementary irrigation.

Reuse of drainage water is already practised on a significant scale, officially amounting to 4.84 Bm^3/year in 2001. The objective is to increase this to 8 Bm^3/year in the future, focusing on newly reclaimed areas (Ministry of Water Resources and Irrigation 2005; Loutfy 2010). The intention is to shift to the reuse of waters from smaller, less polluted drains further upstream, including 'immediate' reuse which would see water from small drains pumped into nearby secondary or tertiary canals. The Egyptian Public Authority for Drainage Projects is also mandated to expand coverage of sub-surface drainage from 5 million to 6.4 million feddan by 2017, improving return flows (Ministry of Water Resources and Irrigation 2005). However, there are also concerns with water quality issues arising the recycling of drainage waters. Mixing drainage waters will increase the salinity of irrigation waters, and the National Water Resources Plan lays out the intention to revise minimum salinity standards in some areas and invest in research in salt-tolerant crops (Ministry of Water Resources and Irrigation 2005). Potentially more serious, the potential for human health to be put at risk by creating favourable environments for pathogens has also been raised, although the potential for climate change to worsen these risks has not been assessed (Evans, & Iyer 2012).

An alternative approach to irrigation system reform based on economic optimization was explored by Gohar and Ward (2010; 2011). They demonstrated that a water trading system based on individual transferable quotas (ITQs) could help support a better allocation of water amongst crops, seasons and locations in Egypt, incentivise water saving, and boost farm income. They calculated that national farm income could be increased by 28% with no change to existing irrigation technologies or total consumption of water. However, the practical implications of this work currently appear limited due to the lack of legal and institutional frameworks for water trading, and the logistical constraints imposed by existing infrastructure.

Adaptations To Improve Treatment And Recycling Of Wastewater

In addition to improvements in the recycling of agricultural drainage water, municipal and industrial wastewater recycling is also a priority for adaptation and the National Water Resource Plan (Egyptian Environmental Affairs Agency 2010; Loutfy 2010). With just 200 wastewater treatment plants in the country, urban sanitation coverage reaching 56% and rural sanitation coverage only 4%, there are considerable problems with water pollution. Developing low cost water treatment facilities could make significant contributions to improving downstream water quality, and make more water available for reuse.

At present the principle focus of activity is to use treated wastewater from Cairo and Alexandria for horizontal expansion of agriculture in reclaimed lands in the Eastern and Western Delta. Plans are to create 250 000 feddans, although there are issues with the timing of supply and demand (Ministry of Water Resources and Irrigation 2005). El Lateef et al. (2011) demonstrated that despite significant capital investment and operating costs for the treatment and transport of water, the internal rate of return for such a project could be as high as 7.6%.

Water demand management in the domestic network has also been contemplated. With little existing incentive for consumers to save water due to low sale price, focus is on awareness raising, and – more politically ambitious – the metering and pricing of water. Estimates of network losses in the municipal supply network reach 70%, and the reduction of leakage has also been identified as an adaptation action (Information and Decision Support Center 2011).

Coastal Adaptation

With respect to the adaptation of coastal areas to the impacts of sea level rise, several studies have examined the potential for hard and soft coastal defences, as well as the impact of managed realignment options. Amongst these proposals are the conversion of near-shore agriculture to aquaculture and non-soil agriculture.

The costs of adaptation to raised groundwater levels for 38 000 feddan in the Ras el-Bar to Gamarsa area have been estimated by the Drainage Research Institute as in excess of LE 133 million. This includes works to improve sub-surface drainage, increase the flow capacity of drainage canals, and upgrading pumping stations (Drainage Research Institute 2011).

A study by the Research Institute for Groundwater in the same area examined two options for preventing salt-water intrusion; wastewater injection into aquifers, and the construction of a sub-surface barrier (Research Institute for Groundwater 2011). The optimum solution identified for injection of aquifers was to pump 600 m^3 of treated sewage every day for 30 years into 13 wells, 300m deep, 2.7 km from the sea, and spaced 3.6 km apart. Modelling indicated a marked change in groundwater salinity, and retention of the saline water interface. By contrast a 70m deep sub-surface barrier was projected to have a negligible effect after less than three years of operation. The study also noted that all groundwater abstractions within 10 km of the coast should be prohibited due to the highly vulnerable nature of groundwater in the area, and that an improved monitoring network was needed to observe changes.

Institutional Adaptations

In addition to the foregoing ‘hard’ adaptation options, there have been attempts to outline needs for institutional capacity development and reform. These can categorised as relating to information or governance.

Informational adaptations include the development of downscaled and integrated climate and hydrogeological models for predicting Nile flows, improving data exchange between riparian countries, enhancing precipitation measurement networks and installing early warning systems, conducting studies and increasing the capacity of researchers to investigate the impacts of climate change on water resources (Egyptian Environmental Affairs Agency 2010; Information and Decision Support Center 2011).

Governance adaptations proposed include more flexible planning systems and improved enforcement, mechanisms to resolve conflicts amongst water users, and an enhanced role for civil society in awareness raising (Egyptian Environmental Affairs Agency 2010). Initial success with improving equity through involvement of Water Users Associations in governing tertiary canals – and, in principle, contributing to the governance of branch, or secondary, canals – has been disappointing, largely due to the lack of preparedness of participatory co-governance in an authoritarian regime (Sowers 2012). Batt and Merkley (2009) instead conclude that farmers were reluctant to accept the reforms because they lacked training on the irrigation improvement techniques introduced through the projects. They suggest a focus on reforming irrigation system improvement policies to be more realistic, and to encourage Ministry personnel to adopt and support participatory water management. Sowers (2012) is more sceptical, but accepts that participatory regimes may become more acceptable in the future.

In general the options proposed for institutional adaptation address relatively peripheral issues and are unambitious. There is, for example, no examination of reformed institutional arrangements for strategic decision making over water allocations, or consideration of suggestions as allocating water rights (Gohar, & Ward 2011). In part this reflects political realities and infrastructural constraints, but in the context of increasing water scarcity it raises the question of political will to consider more radical solutions.

2.1.3.3 Summary – proposed adaptations

In Egypt at present there is little practical experience in adaptation to climate change, although there is an extant body of experience and expertise on adaptation to water scarcity. In the context of climate change, many of the proposed measures for adaptation to water scarcity can be considered also as appropriate climate adaptations. The list below highlights specific climate adaptations rather than more general actions for coping with water scarcity.

- Engineering works to increase storage and flow capacity to meet increased or uncertain Nile River flows
- Improved land-use management in upstream riparian countries
- Rainwater harvesting in desert and coastal areas
- Engineering works to reduce losses from evaporation in irrigation canals
- Reducing on-farm evapotranspiration through use of new crops, cropping patterns, and irrigation regimes, especially the timing of irrigation
- Improved agricultural drainage in coastal areas
- Recharge of coastal aquifers using wastewater
- Improved control and enforcement of groundwater abstractions in coastal and other climate vulnerable areas
- Improved research, monitoring, and sharing and management of knowledge on climate impacts on water resources

In terms of actions to adapt to increased water scarcity in general, the greatest internal efficiencies are likely to be gained through maintaining water quality, increasing water reuse, particularly in agricultural drainage waters, and reforming institutions for the allocations and governance of water.

2.1.4 Knowledge assessment

Knowledge creation on climate change has gathered pace in Egypt over the last five years. However, significant gaps in knowledge and expertise remain, particularly in adaptation.

The range of uncertainty over future Nile flows is still large, but has been greatly reduced over the last five years. However, little of this work is conducted in Egypt, and climate modelling capacity in general remains weak. One area where work has progressed in Egypt is in assessments of climate change impacts on agricultural yields and consumption of water in the Nile Valley, particularly in cereal crops. By comparison no studies could be found on the impacts of climate variability on water resources and agriculture in vulnerable desert and coastal areas such as Sinai. No studies could be found on the impacts of climate change on municipal, touristic or industrial water demand, water-mediated interactions between climate and human health, or the impacts of climate change on water quality. Limited research has been conducted on the impact of sea level rise on coastal groundwater resources, and no work was identified on the impacts of climate change on groundwater recharge. No work was identified on institutional vulnerabilities to climate change in the water sector.

Egypt's internal water system is uniquely buffered from the impacts of climate variability on water resources due to the entry, storage and control of waters at Aswan. Demographic pressure on water scarcity is also more intense than anticipated pressure from climate change. These perceptions may have contributed to a lack of research on potential impact pathways and the limited state of knowledge.

Similarly, whilst considerable attention has been given to developing proposals for adaptation to increased water scarcity, work on climate adaptation is even more limited. With the exceptions of a few studies, it has been principally constrained to priority setting exercises and explorations in the contexts of the Second National Communication and the draft National Adaptation Strategy policy documents. The focus in these documents is on technical and engineering adaptations rather than social or institutional adaptations, a strong contrast to countries reliant on direct precipitation where there is increasing attention on adapting local institutions to climate change and variability. The measures proposed also focus on coping strategies rather than transformative adaptations based on radical innovation or reform of the water system.

Missing from the available policy documents is a clear analysis of how proposed adaptations have been identified and prioritized, and how they logically contribute to adaptation to overall water scarcity. For example, the three policy documents offer no firm vision on how gains made from increased water efficiencies in agriculture will be used, mentioning both horizontal expansion of agriculture and eventual reductions in the consumptive use of water by agriculture. This appears to be symptomatic of a generally limited capacity for systematic knowledge creation to support policy making. For example, no modelling could be found of the impacts of increased water efficiencies in agriculture on return flows to, and abstraction rates from, aquifers. Similarly, very limited assessments of social and economic costs and benefits of proposed adaptations appear to have been made.

2.2 Initiatives and capacity gaps on adaptation

2.2.1 Focus areas in climate change and water

Over the last five years activities on climate change in Egypt have increased substantially. Water, agriculture, coastal zones and human health are the dominant priorities in both the Second National Communication and the draft National Adaptation Strategy.

Governmental, donor and research activities on water resources and management in Egypt have a long, deep and complex history. Work on climate change and water is therefore best viewed as an additional dimension to an existing policy, research and institutional landscape that is already both crowded and fragmented.

This section provides a summary narrative assessment of this landscape rather than dwelling in detail on specific initiatives.

2.2.2 Policy priorities and activities

Nile River Supply

Strategically the Egyptian government is concerned to maintain Egypt's water share from the Nile River. This is mainly in the context of increased demands from riparian nations. There is considerable pressure in East Africa, particularly in Ethiopia, Kenya and Uganda, to use Nile water flows to for irrigation in arid and drought prone areas. Ethiopia also sees highly significant hydropower potential and has plans to construct eight dams on the Blue Nile and Atbara Rives over the next 25 years. This includes the Renaissance Dam which is planned to have a capacity of 63 Bm^3.

The Egyptian government is engaged in constant diplomacy on these issues, both bilaterally and through the Nile Basin Initiative (NBI). The Foreign Ministry takes the lead in these matters, with technical advisory from the MWRI's Nile Water Sector. In the last 12 months there have been signs of a possible change in direction from that under the former regime, with the Egyptian government agreeing to review the plans for the Renaissance Dam, and more informal discussion over the potential benefits of reduced evaporation losses from water storage in the Ethiopia Highlands and the possibility of purchasing hydroelectricity. Formally, however, the government remains opposed to these plans, saying that they threaten Egypt's water security and that the impacts of siltation and climate change have not been sufficiently accounted for.

Another line of activity is to work on utilisation of greenwater flows in East Africa. The vast majority of the Nile Basin's 2 000 Bm^3 water budget is lost to evapotranspiration each year. There has been contemplation of technical assistance to riparian nations for works improving flows to tributaries, although there is no publically available information about any proposals to do so. There are also increasing investments in land in upstream countries by Egyptian investors for growing food, with the intention of effectively increasing Egypt's supply through virtual water imports. The role of the government in these activities is unclear, and little information is available.

With specific reference to climate change, the main focus of current activity is the Forecasting & Integrated Water Resources Management Project, implemented in MWRI's Planning Sector with funding under the Climate Change Risk Management Project. This work is intended to address the need for more certainty and information regarding the direction and magnitude of climate impacts on Nile River flows reaching Egypt through the development of a PRECIS regional climate model (RCM). However, there is cause for concern in that best practice is to use ensemble results from multiple RCMs rather than rely on outputs from a single model. The uncertainty of climate projections can be difficult for policymakers to appreciate or handle, and there is a significant risk that model outputs could be taken too literally and their internal uncertainty overlooked. The potential for maladaptation should significant policy and investment decisions be based on outputs from just one model is considerable. There are also questions to be asked about the long-term sustainability of this investment in modelling capacity in the MWRI.

Developing and maintaining modelling capacity is resource intensive, and to develop and maintain a whole ensemble of models for the Nile Basin is likely to be unaffordable for Egypt. It would be more efficient for Egypt to draw on expertise in global centres to develop assessments of future Nile Water flows using ensemble model results. What Egypt does need is the capacity to understand and interpret projections and uncertainties, impact and vulnerability models, and translate them into water decision-making.

However, there is also a strong incentive for Egypt to develop its own capacity for modelling future Nile flows given uneven relationships with Nile Basin Initiative countries, and the politicisation of scientific results.

Alternative Sources of Water

Aside from water re-use, which is increasingly mainstreamed in water policy and practice, this area has been little developed as yet. The National Water Resources Plans includes just 5.7 billion LE for developing new water resources between 2003 and 2017, with 75% of that devoted to new groundwater sources. Just 800 million LE is set aside for desalination, and that appears to be anticipating private sector interest – presumably mainly focused on desalination in tourist resorts of the Sinai and Red Sea rather than desalination for agriculture.

National organisations with an interest in this sector include the Alexandria University Desalination Studies and Technology Centre, and the Research Institute for Groundwater and the Water Resources Research Institute at the National Water Research Centre. The EU SWIM programme supports the SUSTAIN WATER MED project, which is trialling wastewater treatment for irrigation in Giza.

On-Farm Water Consumption

This is a key interest of MALR, with the MWRI having a significant interest due to agriculture's dominant consumption of water. There are two principal areas of focus, the first being issues related to selecting crops maximising water productivity and efficiency, the second being issues related to reducing losses and consumption in irrigation. These activities are specifically mentioned within the agricultural domain of the draft National Adaptation Strategy under the objective of increasing water use efficiency.

Key activities in the former include the breeding of new varieties, identification of optimal agro-ecological zones for different crops, and development of new cropping patterns and soil management techniques. The Agricultural Research Centre, specifically the Central Laboratory for Agricultural Climate, are heavily engaged in this work, with projects supported by FAO, CGIAR centres (particularly ICARDA), and university researchers inside and outside of Egypt. UNDP currently fund the Vulnerability & Adaptation of the Agricultural Sector project with MALR on this topic.

Increasing on-farm irrigation efficiencies remains a significant activity, with the World Bank in particular having spent 245 million USD in this sector since 2007 with the MWRI and MALR. IFAD is also a significant investor, with an 87 million USD project on water use efficiency including pilot sites in Kafr el Sheikh. Currently one of the largest projects in this sector is the Farm-level Irrigation Modernization project with a total value of 180 million USD targeted at 140,000 small-scale farmers on to 200,000 feddans in the Nile Delta, representing an investment of 900 USD per feddan. Within the MWRI, the Irrigation Development Sector of the Irrigation Authority is a key organisation, involved in the 300+ million USD Integrated Irrigation Improvement and Management Project (IIIMP, 2005-2014) both at the main network and *mesqa* level. The IIIMP builds on the activities and lessons of the long-running Irrigation Improvement Program (IIP, 1984 – present). Both these projects are extended into the future under the National Water Resources Plan, which projected the costs of irrigation related activities in this sector at 10.2 billion LE between 2003 and 2017, 7% of its total budget.

With 7.2 million feddans of cultivated land in Egypt, questions remain about how to scale out results of these projects, given the under-resourced agricultural extension services and structure of incentives for individual small farmers. It is notable that the National Water Resources Plan includes investments of 3 billion LE in improved on-farm irrigation by the private sector. Most farmers in Egypt are land-constrained rather than water constrained and lack capital for investment, so the incentives are not structured towards water conservation. Key questions for water conservation remain largely related to policy, water pricing, and institutions rather than technology. Whilst donors typically include these dimensions within their projects, they are frequently viewed as landscape features to be worked around rather than reformed.

Irrigation Network Improvement

This is a major area of activity for the MWRI, being the largest area of investment for water use efficiency under the National Water Resources Plan with a budget of 18.2 billion LE (12.5% of the total budget) between 2003 and 2017. The single largest investment in this sector was anticipated to be the rehabilitation and development of pumps along the canal network, estimated at 10 billion LE for the same period. Rehabilitation and improvement of canal regulators and barrages, and maintenance and dredging of canals and waterways are significant operational costs in this area, and the budget also includes for activities for institutional reform through increased participation at the mesqa (tertiary canal) level and the reform of regional water allocations. These activities are supported by donors including JICA and the African Development Bank. Strategy is developed within the MWRI's Planning Sector, the Irrigation Authority is responsible for implementation, and the National Water Research Centre plays a supporting role. The Irrigation Improvement Program (1984 - present) has been an umbrella for activities in this sector aimed at improving main and branch canals.

As the National Water Resources Plan made clear, significant reductions in leakages from irrigation networks can be made from upgraded infrastructure and maintenance. However, what is striking about the budgetary allocations of the National Water Resources Plan is the limited investment funds available to the MWRI. The budget gives the total figures of investments at 145 billion LE over 15 years, with additional operational and maintenance (O&M) costs of 43.8 billion LE (Tables C1 & C2 Ministry of Water Resources and Irrigation 2005). By contrast, in 2003/4 the government spent 4.09 billion LE on water infrastructure, of which 3.23 billion LE was spent on new infrastructure and 0.86 billion LE went to O&M (Mohamed, & Jagannathan 2009). These figures imply an increase in new water infrastructure spending of 250%, and an increase in O&M of 340%. Given the current condition of the government finances, the only option for realisation of these plans at the moment appears to be massive donor investment.

Given the high costs of maintaining and operating infrastructure, and the limited budgets available, this does perhaps contextualise the MWRI's focus on maintaining the existing system rather than considering more costly reform options such as facilitating water transfers between regions (which could also require significant legal reforms).

Wastewater Management

This is a significant area of concern for the MWRI, and the priorities of the National Water Resources Plan were clearly for the Delta region. The plan called for an increase in agricultural drainage water pumping capacity in the Delta from 3.2 Bm^3 in 1997 to 8.5 Bm^3 in 2017, along with improvements to sub-surface drainage, improvements in drainage canals. In addition to this infrastructural development, the plan also called for reform of policies allowing higher salinity levels in irrigation canals and research into the development of salt tolerant crops. Projected investment costs were relatively slight at 4 billion LE, just 2.8% of the total budget, but measures under this umbrella were consistently assessed as likely to be effective.

Activities in this area are most concentrated in the Nile Delta, especially the northern governorates where declining water quality and quantity at the periphery of the irrigation network has its greatest impact on agriculture.

The Egyptian Public Authority for Drainage Projects is the MWRI's lead organisation in this area, supported by the Drainage Research Institute of the National Water Research Centre. In 2010 the World Bank approved an additional 30 million USD to extend the Second National Drainage Project (SNDP), which had already received over 140 million USD from the World Bank, KFW, the European Investment Bank, and the Dutch Government. By 2008 the SNDP had installed sub-surface drains in approximately 990 000 feddans and improved open drains on 440 000 feddans. Perhaps the most significant research program is conducted by the International Water Management Institute, which is examining the effects of different hierarchical levels of management on water quality in the Delta irrigation and drainage network.

Non-agricultural wastewater treatment and recycling is perhaps the largest area of current investment, with sizable commitments made through the Mediterranean Hot Spot Investment and Sustainable Water Integrated Management Programmes of the European Union, in addition to projects financed by the African Development Bank and others. The National Water Resources Plan calls for 65.5 billion LE investment in municipal and wastewater treatment, fully 45% of the entire projected budget. The principal focus here is improved sanitation and public health, but the plan also calls for increasing recycling 2.4 Bm^3 from sewage as well as anticipating a 237% increase in industrial water demand whilst improving recycling from 90% to 95%. Demonstration projects include treated municipal wastewater from Alexandria being used for orchard irrigation in the West Delta. The EU SWIM programme supports the SUSTAIN WATER MED project, which is trialling wastewater treatment for irrigation in Giza.

A number of other projects in the coastal zone focus on reducing pollution flows into the Mediterranean, with funding from the European Union and World Bank amongst others. These include the Alexandria Coastal Zone Management Project which has multiple funds through the World Bank, and includes a commitment from the Egyptian government of 626 million dollars and focuses on reduction of pollution from agricultural drains.

Nile Delta Coastal Zone

The delta coastal zone is currently the focus of considerable attention, not only due to the attenuating water supplies and quality at the periphery of the irrigation network, but also due to the risks of sea level rise, saltwater intrusion, and increasing groundwater levels. The interactions between these impacts make farmer in this region amongst the most vulnerable in the country. However, as yet, no project has taken a comprehensive approach to climate adaptation in this area and current activities are quite fragmented.

The UNDP/GEF funded Adaptation to Climate Change in the Nile Delta Through Integrated Coastal Zone Management (ACCND-ICZM) is examining the potential for soft adaptation options as low cost alternatives to sea walls, as well as options for reforming institutions governing the coastal zone. It has benefitted from a completed IDRC project examining trade-offs and preferences for different adaptation options in rural communities. The GEF-funded Alexandria Coastal Zone Management Project also contains a flood-protection component. The IMPROWARE project supported by the EU's SWIM programme is investigating the recharge of coastal aquifers, whilst FAO has a project monitoring the impacts of sea level rise on agriculture. The Dutch government supports a small project to develop a management for Burullus Lake focused on water quality management. The MWRI wish to develop an adaptation project in the nearshore area that will convert agricultural area to aquaculture, avoiding problems with groundwater levels and salinity. However, it was rejected by the UN Adaptation Fund board and is currently awaiting redrafting of the proposal.

The key missing capacity in this area is for integrated planning and management of the coastal area, with effective governance and enforcement. Capacity to make strategic plans is weak, and so far there has been no coherent strategizing on how to adapt to the impacts of climate change in the coastal zone.

2.2.3 Research

Research on water in Egypt is well established, where-as research on climate change is relatively under-developed. Egyptian researchers and research institutes engaged on water issues generally focus on technical and engineering aspects. Groundwater, irrigation and drainage engineering are well supported by specific institutes at the National Water Research Centre as well as university departments, particularly Cairo and Ain Shams. Comparatively little work is done water economics or social or policy aspects of water, although political science institutes, such as the Al Ahram Centre for Strategic Studies, do focus on riparian issues. This is in contrast to agricultural economics, which has a specific institute at the Agricultural Research Centre.

Agricultural research is significantly better resourced. The Agricultural Research Centre employs over 12 000 researchers, and there are notable sources of agricultural expertise at national universities and research centres, in particular the National Research Centre, and Cairo, Alexandria, Mansoura and Ain Shams Universities, as well as specialist centres such as the American University in Cairo's Desert Development Centre. A very broad range of expertise exists, although most falls into the category of agricultural engineering. Genetic engineering and crop breeding is a growing interest, with a priority funding stream from the Ministry of Higher Education and Scientific Research. A few institutions have broader expertise, covering aspects such as participatory rural development, such as the University of Alexandria's Faculty of Agriculture. The American University in Cairo also has anthropologists experienced in multidisciplinary work in agriculture.

Until recently climate change research has been principally limited to climatology, agrometeorology, sea level rise impacts, and the impacts of climate change in agriculture. Climatology capacity is mainly confined to Cairo University and Al Azhar University. These departments have also collaborated with the Central Laboratory for Agricultural Climate of the Agricultural Research Centre on agrometeorology studies and the impacts of climate change on agriculture. Studies on sea level rise impacts have been conducted by researchers at the University of Alexandria since the 1990s, although much of this work has now been superseded. Currently the Coastal Research Institute of the National Water Research Centre is leading in this area, although they lack the modelling capacity to downscale impacts of sea level rise. The Alexandria Research Centre for Adaptation was created with IDRC funding at the University of Alexandria in 2011 to develop capacity on climate adaptation research and develop research on the economics of adaptation. At the moment it is the only research centre in Egypt with specific expertise on climate adaptation and economics, although the Arab Academy of Science and Technology hosts a Regional Centre for Disaster Risk Reduction funded by UNISDR that also includes some climate adaptation activities.

The Consultative Group on International Agricultural Research (CGIAR) has three active centres in Egypt focusing on rural development and cropping (ICARDA), aquaculture (WorldFish), and water management (IWMI). These centres have the mandate to work closely with and strengthen capacity in national agricultural research systems. Similarly, many Egyptian researchers are involved in international consortia, most notably those funded through the EU Seventh Program Framework (PF7). These include several projects on climate change and water, although the contributions from, and benefits to, Egyptian researchers could be stronger.

In general, Egyptian researchers are well trained and technically competent, although more used to working within disciplinary silos rather than engaging in multidisciplinary applied work. Principal weaknesses come from poor institutions and administrative support, under-resourcing and low research funding, and lack of incentives rather than lack of individual ability. However, many researchers do not have experience in preparing proposals, publishing results, or developing strategies for influencing policy-makers.

2.2.4 NGO activities

NGOs in Egypt are highly constrained organisations with variable capacities, including local legitimacy. Funding NGOs is potentially complex, bureaucratic and subject to approval by security authorities. This is one reason for the limited capacity of this sector in Egypt. This section of the report is very general, as local conditions vary considerably.

Civic Participation And Mobilisation

At local levels – i.e. village levels – the 3 principal relevant forms of non-governmental organisation are cooperatives, water users associations (WUAs), and community development associations (CDAs)[1]. Agricultural cooperatives and WUAs are created under legal mandates of, and with support from, MWRI and MALR, often through specific projects. Around 1 100 WUAs were created through the Irrigation Improvement Program by 1998, for example. These organisations vary greatly in capacity, with some barely functioning and others active. They operate within defined limits, do not have trained staff, and lack administrative capacity. They can be useful as entry points to groups of farmers, although

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[1] Starting in 1998 there were also attempts to develop Drainage Users Associations, but these have apparently been abandoned due to lack of farmer interest (Allam 2004).

CDAs are usually more effective depending on local circumstances. CDAs are registered under the NGO Law (Law 84 of 2002), and are a different legal and functional category of organisation.

'Proper' NGOs in Egypt are registered with the Ministry of Social Solidarity by geographic region – either at a national or governorate level. In the articles of each NGO it defines the geographic extent of their activities, so an NGO registered in Kafr el-Sheikh cannot legally function in Mansoura, for example. They will also register a specific sphere of activity, so an NGO registered to work on environmental awareness cannot easily develop activities on community health, for example. Most NGOs registered at a governorate level will specific a specific town, village or community to work in. This is most likely because it enables tighter governmental control of civil society, and social entrepreneurs and communities find it easier to focus on specific areas (usually their own neighbourhoods) rather than attempt to cover a whole governorate. National NGOs are generally free to operate across the country, although International NGOs (INGOs) can have specific governorates defined in their country agreement, which makes it difficult for them to operate elsewhere. Generally NGOs that focus on a specific community are known as Community Development Associations, whilst those that cover whole governorates or work at the national level are known as NGOs. Despite this common distinction, both are legally defined as Community Development Organisations.

Inevitably, local CDAs vary greatly in capacity for implementing projects. Those that have previously partnered with projects through foreign donors and International NGOs tend to have the strongest capacities, often assisted by direct capacity strengthening activities. Some other NGOs are only nominally 'non', being created by governmental employees or even as a strategy by government institutions. One study found that 38% of all CDAs in South Sinai were created by government employees (Egyptian Environmental Affairs Agency 2005). Such 'N'GOs can be useful in partnering with local authorities, but can also lack legitimacy in the eyes of communities. It is therefore extremely important to consult with experts in specific fields and geographic areas who have prior experience of working with specific NGOs before partnering with them.

There are a few NGOs operating at a national level with strong capacity for engaging with local communities and implementing project activities in the field. These include not-for-profit companies such as the Centre for Development Services, international NGOs such as CARE International, or national organisations such as the COPSE-Egypt or CEOSS, all of which provide different capacities in agricultural extension. Most of these organisations focus their activities in specific geographic areas, developing strong community linkages over time, but making them less effective when engaging in new areas. Some national organisations have political dimensions and need to be handled with care. Some International NGOs are not officially registered with the Ministry of Social Solidarity despite long standing working agreements, and these can mean project risks. Expert advice should be sought from within GIZ's Egypt office and programs before partnering with national level organisations.

In between the very local and the national level there are few credible, functioning NGOs capable of community engagement in rural development and agriculture. Better Life in Minya is one such NGO that operates at the governorate level, for example, and the new Egyptian National Initiative for Development (ENID) is initially focused on the governorate of Qena. No such organisation could be identified in Kafr el-Sheikh or Beheira Governorates during this assessment. Previous and current GIZ programs in these governorates might be sources of knowledge regarding such institutions.

Following the 2011 Revolution there are a number of new initiatives to develop such capacity, including Nawaya based in Giza. Members of the Green Arm of Nahdet Masr have also proposed the development of a Delta Alliance, a bottom-up network of delta communities to exchange knowledge and articulate concerns to policy makers. However, all these initiatives are currently in their infancy with limited capacity.

Climate Advocacy and Awareness Raising

A few national organisations are active in the field of environmental and climate advocacy and awareness raising, notably the regional hub for 350.org, Nature Conservation Egypt, and the Green Arm. The new Water Institute for the Nile is oriented towards basin level issues and building bridges with riparian countries, and intends to be focused on developing an expert consensus amongst riparian scientists and NGOs. The regional coordinator for 350.org is based in Cairo, and she promotes a number of activities aimed at youth leadership on climate issues and public awareness to kick-start community based projects such as sustainable transportation or water use. The Heinrich Bolle Foundation is exploring the creation of an office in Cairo, and their officer is developing a programme on climate change activities and awareness raising. The Green Arm has also conducted some climate awareness activities, as has Nature Conservation Egypt and the Arab Network for Environment and Development (RAED).

In general capacity for environmental and climate change awareness raising programs in Egypt is low. It is a less 'marketable' message by comparison to how relates to the experiences of people in rainfed countries such as Kenya, and there is little funding or sustained support for such activities. However, there are a growing number of activists coordinated by 350.org. They have potential for growth so long as they can continue to relate climate issues to the development needs of Egyptian citizens.

2.2.5 Gaps

2.2.5.1 Policy

Coherent Strategy for Agricultural Water Use

There is a noticeable tension within the National Water Resource Plan between the desire to reduce water losses to sinks (evapotranspiration, desert and sea) and reduce agricultural water consumption in general, and plans for horizontal expansion of agriculture. The plans projection for 2017 actually shows loss to sinks in agriculture increasing from 39.3 Bm^3 in 1997 to 41.0 Bm^3 in 2017, balanced by reduced drainage to the sea and losses elsewhere.

However, previous experiences in reclaiming new lands for agriculture in Egypt have generally been less successful than anticipated, leaving grounds for scepticism over these figures. Further, the 2017 water budget anticipates an increase in municipal demand from 4.7 to just 6.6 Bm^3 over the same period, raising questions about the impacts of agricultural water efficiencies on the recharge of aquifers and those reliant on groundwater for domestic use.

Coherent Adaptation Policy

There is currently no coherent climate change adaptation policy for water resources in Egypt. The National Water Resources Plan specifically excludes climate change, and the draft National Adaptation Plan's treatment of water resource issues is thin. This is largely due to the lack of research and knowledge on the impacts of water resources within Egypt. Multiple potential pathways for climate impacts exist – including through water quality, human health, increased evaporation in canals, and increased municipal demand – yet knowledge is very low.

Financing

State budgets are extremely limited, and, with little incentive for financing by the private sector, donors remain the principal means for Egypt to maintain and develop its water infrastructure. Many international donors are interested in demonstrating innovations with the expectation that the Egyptian government will scale them up. This is generally a currently unrealistic expectation in Egypt. Most MWRI staff are looking for resources to maintain or repair what they already have, rather than further demonstrations.

Climate Policy Coordination

In general policy coordination is weak. In the water domain working relationships between key actors are mostly functional, if strained (e.g. in strategic differences over the dominant consumption of water by agriculture). By contrast, climate policy is less coherent. The Ministry of Environment claims dominance over this arena, yet the National Adaptation Plan is being developed by the Information and Decision Support Centre, whilst discrete projects within the agriculture and water ministries develop their own approaches. Within the Ministry of Environment there is no unified organizational approach to climate issues, with different departments running different activities.

In general, Egypt's policy environment increases the risk of strategic maladaptation through the 'tyranny of small decisions', where individually rational small decisions cumulatively result in sub-optimal outcomes (Kahn 1966; Odum 1982).

Coastal Development Policy

Similarly, significant conflicts and policy gaps exist over the strategic development and adaptation of the Nile Delta Coastal Zone. Various attempts are underway to develop a better understanding of the likely impacts of climate change in the coastal zone and possible adaptations, but there is no strategic direction or process for agreeing one. The UNDP/GEF project on adaptation in the Nile Delta coastal zone is attempting to develop a plan for a process towards integrated coastal zone management. The development of a consensus-based strategic spatial plan would be highly advantageous for planning urbanization, agriculture, water use, and industry in the coastal zone. Without it, there is a significant chance for maladaptation or wasteful use of resources in urban development, the construction of sea walls, protection of coastal aquifers, rehabilitation of coastal ecosystems, investment in aquaculture, improvement of drainage etc., some of which are contradictory.

2.2.5.2 Knowledge

Climate Modelling

Egypt does not have extensive capacity for climate modelling. Two specific needs are for integrated climate and hydrogeological models for the Nile Basin, and downscaled models for projecting sea level rise. However, as discussed above, the costs and uncertainties involved mean that it is likely to be most efficient for Egypt to obtain projections from external suppliers.

Models analysing vulnerabilities and projecting impacts on agriculture, water demand etc. are a different matter, and are likely to be continually developed, particularly in the agriculture domain.

Managing Climate Uncertainty

In general, there is poor appreciation of the scientific uncertainties surrounding climate change and subsequent impacts. This potentially compounds opaque and politicised decision-making processes, with weak connections at the science-policy interface.

Egypt's research capacity on climate change is currently focused on specific, technical issues. More expertise is needed on risk management, climate economics and policy, and societal responses to change. In particular, the step between developing engineering applications and selecting appropriate options based on the developmental needs of people and their preferences needs to be bridged. An example would be in developing appropriate responses to the risks posed by sea level rise and coastal change.

Vulnerability Assessments

There remains a lack of assessments of social vulnerabilities to climate change. The vast majority of climate vulnerability assessments so far conducted focus on biophysical vulnerabilities, particularly agriculture and water. Very few studies have been conducted on the social vulnerabilities of poor urban communities, of rural women, or on nutritional or health impacts. As a consequence, there is little knowledge about the effects of climate change on Egyptian people.

Community Based Adaptation

Capacity is extremely low for community-based adaptation work. Agricultural extension services and NGOs are weak, and there is little expertise in climate adaptation. Considerable effort is being placed in development of new techniques for agriculture and irrigation, new crops, varieties and cropping patterns. However, historical experiences in Egypt have shown that attempts to scale out new technologies are extremely difficult and generally less successful than anticipated. This is largely attributed to widespread institutional weaknesses. This in turn indicates that rather than investing in technology, institutional reform and capacity building should be the priority.

Oases and Deserts

With the majority of attention on the Nile Delta, little attention has been paid to the impacts of climate change on desert and oasis communities. This is understandable in the sense that they are numerically less significant that the population of the Nile Valley. However, both communities are more exposed to temperature extremes, and desert communities are also highly exposed to increased variability or long term declines in rainfall. Bedouin communities in Sinai and the North Coast largely reliant on rainfed agriculture and pastoralism are likely to be particularly at risk. Little work has been done with these communities, and no climate vulnerability assessments could be found.

Impacts of Climate Change on Water Demand

No research could be found that rigorously analysed the impacts of climate change on water demand in the municipal or industrial sectors. Research on impacts in agricultural water use remains limited, generally confined to field-level models rather than considering whole irrigation systems. The impacts of climate change on evapotranspiration rates in reclaimed agricultural lands also requires more work.

Impacts of Climate Change on Water Quality

No research on the impacts of climate change on water quality could be found. However, research elsewhere has demonstrated linkages between climate change and human health mediated via water, including both vector borne and water borne diseases. In addition, climate driven changes in water consumption and quantity are likely to exacerbate existing problems with water quality. This should be a priority area for research.

2.3 Entry points for ACCWAM

Innovation Project

The MWRI has proposed a pilot study for intermediate drainage water recycling in Beheira governorate. With little further information at this stage, this study suggests ACCWAM should consider how to frame the project in relation to climate change specifically, rather than adaptation to water scarcity in general. Climate vulnerability assessments might indicate specific impact pathways leading to refinement of recycling techniques, or other aspects of water management.

The impacts of climate change on drainage water quality may provide a specific entry point. For example, will seasonal temperature changes or heat waves imply different optimal mixtures for drainage and irrigation waters? The human health aspects of water quality, specifically in terms of pathogens, could be another entry point for innovation. How do incentives for participation vary amongst the up-stream and down-stream farmers in the pilot, and how might these vary seasonally or with climate change?

Aspects of community-based adaptation might also be worth exploring consider, in terms of the potential contributions and climate vulnerabilities of community-level institutions. How will the water-user association be involved in the sustainability of the project? Will they have ownership of infrastructure or control of water mixing, and do they have the knowledge and capacity to change mixture levels depending on (possibly climate driven) changes in water quality? The potential for scaling out results through community and development networks, agricultural extension, government programs and institutions should also be assessed.

Capacity Building

The greatest challenges are institutional capacities such as civil service regulations, salary scales, and administrative procedures, which ACCWAM is not intended to address. In terms of individual technical capacities, Egypt is strong in engineering but lacks expertise in soft systems approaches, climate vulnerability assessment, adaptation, and adaptation economics. Egypt may benefit from Jordan's experience on wastewater reuse, Jordanian expertise in solar energy.

A key target that ACCWAM could address would be to help the MWRI develop an approach that would factor climate change in to the next iteration of the National Water Resources Plan. This is presumably due to be published in 2017, and therefore preparations should be beginning within the next few years. This would be a major contribution.

Policy

The policy processes most relevant to ACCWAM which are currently underway are the Third National Communication, and the development of a new legislative framework for integrated coastal zone management under the UNDP/GEF Coastal Zone Management Project housed at NWRC. The process for finalisation of the draft National Adaptation Strategy is not clear, but the indications to date are that the document will either be approved or abandoned before ACCWAM has results to share.

Awareness Raising and Civil Participation

In terms of identifying partners for civic awareness raising and participation, GIZ ran a water management project in Beheira Governorate that worked with community development associations at a local level. The records of this project should be consulted to garner contacts, and local experts should be consulted with to assess the capacities of CDAs in the pilot project area. No appropriate governorate-level NGOs was identified in Beheira or Kafr el-Sheikh. ACCWAM should consult experts with local knowledge to identify them. A national level organization such as the Centre for Development Services or CARE International could play a strong capacitating role to both local CDAs and governorate level NGOs. They are also potential intermediaries for sub-contracting and administration between GIZ and local partners with weaker capacities.

For public awareness raising, 350.org is the most likely candidate for national level awareness raising activities. However, their capacity is limited and will need careful assessment.

Regional Aspects

With Egypt's focus on the Nile, it is not clear the extent to which they will prioritise engagement in a regional network focusing on the Middle East and North Africa. It may be difficult to identify a clear role for the technical advisory services and capacities of ACSAD and ESCWA, although adding a clear climate dimension to the project could strengthen this. ACSAD's strengths are most likely to be relevant to desert and rainfed areas. Climate projections for the Sinai, Mediterranean and Red Sea coasts would be of interest to agricultural and water officials working in those areas, including those based in the directorates of appropriate governorates.

3. Jordan

3.1 Climate change, vulnerabilities & adaptation in the water thematic

3.1.1 Climate change and water resources situation

Jordan has a predominantly Mediterranean climate, with a hot dry summer and a cool wet winter. Around 75% of precipitation falls during the winter season from December to March, mostly as rain but with snow settling on highlands. Precipitation reaches almost 600mm per year in northern Jordan and declines towards the south and east, reaching just 32 mm per year in Aqaba (Tarawneh, & Kadioglu 2003; Jordan's Ministry of Environment 2009). Water management is complicated by the high spatial and temporal variability of precipitation and temperature, with pronounced dry and wet seasons, inter-annual variability, concentrations of water along the highlands and coasts, and unstructured and highly localised rainfall (Hoff et al 2006; Dahamsheh, & Aksoy 2007).

The two major rivers, the Jordan and it's tributary the Yarmouk, are shared with Israel and Syria, leaving only small shares for Jordan. A second tributary of the Jordan, the Zarqa, is heavily polluted by industrial and municipal wastewater. 54% of Jordan's population is within the River Jordan Basin, which also contains the majority of irrigated agriculture (Phillips et al 2007). Most of the Jordan River Basin's runoff comes from the upper catchment, with smaller contributions from the southern tributaries. One consequence is that water transfers and groundwater play a crucial role in the south and east of the basin (Hoff et al 2011).

High population growth and strong urban development, particularly in the Amman-Zarqa sub-basin, has increased water demand (Venot et al 2008). It is important to note that in addition to natural population growth, Jordan has also absorbed successive waves of immigration including refugees. Iraqi refugees increased the population by over 15% following 2003, for example, and Palestinians make up almost half the population (Oroud 2008). The government has gained social and political stability in part through converting land from traditional agro-pastoralism to irrigated agriculture, particularly in the Lower Jordan Valley, but these land-use changes have contributed to unsustainable water resource use in agriculture (Venot et al 2008).

As a result of this increased water demand and scarce resources, Jordan has one of the highest rates of water scarcity in the world. Official figures show annual per capita water availability declining from 3600 $m^3\ yr^{-1}$ in 1946 to 145 $m^3\ yr^{-1}$ in 2008, well below the Falkenmark Index for water scarcity of 1000 $m^3\ yr^{-1}$ and water poverty line of 500 $m^3\ yr^{-1}$ (Jordan's Ministry of Environment 2009). As a result of scarcity, water demands exceed renewable supply. The deficit is made up by the unsustainable use of groundwater through overdrawing of highland aquifers, resulting in lowered water table in many basins and declining water quality in some, and supply rationing to the domestic and agricultural sectors (Ministry of Water and Irrigation 2009; Jordan's Ministry of Environment 2009). Hoff et al. (2011) characterise the modern Jordan River as a highly complex 'closed' system, with all renewable resources fully allocated and some severely overexploited (Table 3.1).

The population is projected to grow from about 5.87 million in 2008 to over 7.80 million by 2022, with demand to reach 1 673 Mm^3 in the same year (Ministry of Water and Irrigation 2009). The National Water Strategy, launched in 2009, intends to reduce the supply/demand deficit from 565 Mm^3 in 2007 to 284 Mm^3 in 2022. Key measures identified are institutional reform and water tariffs, reducing groundwater exploitation, increasing water use efficiency, reducing highland irrigation, and developing of two key water supply projects – the Disi and Red-Dead conveyances (Ministry of Water and Irrigation 2009). However, despite this policy to reduce groundwater exploitation, non-renewable groundwater extractions will actually increase by 59 Mm^3 (Table 3.2) due to the construction of the Disi Water Conveyance Project from the non-renewable Disi Aquifer to Amman.

Table 3.1 Water demand and allocation in 2007, in millions m^3. (Source: Ministry of Water and Irrigation 2009)

Sector	Demand	Allocation	Deficit
Irrigation	1080	597	483
Industry	49	49	0
Municipal	366	284	84
Tourism	10	10	0

Table 3.2 Water sources in 2007 & 2022, in millions m^3 (Ministry of Water Resources and Irrigation 2009).

Source	2007	2022
Safe yield groundwater	275	275
Non-renewable groundwater	91	150
Artificial recharge	55	25
Peace Treaty	50	25
Desalinated water	10	520[2]
Treated wastewater (irrigation)	87	220
Treated wastewater (industry)	4	27
Developed Water Surfaces	295	365
Total	867	1632[3]

In addition to the stresses caused by population growth, Jordan is confronted by climate change. The National Water Strategy runs only until 2022 and ignores issues of climate change, although efforts are under way to update it. The projected impacts of climate change are dealt with in the next section, but the indications are it will pose considerable challenges to Jordan's water resources. Several studies indicate that significant changes in the spatial and temporal distribution of temperature and precipitation since the 1980's might be attributable to climate change (e.g. Abdulla, & Al-Omari 2008; Al-Omari et al 2009). At least one study has identified decrease in the number of rainy days and the total amount of precipitation falling starting in the 1950's (Smadi, & Zghoul 2006).

3.1.2 Climate impacts and vulnerabilities

3.1.2.1 Impacts on Precipitation

Understanding the impact of climate change on rainfall is important because of the consequences for runoff and blue-water flows and the significance of rain-fed agriculture,

[2] Reflects the potential supply of desalinated water from the Red-Dead Project.

[3] 25 Mm3 is missing from the source data.

which remains the most important source of employment and food production in rural Jordan (Smadi, & Zghoul 2006). Jordan's small size means that the results of low resolution Global Circulation Models (GCMs) need to be interpreted with considerable caution. The majority of recent work has focused on the use of downscaled Regional Climate Models (RCMs) at the basin level.

3 GCMs used for Jordan's Second National Communication to the UNFCCC projected temperature increases of less than 2C by 2050, with stronger warming in summer months. The models disagreed over seasonal changes in precipitation, with 2 models indicating precipitation increases during the winter and decreases during the summer, and the third indicating the opposite (Jordan's Ministry of Environment 2009).

A study using the B2 scenario in a dynamic downscaled regional climate-hydrology model indicated mean annual temperature increases of up to 4.5C°, and 25% decreases in mean annual precipitation in the mountainous part of the Upper Jordan Catchment by 2100 (Kunstmann et al 2007). Another study based on a single RCM and the IS92a scenario projected temperatures to increase by 6.5C and precipitation to decrease 27.6% relative to 1860 values by 2100 (Falloon et al 2007). A study using two RCMs and the A1B scenario to 2099 projected an increase of 3.7C compared to 1991, and with mean precipitation to decrease between 11.5% and 20%, and an increase in heat waves and interannual variability (Smiatek et al 2011). The results of another study based on 2 RCMs to 2060 indicated that maximum daily summer temperature is expected to increase by between 2.5°C and 3°C, with an increase in warm spell length. They also found that precipitation extremes would increase with longer dry spells, shorter wet spells, and increases in heavy rainfall (Samuels et al 2011).

A single RCM running the A2 scenario to 2100 made predictions regarding seasonal changes in precipitation, finding significant decreases in November, and the largest changes at the peak of the rainy season in December and January with reductions of between 30-40% (Black 2009; Wade et al 2010). (Other studies, however, have pointed to the difficulties of predicting seasonal changes in this climatologically complex area (e.g. Smiatek et al 2011). The model also projected temperature increases of 2C, and hence an increase in evapotranspiration. However, the model also indicated a slight lengthening of the rainy season, partially offsetting the decrease in precipitation at its peak (Wade et al 2010).

The studies all suffer from similar weaknesses: the reliance on limited numbers of models and scenarios, problems with data inputs, the sensitivity of precipitation relationships in an arid region, and relatively low spatial resolution in an area known to be highly climatically variable. Despite disagreements amongst the models on magnitude of changes, they agree on the direction of changes, with significant increases in temperature and decreases in precipitation expected. What is critical to develop further are assessments of climate change impacts on seasonal, monthly and daily precipitation, due to the importance of these features to streamflows.

3.1.2.2 Impacts on Streamflows

The relationships between rainfall, temperature, soils and vegetation, and streamflows are complex and sensitive. Due to the importance of surface waters, particularly the River Jordan, the sensitivity of runoff to climate change has been the subject of considerable investigation.

Using a simple physical model, Oroud (2008) demonstrated the non-linear relationship between precipitation, temperature and water yield in Jordan. The study found that a 1C temperature increase reduced annual water yield by about 10 % in wet and 17 % in dry areas, and that a drop of 5 % in precipitation caused 10 % and 23 % reductions in water yield in wet and dry areas. The combined effect of a 2° C increase along with a 10 % drop in precipitation – well inline with the projections reviewed above - caused annual water yield reductions of between 45 % and 60 % (Oroud 2008).

A study using the B2 scenario in a dynamic downscaled regional climate-hydrology model indicated that by 2100 total runoff at the Upper Jordan Catchment's outlet would decrease by 23%, accompanied by a significant decrease of groundwater recharge (Kunstmann et al 2007). A Basin level study combining a GCM with a hydrological model found that between 2036 and 2060 more noticeable increases in precipitation and temperature increases induced streamflow reductions of around 10% in the Jordan (Samuels et al 2009). By contrast, an integrated RCM/hydrological study for the A2 scenario found that low (base) flows would remain similar to present conditions until 2100, and that moderate flows would not be significantly, although there would be a reduction in flood magnitudes during winter months (Wade et al 2010). In addition to their disagreements over the magnitude of changes, these broadscale assessments do not capture either the temporal aspects of rainfall-runoff relationships, or their spatial variations.

Studies on the Zarqa and Yarmouk sub-basins conducted for the Second National Communication (SNC) found complex and non-linear relationships between temperature increases, the direction and magnitude of changes in precipitation, and resulting runoff. These studies were both conducted with inputs from 3 GCMs. They found that runoff would increase by 5% with a 10% increase in precipitation and a mean temperature increase of no more than 2C for both sites. Runoff would increase 22% in Zarqa and 9% in Yarmouk with a 20% increase of precipitation and a temperature increase of 4C. However, with a 4C increase in temperature and no increase in precipitation runoff would decrease 20% in Zarqa and 9% in Yarmouk (Jordan's Ministry of Environment 2009). A similar study on Zarqa runoff using 2 GCMs and 10 incremental scenarios found that changes of +4C and -20% precipitation would reduce runoff by 70%, whilst temperature increases of 2C-4C and precipitation reductions of 10% would reduce runoff by 40-60%, although results should be interpreted with caution due to model being calibrated with just 7 years of data (Abdulla, & Al-Omari 2008).

Studies on the effects of temporal variability and consistency of precipitation on runoff have indicated that the number of individual rainfall events affects mean flow. A month with only a few rainfall events or clumps of several consecutive rainy days is likely to have a lower mean flow (for a given rainfall total) than a month with many individual events (Wade et al 2011). With the majority of precipitation falling in the winter, these relationships are important to understand but difficult to model. The SNC study in Yarmouk they found that monthly runoff in the rainy season (October to March) would decrease under most scenarios, with reductions up to 30%. However, they also noted possible large increases in runoff under scenarios combining increases in precipitation of 20% and temperature of 1C (Jordan's Ministry of Environment 2009). Abdulla and Omari (2008) found similar results for Zarqa, with a 2C temperature increase and 20% precipitation increase resulting in a 20% increase in runoff. A study in the Azraq basin found that increased temperature and precipitation variability would lead to an overall reduction in mean recharge for the Azraq basin (Al-Zu'bi 2009). The variation in results from these studies indicate the local importance of studies on frequencies and durations of rain events, and changes to monthly and daily rainfall (Black 2009).

Studies have shown that interactions with vegetation, soil, and groundwater mean that the intensity of rain events can also affect runoff, with a small number of intense rain events can lead to less stable and consistent streamflows whilst increasing risks of floods. However, at a basin level 80% of the Jordan's baseflow comes from karstic springs, and groundwater systems appear to act as a buffer between rainfall and streamflow. For example, the baseflow into the Dan, the Jordan's largest tributary, is known to have a recession constant of 300 days, implying a system memory of 2-3 years (Samuels et al 2009). Neither Black (2009) nor Wade et al. (2010; 2011) found significant indications of increased rainfall intensity or extreme flows in the Upper Jordan Catchment, and concluded that groundwater served as a buffer to maintain moderate or low flows. However, another study found an increased probability of more intense surface flow in the Hermon stream in Lebanon (Samuels et al 2009). This again indicates the disparity between events at the local and basin scale. Samuels et al. (2009) also found that in Hermon so long as annual rainfall was in excess of 400 mm per year, the relationship between rainfall and streamflow was fairly linear. However, when rainfall fell below 400 mm in a drought year, the reduction in surface flow was significantly stronger than the reduction in precipitation.

Studies elsewhere indicate that climate change can have severe impacts on the seasonal distribution of streamflow due to more rapid spring melting of highland snows. However, the only study that could be found for the Jordan River discounted the significance of this impact. This was partly due to the small snowfall in the area, the frequently high winter temperatures that see early snowmelt in the present, and the role of lagging mechanisms such as groundwater flow that even out the effect of surface precipitation (Samuels et al 2010).

Considerable work remains to be done on these issues. However, a broad assessment of the gathered evidence suggests that the impacts of temperature and precipitation changes on surface runoff will vary at local levels due to ecohydrological differences, but that trends in reduced mean precipitation will lead to reduced mean streamflows. However, the Jordan River may be less affected by inter-annual variability in precipitation due to the buffering capacity of karstic groundwater systems, and changes in river flow are likely to be directed by changes in precipitation quantity rather than timing.

3.1.2.3 Extreme events

Despite the buffering effects of groundwater systems, two studies indicate that there may be increase risk of extreme flooding events. A study in Wadi Faynon for the A2 scenario up to 2100 indicated that although mean precipitation and streamflows will decline, peak flows could increase by 25%, although the author does caution that these results could be a model artefact (Wade et al 2010). Similarly, a study on the Dan tributary found an increase in peak flows (Samuels et al 2010).

3.1.2.4 Impacts on water demand

The GLOWA project developed an assessment of the interactions between climate change and increased water demand, finding both contributed roughly equally to future water deficits (Hoff et al 2011). One study could be found on the potential impacts of climate change on combined agricultural, municipal and industrial water demand appeared to have factored in increased irrigation demand from agriculture due to increased variability in rainfall. The study calculated that demand would increase by 38 Mm^3 for a +1C temperature increase, rising to 114 Mm^3 for +4C (Abu-Taleb 2000). The climate scenarios used for the study are highly rudimentary (one considers a 4C increase by 2020) and there is little detail in the calculations, but it is an initial attempt to develop an estimate for the municipal and industrial sectors.

More work has been done in the increase in demand from irrigated agriculture. Using a water evaluation and planning tool, Haering et al. (2011) found that general trends in increasing unmet irrigation demands in the highlands would be highest in the Amman-Zarqa sub-basin, and comparatively lower in the Jordan Valley. Another study estimated that irrigation demands increased by 5% for a 10% reduction in precipitation and by 18% for an increase in evapotranspiration of 10% (for approximately 2C temperature increase) (Matouq 2008). A third study indicated that for northwest Jordan by 2100 under the A2 scenario, irrigation demand for growing vegetables would increase 212%, assuming 70% irrigation efficiency (Menzel et al 2009). The same study suggested a 67% increase in agricultural water demand over the entire region and up to a 50% decrease in water availability in northwest Jordan by 2050.

3.1.2.5 Social vulnerability

The SNC used pilot sites in the Zarqa and Yarmouk basins to assess impacts, vulnerability and adaptation (Jordan's Ministry of Environment 2009). The attempt to develop initial assessments of social vulnerability stands in contrast to the neglect of this dimension in the Egyptian SNC. Changes in the spatial and temporal distribution were found to have the potential for causing a wide range of health effects, particularly in communities within or at the edge of deserts where water is scarce, highly polluted or salinized, and in communities where there are competing demands from household consumption, agriculture and other industrial sectors. The assessments indicated a concern not only with precipitation changes, but also declining quality of surface and groundwater.

3.1.2.6 Institutional Vulnerabilities

There are three agencies responsible for water management in Jordan: the Ministry of Water and Irrigation (MWI), the Water Authority of Jordan and the Jordan Valley Authority. Many Jordanian water experts and NGOs have argued that the overlapping responsibilities of these three agencies and insufficient coordination have resulted in a lack of cohesiveness and integration in water policy and management efforts (Grover et al 2010). A critical analysis of water institutions and power in Jordan (Zeitoun et al 2012) also reflects on the tension between the technocratic Royal Committee for Water, which drew up the National Water Strategy, and the Higher Agricultural Council (HAC) which has more political power and influence and responds primarily to the most powerful farmers' interests. According to this analysis water demand management is unsupported by the HAC, despite its position in the National Water Strategy. Responsibility to advance water demand management belongs to the MWI, but does not have sufficient technical or donor support to make significant progress. Meanwhile, those most in favour of demand side management – the NGOs, small farmers and Ministry of Environment, have least influence on policy and implementation (Zeitoun et al 2012). This analysis of power networks and interests indicates institutional weaknesses in reducing water deficits and tackling some climate change impacts.

In terms of transboundary relationships, Jordan's share of the Jordan River is waters is fixed through bilateral agreements, and also receives 50m^3 per year under the Peace Treaty with Israel (Dellapenna 1996). Some authors have noted risk exposure to prolonged drought in these arrangements, which are set at fixed amounts rather than by proportionate shares, and that more equitable sharing of waters would gain Jordan's an additional 281 Mm^3 per year (Phillips et al 2007). However, others have noted that whilst the absence of a drought provision in the Treaty with Israel does leave the countries vulnerable to conflict, during the 1998/9 drought the Joint Water Committee was able to revise allocations to reflect availability (Odom, & Wolf 2011).

3.1.2.7 Summary – key vulnerabilities

- Increased variability and reduction in precipitation quantity, seasonality, frequency and duration will negatively affect rainfed agriculture and the livelihoods dependent upon it, frequently the poorest and most vulnerable members of society
- Increased variability and reduced precipitation quantity will impact communities dependent on rain for water supplies, typically in desert areas, frequently the poorest and most vulnerable members of society, particularly in terms of human and livestock health
- Increased variability and reduction in precipitation quantity, seasonality, frequency and duration will lead to increased irrigation demand from agriculture
- At a local level, increased variability and reduction in precipitation quantity, frequency and intensity may impact streams and surface flow, reducing water availability
- At a local level, extreme events may become more frequent
- Long term declines in Jordan River flows can be expected, although inter-annual variability should not affect mean flows
- Increased temperatures may drive increased municipal and industrial water demand
- Internal institutional and interest-based conflicts over water demand management may hinder adaptation efforts
- Existing bilateral relationships and institutional arrangements may lead to conflict in the event of prolonged drought and reduced Jordan River flows

3.1.3 Adaptation

Jordan has neither a single institution responsible for coordinating climate adaptation action, nor a national strategy for adaptation, although UNDP is currently supporting the development of such a strategy. Few climate adaptation pilots have been implemented, and most available documents focus on opportunities for exploration rather than empirical demonstration.

Two key documents form the basis of adaptation in the water sector. The National Water Strategy does not specifically deal with climate change, largely because it covers a period up to the year 2022 (Ministry of Water and Irrigation 2009). However, sustainable and strategic planned adaptation will have implications for water investments and management before 2022, and as a result UNDP is funding a study to revise and update the National Water Strategy to incorporate impacts of and adaptation to climate change. The Second National Communication to the UNFCCC contains sections on water, agriculture, health and socio-economic adaptation, but at quite a general level (Jordan's Ministry of Environment 2009).

3.1.3.1 Supply side adaptations

The SNC considers a number of supply side for adaptation to increased climate variability and reduced precipitation and streamflow. These include increasing numbers of surface water reservoirs, desalination, artificial groundwater recharge, and water-harvesting (Jordan's Ministry of Environment 2009). The National Water Strategy also contains significant measures to increase water supply, despite its policy emphasis on improving water demand management (Ministry of Water and Irrigation 2009).

Surface Water Development and Water Harvesting

The SNC lists several water harvesting and surface water management measures including surface and subsurface storage, soil improvement programs to reduce evaporation, converting open canal systems to pressurised pipes, and prioritising projects that will make significant contributions to meeting municipal and industrial water demands (Jordan's Ministry of Environment 2009). In particular there is interest in developing storage basins for capturing wet season and year flows for use in dry periods.

Water harvesting systems in the region have been known since antiquity. For example *muhafir* are thought to have been used since between the 7th and 9th centuries (Agnew et al 1995). *Muhafir* are shallow (3m deep) subsurface basins that can store tens of thousands of m^3 of water from surface runoff, and are typically used to support livestock during drought years. As some studies have indicated that evaporation losses from earth dams can reach 3m (Badia Program, cited in Jordan's Ministry of Environment 2009), subsurface storage is of particular interest, as are measures to combine storage with contour furrows to improve barley production in arid areas (Jordan's Ministry of Environment 2009).

The SNC also speculates that water harvesting might be used to improve groundwater recharge and rangeland management. However, as rainfall is quite variable and generally results in direct runoff for less than a few days, developing infrastructure to enhance supply from this source may not always be cost effective and should be carefully assessed.

Non-Conventional Water Resources Development

Considerable emphasis is placed on wastewater treatment by both the SNC and the National Water Plan. Jordan already has considerable capacity in wastewater treatment, with 22 operational municipal wastewater treatment plants providing waters for agricultural use. The MWI is developing a wastewater mast plan aimed at increasing water recycling, establishing targets for management performance and water quality, and improving monitoring and enforcement of violations in standards from industry (Jordan's Ministry of Environment 2009). However, Carr et al. (2011) note that use of treated wastewater for irrigation also brings challenges to agriculture and farmers in Jordan, including the management of salinity, damage to irrigation systems, and the marketing of produce, which they need support to cope with.

Both the SNC and the National Water Strategy place desalination as the most significant means of increasing water supply, principally through the developing Red Sea-Dead Sea Conveyance Project (RSDSC). The first RSDSC is planned to add a total 930 Mm^3 through desalination by 2055, with some anticipating that it could help meet increased agricultural water demand (Al-Omari et al 2009). To date desalination is used principally in the coastal area and town of Aqaba, although the SNC also outlines a research program for solar desalination and use of brackish waters in agriculture and industry (Jordan's Ministry of Environment 2009). Waters from Hisban, Kafrein, Faisal Greenery, Karamah, Abu Zighan, Deir Alla, Karamah Dam, and Znia (Mafraq) are all targeted for use in desalination projects in the short-term (Ministry of Water and Irrigation 2009).

Groundwater Protection

With most groundwater aquifers are exploited at more than double of their safe yield the National Water Strategy and SNC set out plans to reduce groundwater extraction, protect, manage and restore aquifers. This includes both reducing government extraction and enacting and enforcing regulation on uncontrolled pumping in agriculture (Jordan's Ministry of Environment 2009; Ministry of Water and Irrigation 2009). However, the near-completion Disi Aquifer Project is also listed in the National Water Strategy as providing

125m^3 yr^{-1}, which actually results in an increase in total groundwater supply by 2022. Despite this, increasing population pressures may mean that the Disi Conveyance has little impact on water deficits (Haering et al 2011).

3.1.3.2 Demand side adaptations

The National Water Strategy places considerable emphasis on water demand management, as does the SNC which highlights reducing losses from supply networks, introduction of water savings technologies, adoption of water efficient cropping patterns, and public awareness campaigns amongst other measures (Jordan's Ministry of Environment 2009).

Reducing Demand from Agriculture

With agriculture consuming 64% of water but contributing just 3% of GDP, there is considerable attention on reducing agricultural water demand. In addition to measures increasing the use of treated wastewaters and reducing groundwater abstraction for irrigation, suggested options for reducing agricultural water demand include changes to agricultural and irrigation practices, as well as strategic rationalisation of water allocations (Haering et al 2011). The SNC highlights opportunities for improving irrigation water efficiency through the implementation of irrigation management information systems delivering exact water requirements to crops (Jordan's Ministry of Environment 2009).

Conservation agriculture is also highlighted as an option for improving soil moisture and organic carbon storage whilst reducing input costs, although means for developing capacity amongst and transferring technology farmers need to be identified (Jordan's Ministry of Environment 2009).

Urban Water Use

The SNC highlights that with increasing municipal demand for water there is an urgent need to devise and implement policies for water conservation in urban areas. In addition to reducing water demands, such measures would also reduce pressure on drainage, supply and sewage treatment systems. However, few specific details are given for this sector of activity (Jordan's Ministry of Environment 2009).

Measures to Improve System Efficiency

The National Water Strategy and SNC also suggests that the overall efficiency of the water resources system is low due to losses in the system, system constraints, constraints of funds and inflow patterns (Jordan's Ministry of Environment 2009). By contrast, other authors suggest that overall efficiency of water use in the Jordan Basin has sharply increased to 87% of controlled renewable water resources (Venot et al 2008). This analysis reflects the closed nature of the Jordan River Basin, particularly in its lower reaches, implying that prospects to make significant gains through increased water use efficiency are limited.

3.1.3.3 Water quality protection

Aside from increasing the recycling, treatment and use of wastewaters, the SNC and National Water Strategy also highlight options for improving the protection of water quality. These include the development of techniques for reducing environmental degradation of areas affected by reduced water flows, and techniques for managing recharge and releases from reservoirs and canal abstractions. They also include measures to reduce agricultural and industrial pollution, reduce seepage from sewage systems, over-pumping of aquifers, and overloading of wastewater treatment plants from population growth. Proposed measures include the implementation and enforcement of regulations governing pollution control, and the development of standards for wastewater usage (Jordan's Ministry of Environment 2009; Ministry of Water and Irrigation 2009).

3.1.3.4 Flood control

The SNC notes the potential for increased risk of flash floods, and suggested that risk and vulnerability assessments should be conducted for specific flood-prone areas. It also suggests that flood control authorities should keep updated records of vulnerable settlements and infrastructure, and enforce planning regulations in flood plains (Jordan's Ministry of Environment 2009).

3.1.3.5 Institutional Adaptations

Legislation, Enforcement and Allocations

The National Water Strategy set a number of goals for institutional development. These included capping and regulating the use of irrigation waters in the highlands, as well as the legal options noted above for setting water quality standards, and the appointment of one organisation for bulk water supply in the Jordan Valley (Ministry of Water and Irrigation 2009). The policy also proposes to improve policies regarding intra and intersectoral water transfers, including legislation allowing the ability of farmers to sell surplus water rights to other farmers.

Other authors have noted that as precipitation is highly variable in space, and the impacts of climate change will vary with ecohydrology and will be felt differently at local, national and basin levels, there is a need for decentralized management at the sub-basin level rather than at a national level (Al-Zu'bi 2009).

Water Resources Monitoring System

The SNC considers improvements to water resource monitoring to be important, particularly in terms of monitoring irrigation waters. The National Water Strategy suggests a policy of strict monitoring and enforcement for large private farmers in the highlands to prevent illegal or overexploitation of groundwater (Ministry of Water and Irrigation 2009). The National Water Strategy also suggests that electronic surveillance and monitoring of irrigation networks could help to reduce losses through leakage.

Participation

The National Water Strategy proposes to empower farmers and local communities in establishing groundwater and basin water users associations, developing participatory approaches with them to set and implement ground and surface water protection measures, and decide on the appropriate uses of water. It also identifies the development and empowerment of farmers associations to retail water locally. All of these proposal will require the introduction of legislation (Ministry of Water and Irrigation 2009).

3.1.3.6 Summary – proposed adaptations

- Develop rainwater harvesting in subsurface storage, particularly in arid areas
- Increasing use municipal and agricultural wastewater in agricultural
- The development of solar desalination for brackish wasters in irrigation
- Research into agricultural production from brackish waters
- Large infrastructure projects to improve water supply, notably the Red-Dead Conveyance and the Disi Aquifer Project
- Reduction of groundwater exploitation to within sustainable levels

- Improve policies and mechanisms supporting water demand management in agriculture, industry and municipal consumption
- Improve agricultural productivity per unit water, and increase on-farm irrigation efficiency through use of precision irrigation
- Improve soil moisture through conservation agriculture
- Improve system efficiencies through upgrading distribution, recycling and treatment infrastructure
- Upgrade policies, legislation and enforcement for water quality management and pollution control
- Develop appropriate institutional mechanisms for central and decentralized water allocations
- Empower farmers and local communities in water decision making
- Develop water rights legislation for farmers and market mechanisms for water transfers
- Improve water resource system monitoring

3.1.4 Knowledge assessment

Considerable effort has been focused on sensitivity studies examining the impact of climate change on streamflow. Results so far indicate that impacts will be highly context specific, and that further research is needed using ensemble model approaches to reduce uncertainty and develop site specific projections that can be translated into management and policy advice. Work on climate precipitation projections is less focused, partly due to limited capacity for climate modelling with Jordan, and partly due to the country's small spatial scale and the low resolution of climate models. Work using RCMs is beginning, but even with these newer approaches the highly variable nature of precipitation in Jordan means that precipitation projections are likely to remain uncertain until more specific techniques are developed. This is a big gap, given the importance of rainfed agriculture and rangeland pastoralism to the poorest and most vulnerable members of society. Work on social vulnerabilities is more advanced than in Egypt, for example, particularly in the human health domain thanks largely to the WHO Centre for Environmental Health in Amman. However, there is much work to be done on social vulnerability analyses.

Knowledge on climate adaptations is limited. Although considerable expertise exists on adaptation to water scarcity in water engineering and agricultural science, the additional dimension of climate vulnerabilities in these sectors is underexplored. There is little publically available information on experiments with implementing different dimensions of adaptation, such as strengthening drought resilience, building adaptive capacity, or transformational adaptation.

There is no clear evidence of strategic and comprehensive thinking on water policy and adaptation in the face of climate change. In part this may be due to the uncertainty resulting from climate impact projections. However, there are also tensions within and between some of the suggested adaptation options, particularly in terms of the stated policy focus on water demand management and the heavy investment in upgrading water supply through the RSDSC and Disi Aquifer Project (Venot et al 2008). Despite the positive work done on the National Water Strategy and the SNC, a sustainable, implementable strategy for meeting future water demands has not yet been developed. The closed and constrained nature of the Jordan River Basin means that few options for significantly increasing use efficiency exist. The concern is that attempts to increase supplies and increase consumption efficiencies will barely keep pace with projected socioeconomic demand, and that the impacts of climate change will severely stress the sustainability of current plans.

3.2 Initiatives and capacity gaps on adaptation

3.2.1 Focus areas in climate change and water

This section provides a summary narrative assessment of this landscape rather than dwelling in detail on specific initiatives.

3.2.2 Policy priorities and activities

Strategic Policy

Key guiding documents for climate adaptation policy in the water sector are the National Water Plan and the Second National Communication to the UNFCCC (SNC) (Jordan's Ministry of Environment 2009; Ministry of Water and Irrigation 2009). Supported by UNDP, initiatives are under way to develop the country's Third National Communication (Ministry of Environment) and to revise and upgrade the National Water Plan to include climate change dimensions (Ministry of Water Resources). The UNDP/GEF implemented MDG Achievement Fund is also involved in attempts to develop a National Adaptation Strategy, identified as a need in the SNC.

Increasing water pressures have led to successive reform of water institutions and policy, with water rationing introduced in 1987, prioritisation of municipal water supply and restriction on irrigation between 2000 and 2003, and the move toward Integrated Water Resource Management in the MWI under the guidance of a World Bank project starting in 1997 (Black 2010). Water management institutions have proliferated, including the introduction of private sector management companies for municipal water supply. As discussed in Section 3.2.1.6, critics have argued these institutions are poorly coordinated, particularly over water demand management policy (Grover et al 2010).

As discussed in section 3.1.3, the existing documents lay out a strategy for reducing water deficits through a mixture of increased supply, water demand management, increased system efficiencies, and improved water quality. However, some authors have raised concerns over the institutional and political contexts of water planning and management in Jordan. The two existing documents, developed by the MWI and the Ministry of Environment with external support from GTZ and UNDP respectively, do not necessarily align with the interests of other, more powerful stakeholders such as the Higher Agricultural Council (Venot et al 2008; Black 2010; Grover et al 2010; Zeitoun et al 2012).

Revision of the National Water Strategy and development of a National Adaptation Strategy should be considered crucial. It is not at all clear whether the provisions and proposed measures of the current version of the National Water Strategy will reduce vulnerabilities to climate change even if efforts to improve water demand management are successful.

Supply Side Initiatives

The Disi-Amman Conveyance Project and Red Sea Dead Sea Conveyance have significant backing at the highest levels of the government and Royal Court. The first will bring 100 Mm^3 of water per year to Amman from the non-renewable Disi aquifer. Work began in 2008, due to complete in 2012/3, and is expected to provide 125 Mm^3 per year for 50 years, at which point the aquifer will be exhausted. As the aquifer is shared with Saudi Arabia, there is the potential for conflict over the exploitation of this resource. The RSDSC Project is in the process of procurement, with the first phase to produce 210 Mm^3 of desalinated water per year by 2018, to be increased to 930 Mm^3 per year by 2055 ().

These projects also should be re-examined in the light of climate change vulnerabilities. For example, water from the RSDSC is planned for use in urban areas of South Amman to absorb population growth, but also to provide water for luxury villas, exclusive developments, and tourism resorts. There can be a tendency for capital-intensive infrastructure projects to feed new economic development projects in order to gain returns on financing and to maximize the economic productivity of water. However, in the context of potentially significant declines in water resources due to climate change, these developments may represent an unsustainable expansion in water demand.

Water Demand Management

In the assessment of Mark Zeitoun and colleagues (2012), despite the prominence given to 'effective water demand management' in the National Water Strategy, the majority of government effort appears fixed on meeting water demand rather than on managing it. In addition to the RSDSC, he notes the continuation of subsidised water for agriculture in the Jordan River Valley, and that the influential Higher Agricultural Council contains representation from elements of the 'shadow' or 'deep' state, including wealthy private individual farmers. Zeitoun remarks that support for water demand management is variable within the MWI, and is most marked in the Ministry of Environment. The Ministry of Finance and the Ministry of Planning and International Cooperation (through its role in coordinating donor activities) are also noted as being favourably inclined towards water demand management.

Donor activity in this area is considerable, with past and existing projects from the World Bank, GTZ, UNDP, the European Union, and IFAD. Several projects also have a regional focus, especially over shared water resources. Several of these projects and programs are implemented by civil society organisations, notably the EU SWIM program which finances the *Rehabilitation of the Lower Jordan River Master Plan* implemented by Friends of the Earth Middle East. Other SWIM projects in Jordan focus on efficient uses of agricultural waters in Irbid, and a component of a shared project with Egypt on wastewater reuse. IFAD is also supporting several projects with a focus on water efficiency in agriculture, including the Irrigation Technology Pilot Project to Face Climate Change Impacts funded by GEF, and the GEF-funded MENARID project which includes integrated water resource management.

Considerable experience has already been gained in wastewater reuse, and several current projects continue to build on that. These include a project implemented by the World Health Organisation, which examines the potential impacts of climate change on human health mediated through wastewater quality.

Capacity Building

A useful function of the SNC is the identification of a series of capacity building needs (Jordan's Ministry of Environment 2009). These include;

- improved meteorological and water monitoring through modernization of equipment extension of monitoring networks,
- improved technical capacity for monitoring and data collection, data management and updating of basic data sets, and preparation of basic maps and databases
- capacity building in methodologies, tools and guidelines for vulnerability and adaptation studies.

- knowledge on sources of financial resources to conduct studies and implement adaptation measures.

3.2.3 Research

Jordan has considerable research expertise in the water sector, spread over a number of national research institutions. These mostly include universities, although the National Centre for Agricultural Research and Extension has an irrigation research program. The National Energy Research Centre and the Princess Sumaya University for Technology contain research programs and expertise on solar energy. In addition to national expertise, Jordan has also been the focus of international research, including consortia funded by the EU FP7, research funded by the German government in the Global Change and Hydrological Cycle program (GLOWA) and SMART program which developed a water evaluation and planning system and decision support system respectively, and research funded by UNESCO on watershed and aquifer dynamics.

Jordan's capacity for climate modelling is very limited, being largely restricted to the National Meteorology Department. Existing results from climate modelling studies (see section 3.1.2) are limited by the small number of models employed, and hence uncertainty around outputs. The majority of these studies also used scenarios which are below actual trends of greenhouse gas emissions, implying that they may underrepresent the potential impacts of climate change on water resources. The SNC identifies a need for the development of downscaled models and research tools both for climate modelling and climate impacts and vulnerabilities, for studies on local vulnerabilities and impacts of climate change, and studies on the vulnerability of sectors not included in the SNC, specifically tourism and sea level rise. There is a need to develop more capacity and expertise for socioeconomic vulnerability assessments, including work on climate change and gender. A further gap is the impact of climate change in rainfed agriculture and pastoralism, and associated vulnerable communities.

Lack of monitoring data and systems is widely recognized as a constraint in developing impact assessments and adaptation strategies (e.g. Jordan's Ministry of Environment 2009; Grover et al 2010; Wade et al 2010).

3.2.4 NGO activities

The institutional review identified a considerable number of NGOs in Jordan active at a strategic/policy level. These included both Friends of the Earth Middle East (FoEME) and the International Union for the Conservation of Nature and Natural Resources who have active projects on water management, including operational implementation of projects at a local level. A number of other high profile organisations exist, often with the patronage of individuals attached to the Royal Court, and these include the Jordanian Hashemite Fund for Human Development and the Royal Society for the Conservation of Nature. FoEME is the only of these organisations with identifiable activities on climate change. However, due to their societal influence several of these organisations might be appropriate vehicles for awareness raising activities.

This review did not identify any NGOs and civil society initiatives at local levels. However, previous and current work funded by GIZ, GTZ, and other German agencies (including research projects such as GLOWA) should be reviewed for their involvement with local NGOs, depending on the location of the selected pilot project. Examples might include Highland Water Forum, the creation of which was supported by GIZ's German-Jordanian Water Programme.

3.2.5 Gaps

Key gaps identified in this assessment include the need for more knowledge, research and implementation activities on:

- impacts of climate change on rainfed communities
- impacts of climate change on national water strategy
- lack of ensemble RCM studies and climate impact assessments
- need for more socioeconomic impact studies
- need to think about low-water transformative adaptations
- managing climate uncertainty in adaptation and water policy
- community based adaptation
- impacts of climate change on water demand

3.3 Entry points for ACCWAM

Pilot Project

The Jordanian Ministry of Water and Irrigation has proposed a pilot study based on transformative adaptation for small-scale farmers away from agriculture and to solar energy farming. With little further information available at this stage, some potential entry points for ACCWAM to consider at this stage are given below.

The strategic feasibility of the proposed innovation needs to be rigorously assessed in terms of the contribution of solar farming to the reduction of climate vulnerability. Such an assessment would need to factor in potential new vulnerabilities this adaptation might generate. At first glance it seems likely that solar farmers will have little agency, and will be at the mercy of energy markets, hence exchanging one source of external vulnerability for another. Vulnerability assessments should also consider the contribution of current copping systems to nutrition and non-food aspects of livelihood, such as livestock fodder, fuel, etc. Measures for mixing fodder crops, food crops, and non-food crops amongst solar collectors could also be investigated to produce a balanced livelihood system that manages risk and reduces water demand.

The economic and policy basis for solar farming should also be explored. Outscaling would require analysis of the economic costs and benefits at individual, local and national scales, existing policy structures, return periods on investment, and sustainability in the context of energy prices and the expected provision of hydropower from the RSDSC. This analysis might include options for donor funding, and provide opportunities for capacity building on proposal developing for the Adaptation Fund or CDM.

Capacity Building

Jordan clearly has an appetite for improved downscaled climate projections, preferably using ensemble model approaches, which is an entry point for ACSAD and ESCWA. Accompanying measures could include capacity building on interpreting and using outputs from climate models, particularly in terms of understanding their inherent uncertainty.

Jordan has requested technical capacity building in climate vulnerability assessment and approaches to planning adaptation, and working through the case study might be an appropriate point for technology transfer. In particular there are opportunities to strengthen policy/management of climate uncertainty in strategic policy making. There is also a need to develop capacity for supporting autonomous adaptation amongst NGOs and to encourage acceptance of autonomous adaptation within the policy community, although this may be beyond the activities of ACCWAM.

Policy

There appear to be opportunities for engagement in both national water planning and adaptation planning. Climate dimensions are being added to the National Water Strategy through a UNDP grant, and UNDP is also in the process of developing a project for a National Adaptation Strategy as well as supporting the Third National Communication. It is recommended that ACCWAM look for opportunities to engage with these efforts strategically, both through the pilot project and through regional activities on mainstreaming adaptation policy.

Awareness and Civil Participation

There appears to be a strong presence of national, expert led NGOs which could have an important role in awareness raising at a national level, and could play a role in influencing societal and political elites. NGOs such as IUCN and FoEME also have the potential to contribute at the regional level. However, in general public participation in even local decision-making appears to have a very limited window of opportunity in Jordan due to political control by the centre. Many local development organisations appear to have or to seek the patronage of societal elites, raising questions about the ability of autonomous institutions to influence policy and decision-making.

Regional Aspects

NGOs such as FoEME, IUCN and the Inter-Islamic Network on Water are already engaged in regional activities related to water management and climate change, and could make significant contributions to a regional network. In the research sector Jordan has specific expertise and experience on wastewater management and usage in agriculture that could add value to pilot projects in Egypt and Jordan. Competencies in solar energy research could also be of value to pilot projects in Egypt, particularly in terms of solar pumps.

4. Lebanon

4.1 Climate change, vulnerabilities & adaptation in the water thematic

4.1.1 Climate and water resources situation

Lebanon's climate is heavily influenced by topography, which is commonly classified in three zones: a Mediterranean climate along the coastal strip (450-1100 mm yr^{-1} of precipitation), wetter mountains parallel to the coast (937-1854 mm yr^{-1}), and a drier inland plateau (200-600 mm yr^{-1} in the north and centre, and 600-1000mm in the south). The coastal and mountain zones are characterized by mild dry summers, cold wet winters, and short spring and autumn seasons. There is usually little to no rainfall between June and August, with the majority of rainfall between November and April (Sene et al 1999; Arkadan 2008). Sene et al. (1999) estimated average precipitation for whole country at between 800-1000 mm yr^{-1}, with around 50-60% of annual rainfall lost to evaporation, although the lack of consistent information means all these figures must be treated with a degree of caution (Ministry of Environment 2011).

Interannual variability in precipitation is high, with annual precipitation ranging from +/- 60-80% of the mean in the coastal zone. Variability is higher still in the dry interior, where ranges of less than 30% to more than 200% of the mean are known (Sene et al 1999). The country regularly experiences droughts with a return period of 14 years, but with no particular periodicity (Arkadan 2008).

Yearly precipitation results in an average yearly flow of 8.6 Bm^3, giving rise to 40 streams and rivers and over 2,000 springs (Bassil 2010). About 1 Bm^3 of this flow comes from over 2 000 springs with average yields between10–15 litres per second, making them strategically and locally important, but hard to systematically capture (Ministry of Environment 2011). Uneven seasonal distribution of precipitation means that ~80% of runoff occurs during winter months with only small baseflows at other times (Karam, & Sarraf 2011), although in some areas springs and snowmelt can even out flows.

Snow can fall in the high mountains between October and March. Sene et al. (1999) suggested that on average snow falls for 10-15 days per year in this region, whilst other studies have estimated that 1 100 Mm3 of snow falls in the Mount Lebanon region every year, implying that this is a huge source of water in the national context (Shaban et al 2004). The principal river basins are the Orontes in the north and the Litani in the east and south. Some coastal basins have flows of similar magnitudes due to higher rainfall and runoff coefficients in the area, but other coastal basins have barely visible surface flows (Sene et al 1999).

The National Water Strategy estimates that of the 8.6 Bm^3 total precipitation, 4.5 Bm^3 is lost to evaporation, leaving total renewable water resources of 4.1 Bm^3. Of this 1 Bm^3 flows across national boundaries as surface or groundwater, and .04 Bm^3 flows to the sea, leaving 2.7 Bm^3 remaining in Lebanon (0.5 Bm^3 as groundwater, 2.2 Bm^3 as surface water) (Bassil 2010). However, only 2 Bm^3 of this is deemed to be practically exploitable (Ministry of Environment 2011). Renewable water resources per capita per year was estimated at 926 m^3 in 2009, and projected to fall to 839 m^3 in 2015 (Bassil 2010). Again, all these figures should be treated with caution.

Storage infrastructure is of small to medium scale, and has decline following the civil war. There were 234 known reservoirs in Lebanon in 1963, but only 48 operating in 2005 (Shaban 2008). The two major reservoirs in the country are Qaraoun Lake on the Litani, and the Faraya in the district of Mount Lebanon. These have a total effective storage of 183 Mm^3, mostly reserved for irrigation but also generating some hydropower and domestic supply (Bassil 2010; Ministry of Environment 2011). The geology of the coastal and mountain areas has high erosion and sedimentation rates, limiting the number of sites suitable for dams (Sene et al 1999).

The construction of a clear assessment of the water resources situation and potential impacts of climate change in Lebanon are hampered by the legacy of the 1975-1991 civil war. Prior to that conflict Lebanon had one of the most developed water monitoring networks in the Middle East, but it broke down during the war and to a significant extent has not recovered (Sene et al 1999). The lack of long-term continuous accurate data impedes the calibration of hydrological and climate models, and is widely remarked upon frustration by those working in Lebanon's water sector (Ministry of Environment 2011).

This lack of information hindered water resources planning during post-conflict reconstruction. Lebanon also experienced large shifts in population distribution and water use during and after the war. During the conflict people settled in previously uninhabited areas, and dug boreholes for agriculture and domestic use. Following the war, coastal cities boomed due to repatriation of citizens and a migrant workforce engaged in construction (Sene et al 1999). As a consequence, populations and water resources are not well spatially aligned, and distribution networks are not sufficient to meet demand. On average, households receive 7.6 hours of water supply per day during the summer, but this falls to 3 hours per day in the Beirut and Mount Lebanon area (Bassil 2010). This is despite the prioritization of developing distribution networks by post-conflict reconstruction efforts. Wastewater systems are even less well developed with around 60% of wastewater being collected by less than 8% being treated (Geara-Matta et al 2010; Bassil 2010).

Irrigated agriculture is the largest water consumer, consuming 810 Mm^3 per year, or 61% of total consumption (industry and domestic uses account for 9% and 30% respectively). Irrigation efficiencies are estimated to be low, with drip irrigation accounting for 6% of all irrigated land and 70% of irrigated land relying on open channels with estimated losses of 40% (Bassil 2010).

High water usage in agriculture coupled with low wastewater treatment and intense fertilizer usage has been correlated with poor groundwater quality in the coastal plain (Saad et al 2003). Other studies have demonstrated connections between groundwater pollution and drinking water quality, and the impact of untreated industrial effluents infiltrating into the groundwater system (Abdulrazzak, & Kobeissi 2002). There is limited public information on water quality, but the discharge of untreated domestic wastewater into river systems has led some to call the Upper Litani a public health hazard and unfit for human use, especially during the dry season (Assaf, & Saadeh 2008; Geara-Matta et al 2010). Conservative costs of the health impacts of water pollution have been estimated at USD 7.3 million per year (MoE, 2001 cited in Ministry of Environment 2011)

4.1.2 Climate impacts and vulnerabilities

4.1.2.1 Physical impacts

Very little climate modelling work has been focused specifically on Lebanon, perhaps in part due to the difficulties of obtaining long-term data for calibrating models (see above). Just three studies could be found focusing on Lebanon specifically. Of these just one used an ensemble approach (Bou-Zeid, & El-Fadel 2002), and was applied to a water balance model rather than projecting climate trends alone. The Second National Communication drew on the outputs of the PRECIS model using one scenario based on data from just two stations – consequently the results must be treated with extreme caution (Ministry of Environment 2011). Regional studies using GCM approaches, such as those reviewed in Section 1, must be also be used with caution due to the large uncertainties surrounding their precipitation projections.

The regional picture (see Section 1) is for temperatures to increase by up to 4C and for mean precipitation to decline up to 30% by 2100. Against that background, the SNC PRECIS study used an A1B scenario, and projected that by 2090 maximum temperatures would increase by 3C in the coastal area and 5C inland, with minimum temperatures evolving similarly. It projected significant rainfall reductions reaching -25% for coastal areas and -45% for inland area by 2090, with 10% and 20% reductions forecast for coastal and inland areas respectively by 2040. Notably it predicted that temperature increases would be more marked in summer, and that precipitation decreases would be more marked in winter. It also noted significant increases in temperature based extreme events by 2098, with modest increases within 30 years. Evapotranspiration was projected to increase by 2% in Beirut, 8% in Cedars, 10% in Zahleh, and 6% in Daher el Baydar by 2090 (Ministry of Environment 2011).

The SNC study concluded that these changes would impact renewable water resources available per capita, and increase water stress. It estimated that climate change would reduce total water resources in Lebanon by 6 to 8% for an increase of 1°C in average yearly temperature, and by 12 to 16% for an increase of 2°C. Total available resources, currently estimated at 2.7 Bm^3, would decrease to 2.5 Bm^3 and 2.3 Bm^3 for 1C and 2C temperature increases respectively (Ministry of Environment 2011).

Two other studies were found which focused on climate impacts to the year 2020. The first, using a single GCM, concluded that a mean increase in temperature of 1.6C and 3% could be expected (Khawlie 2003). The second using an ensemble of 4 GCMs applied to a water balance model concluded that PET would increase up to 6.6%, soil moisture deficits would increase by 3%, and runoff would decline between 6.5-15% in the Beirut area (Bou-Zeid, & El-Fadel 2002). The same study found slightly different impacts in the Bekaa area, with PET increasing up to 6.1%, soil moisture deficit increasing between 3-6%, and runoff declining 3.5-11%. The authors concluded that this implies significant impact for agriculture in Bekaa, with irrigation demand increasing by up to 6% by 2020.

The SNC acknowledges that the assessing the impacts of climate change on streamflows is difficult to due to the lack of consistent data on river flows, withdrawals and losses (Ministry of Environment 2011). Instead, the SNC study focuses on projecting precipitation, and does not attempt to assess impacts on streamflow. Acknowledging the same shortcomings, Shaban (2008) attempted to develop an assessment based on historical data. According to his data, there was a 12% decline in annual precipitation between 1967 and 2006, and 12 rivers and 9 major streams investigated exhibited a decline in streamflow of 23% and up to 50% respectively. Shaban also noted that dense snow cover had fallen from an average of 2280 km^2 prior to the 1990s to an average area of about 1925 km^2, with the delay in meting reduced from 110 days to 93 days. This historical study is the only assessment that could be found relating climate impacts to streamflow in Lebanon.

4.1.2.2 Demand side vulnerabilities

It is accepted that hydrological drought in Lebanon is due not just to climate change, but also to increased human demand and alterations to water courses (Shaban 2008). The National Water Strategy examined three scenarios for changing socioeconomic demands of water to the years 2020 and 2035 (without accounting for internal or external changes in water supply). The results of the exercise concluded that the most optimistic scenario would see overall demand remain roughly stable, whist the most pessimistic scenario saw water demand rise from 1473 m^3 per capita in 2010 to 2518 m^3 per capita in 2035 (Bassil 2010). The SNC developed qualitative vulnerability assessments based on 2 socioeconomic scenarios to the year 2030 based on assumptions about population, technology and socioeconomic drivers. Scenario A reflected uneven and moderate economic growth, low population growth, improved government action and planning, and no increase in the standard of living. Scenario B reflected high economic growth (8% pa), high population growth, intensification of agriculture, increased standards of living, and no land-use planning. The assessment concluded that Scenario B would lead to greatly increased water demands and likely increases in water deficits, but noted the possibility that the greater economic growth might translate into greater adaptive capacity that could offset some negative impacts, for example through greater affordability of desalination technologies (Ministry of Environment 2011).

The SNC concluded that key vulnerabilities were increased water demand, supply issues, degraded water quality, and low adaptive capacity. The SNC concluded that domestic, industrial and agricultural water demand would increase with increased temperatures, more frequent heat waves, and longer dry periods (Ministry of Environment 2011). It is worth noting that the National Water Strategy projects irrigated areas to increase from 90 000 ha in 2010 to 150 000 ha by 2035, which will further exacerbate water demands from the agricultural sector (Bassil 2010). (No quantitative assessments could be found of impacts on the agricultural sector, although some hypothesize that increased urban demand will require a shift away from agricultural allocations (Karam, & Sarraf 2011).

In terms of water supply, it noted that networks will be under pressure due to increased demand and decreasing water availability, coupled with low storage capacity. Water quality was also assessed to deteriorate as a result of increasing demand (Ministry of Environment 2011). It is notable that this part of the assessment did not specifically highlight decreased precipitation and increased variability. That may be either a contextual issue in the framing of the report, or reflect the greater certainty around significantly increased demand (<+170%) by comparison to the uncertainty surrounding less significant reductions in precipitation (<-30%). Other assessments have highlighted water quantity and quality as key vulnerabilities, rather than focusing on particular aspects of quantity e.g. (Khawlie 2003).

The SNC concludes that groundwater salinity will increase due to lower recharge coupled with higher abstraction, in addition to hydrostatic pressures from rising sea levels (Ministry of Environment 2011). Salt-water intrusion is considered a serious threat to aquifers, and in some locations such as the Choueifat-Rmeileh region, salt-water intrusion has been observed several kilometres inland (Moujabber et al 2006). Salt water intrusion has also been noted in areas such as Naquora which are not subject to groundwater abstraction (Shaban 2008).

4.1.2.3 Institutional Vulnerabilities

Lebanon's water sector appears to be in disarray, experiencing severe challenges in meeting current water deficits and scarcity issues, let alone preparing for the future hazards of climate change. The Ministry of Energy and Water's Water Plan 2000–2009 laid out a program for developing water infrastructure including wastewater treatment, but by 2010 the plan had not been achieved and was extended to 2018 (Hreiche, 2009 cited in Ministry of Environment 2011). The National Water Strategy reviewed for this study was released in draft form in 2010 but not formally approved and released until 2012.

Lebanon's Second National Communication summarises institutional vulnerabilities in bleak terms, noting that the inadequacy of public water supply to meet the country's growing water needs has led to a shift toward private – frequently illegal - solutions for water supply. It claims that private provision of supply has accelerated the depletion of groundwater resources, particularly through illegal wells for supplementary agriculture, and that this has led to salt-water intrusion in coastal areas, further exacerbated by the continuous urban growth and repeated natural drought conditions (Ministry of Environment 2011).

Institutional reforms have been instigated separating policy and service provisions of the MEW and four regional water establishments. However, inter-agency coordination, cost recovery, efficiency, and regulation and enforcement of private provision and water pollution are all poor (Bassil 2010; Khawlie 2003; Ministry of Environment 2011; Karam, & Sarraf 2011). Underlying all these issues are a chronic lack of data, knowledge bases, and assessment tools for conventional water management, much less assessing and adapting to the impacts of climate change.

4.1.2.4 Summary – key vulnerabilities

As can be seen from this review, research on climate impacts and vulnerabilities in Lebanon appears to be under-developed. Climate modelling work is light, and hampered by a lack of ensemble modelling and limited use of alternative emissions scenarios. Impact and vulnerability assessments are largely qualitative and limited in number. No social vulnerability assessments were identified, and the only research conducted on climate change and human health appears to looked at the impacts of air pollution and heat extremes, not water-borne disease or impacts of decreased water quality (Habib et al 2010).

- Increased variability and reduction in precipitation quantity, seasonality, frequency and duration will negatively affect rainfed agriculture and pastureland and the livelihoods dependent upon it, frequently the poorest and most vulnerable members of society
- Increased variability and reduction in precipitation quantity, frequency and intensity may impact streams and surface flow, reducing water availability
- Long term declines in river flows can be expected
- Increased variability and reduction in precipitation quantity, seasonality, frequency and duration will lead to increased irrigation demand from agriculture
- Increased temperatures may drive increased municipal and industrial water demand
- Declining supply coupled with increased demand are likely to stress water networks and infrastructure
- Water quality in surface and groundwater likely to decline, particularly in hot periods, exacerbating human health vulnerabilities and leading to increased groundwater salinization
- Salt water intrusion in coastal aquifers likely to continue due to over-exploitation coupled with sea level rise
- Institutional issues may hinder adaptation efforts
- Existing bilateral relationships and institutional arrangements may lead to conflict in the event of prolonged drought and reduced river flows

- Lack of long term precipitation and water monitoring data and studies means that considerable uncertainty remains over the extent of impacts and vulnerabilities, and is likely to impede adaptation efforts

4.1.3 Adaptation

No documents were found presenting results or analyses of climate adaptation experiments or projects in Lebanon. The SNC, National Water Strategy, and various reports and academic publications identify adaptation options, but without presenting analysis of potential costs and benefits or any significant details. Most documents simply present a list of ideas, with no discussion or analysis.

4.1.3.1 Supply side adaptations

Options identified for improving water supply focus mainly on infrastructure. Investments in infrastructure are widely seen as important, apparently in the context of an aging water distribution network that was severely disrupted by the civil war. Amongst the areas identified for investment are improvements in water supply system efficiencies, upgrading and extending water supply networks, rehabilitating municipal networks, restoring aquifers, upgrading networks, and implementing rooftop water harvesting projects (Khawlie 2003; Ministry of Environment 2011; Karam, & Sarraf 2011). The National Water Strategy calls for maximizing the use of surface waters, although elsewhere they are referred to as almost completely committed (Bassil 2010). Only one paper was found expressing the importance of exploring unconventional water resources other than wastewater recycling, such as desalination (Khawlie 2003). Improved management of watersheds was also identified as an option by one paper (Karam, & Sarraf 2011).

4.1.2.2 Adaptation to increased variability

Several authors identified options for increasing surface (dams, hill lakes) and groundwater storage to buffer against drought and increased climate variability (Bassil 2010; Ministry of Environment 2011; Karam, & Sarraf 2011). The National Water Strategy identifies 42 sites with potential storage of 670Mm3, although it is not clear if these have been evaluated for the impacts of erosion and sedimentation (Bassil 2010). Although the potential for flooding events has not been evaluated, others have noted that more use could be made of flood waters, including aquifer recharge (Karam, & Sarraf 2011). Groundwater is a focus of the National Water Strategy, which advocates improving management and protection, reducing extractions, and promoting artificial recharge (Bassil 2010). The National Water Strategy also stresses that groundwater should be considered a strategic reserve, and that whilst stored water can be used to address deficits at the level of subnational water establishments, surface storage should be used first.

4.1.2.4 Coastal aquifers

The vulnerability of coastal aquifers is well recognized in the SNC, which identifies a number of action points. These include studies to identify over-exploited aquifers which could be potential sites for artificial recharge, assessing the feasibility of artificial recharge in major areas such as the Beirut and Mount Lebanon region, stricter enforcement and improved monitoring capacities of wells and abstractions in coastal areas, and the definition of buffer zones with land-use restrictions (Ministry of Environment 2011). However, there are considerable challenges with the recharge of coastal aquifers in the Beirut area, notably the lack of water supplies to use in recharge.

4.1.2.3 Improve wastewater recycling
With just 8% of Lebanon's wastewater currently being treated, a number of sources have identified improvements in wastewater reuse as being a key measure to adapt to water scarcity, and also to mitigate against increased risks to human health (Assaf, & Saadeh 2008). Identified infrastructure needs include increased coverage of wastewater collection networks and treatment facilities, and the improvement of existing treatment networks, processes and sludge disposal (Bassil 2010; Karam, & Sarraf 2011).

The use of greywater and recycled water for domestic, industrial, recreational and agricultural purposes has been proposed, including the reuse of treated sewage and storm water runoff in irrigation, and the use of treated water in aquifer recharge (Bassil 2010; Ministry of Environment 2011; Karam, & Sarraf 2011). The SNC notes that standards and guidelines for water reuse need to be developed before wide-scale implementation (Ministry of Environment 2011). Research conducted by the Middle East Centre for Appropriate Technology (MECTAT) on household greywater reuse identified technical sustainable solutions (Haddad et al 2007). However, the research was criticized for being of limited practicality and not addressing strategic needs in wastewater recycling (Welle et al 2007).

An assessment of two different plans for wastewater investments, one prepared by the Council for Development and Reconstruction and the other commissioned by USAID, found that the USAID plan was likely to be more cost-effective and scalable, and required less capital investment (Assaf, & Saadeh 2008). This reflects the difficulties in developing integrated national systems across Lebanon's coastal plain.

4.1.2.4 Demand side adaptations
Demand side adaptations focus on agricultural water use and institutional measures encouraging water efficiency. Institutional measures include restructuring water tariffs, water metering, and stricter enforcement of abstraction rates, particularly in the most vulnerable areas (Ministry of Environment 2011). These measures are not articulated by sector or region, so it is not possible to assess whether households – particularly those already subject to water rationing or purchasing water from private suppliers – would respond to changed tariff structures.

In managing agricultural water demand, suggestions are also made for restructuring water fees incentivizing water efficient irrigation techniques, as well as developing and spreading more efficient irrigation technologies, including on-demand irrigation which is known to reduce evapotranspiration losses. The adoption of crops and cropping patterns consuming less water is also identified (Bassil 2010; Ministry of Environment 2011; Karam, & Sarraf 2011). The National Water Strategy also aims to deliver adequate quantity and quality of irrigation water, but projects that through increased on-farm and irrigation network efficiencies, water demand will fall from 9000 m^3 ha^{-1} to 7000 m^3 ha^{-1} by 2035 – however these projections do not account for increased evapotranspiration demands driven by climate change (Bassil 2010).

4.1.2.5 Institutional adaptations
The reviewed documents made a number of recommendations regarding institutional development, perhaps the largest grouping of adaptation measures proposed. Key elements are reform of institutions and regulations, and the development of knowledge and knowledge bases.

The National Water Strategy highlights the need to complete institutional reforms separating the functions of the Ministry of Energy and Water (MEW) and the regional water establishments (Reform Law 221 of 2000), delineating capital spending responsibilities, and improving inter-agency coordination and spending efficiency, particularly in management of the irrigation sector (Bassil 2010). Others note the importance of developing the institutional bases for watershed management, penal codes covering pollution, and emergency plans for responding to pollution events in coordination with security forces (Khawlie 2003; Ministry of Environment 2011). Attention is also given to improved enforcement, monitoring and pricing structures for groundwater abstractions, and structuring water tariffs to ensure recovery of operational costs of water and treated wastewater (Karam, & Sarraf 2011).

Proposed measures addressing deficits in data and knowledge cover a wide variety. Inevitably they include the development of long-term precipitation, river, spring, snow, and groundwater monitoring programs, and also the assignation of a single national institution responsible for the collection and management of monitoring data (Khawlie 2003; Bassil 2010; Ministry of Environment 2011; Karam, & Sarraf 2011).

A number of specific studies are also identified as being crucial for developing evidence-based policy: a comprehensive database of groundwater wells; the identification of under- and over-exploited aquifers; feasibility studies for aquifer recharge; and a review identifying water facilities in need of upgrading and rehabilitation. In terms of climate-specific knowledge, improved downscaled climate projections, studies assessing water balances of each watershed in terms of projected climate change, studies prioritizing watersheds according to their vulnerability to climate change, and the development of management plans including climate dimensions are all identified as priorities (Bassil 2010; Ministry of Environment 2011; Karam, & Sarraf 2011). Knowledge sharing and dissemination systems are also identified, such as early warning system for extreme events (Ministry of Environment 2011). The SNC also calls for the creation of a Lebanese Centre for Water Conservation and Management, which has since received funding from UNDP (Ministry of Environment 2011).

The focus on institutional issues appears to be strongly related to shortcomings in existing water governance frameworks, which already struggle to cope with aligning water supply to water demand – a challenge that climate change will exacerbate. Institutional reform is therefore seen by many as a necessary first step in preparing for climate adaptation, and also as a no-regrets strategy (Karam, & Sarraf 2011).

4.1.2.6 Summary – proposed adaptations

- Upgrade and extend water supply networks, especially reducing inefficiencies in urban water supply
- Extend coverage of wastewater collection and treatment for reuse
- Protect and rehabilitate aquifers, including artificial recharge, for use as a strategic water reserve
- Develop surface storage capacity as an adaptation to increased variability in precipitation
- Reform administrative and financial instruments to incentivize reduced municipal and agricultural water demand
- Improve on-farm irrigation efficiencies through improved technologies, and crops and cropping patterns that use less water

- Institutional reform improving coordination, control of expenditures and investment, decentralised water management, and stricter enforcement and monitoring of consumption
- The development of knowledge bases, monitoring networks and research programs to better understand vulnerabilities and evaluate adaptation options

4.1.4 Knowledge assessment

In general the state of knowledge on the impacts of and vulnerabilities and adaptations to climate change on the water sector in Lebanon is poor. The lack of long-term monitoring data is a considerable obstacle, but there is also a lack of social vulnerability assessment, practical experience in climate adaptation, or work on climate policy or the economics of adaptation. What knowledge does exist is mostly qualitative, and much of the reviewed literature is based on argument from theory and common sense rather than empirical experience. The SNC itself acknowledges these weaknesses:

> *"In general terms, lack of and access to data are the main barriers that proved to be the most hindering. The absence of scientific assessments and research in terms of assessing e.g., economic impacts of climate change, the ecological impacts of global warming and the degree of resilience of the different systems are hindering the prioritization of adaptation strategies in the decision-making process. The lack of expertise in climate simulation is also considered as a major gap."* (Ministry of Environment 2011)

Although the general state of research and research institutions in Lebanon is considered more advanced than in Egypt or Jordan, the area of climate change and water is comparatively less advanced, which is surprising given the number of researchers and organisations interested in the topic.

4.2 Initiatives and capacity gaps on adaptation

4.2.1 Focus areas in climate change and water

Many of the adaptation measures reviewed above stress the need for institutional reform and the development of suitable policies. However, on-going attempts at reform are apparently in difficulty. For example, law 221 of 2000 separated a policy function in MEW and service provision function in four created regional water establishments (WEs). By 2010 the law had not been fully implemented, with the MEW involved in capital projects and operations and maintenance due the WEs remained are under resourced and lacked autonomy (Bassil 2010). Meanwhile, efforts to develop several wastewater treatment plants and sewage networks do not seem to be coordinated or based on comprehensive and integrated assessments of current and projected conditions in the basin (Assaf, & Saadeh 2008).

In terms of climate change, although Lebanon is engaged in international processes such as the UNFCCC, there appears to be no concerted effort by the government to coherently tackle climate issues. The majority of activities appear to be donor-driven without significant leadership or strategy from government. As an example, the identification of vulnerable sectors to be treated by the Second National Communication was apparently based on desktop studies conducted by the donor rather than determined by in-country research carried out after the first national communication (Mustasem el-Fadel, pers. comm.).

4.2.2 Policy priorities and activities

Climate

The majority of activity related to climate change was observed in the energy domain, particularly in developing and promoting sustainable or energy conservation policy and technology. UNDP and MEW are the principal stakeholders in terms of promoting solar and other carbon-alternative technologies and developing energy conservation policy, although the Council for Reconstruction and Development will inevitably be a key stakeholder in final implementation and scaling out. Renewable and alternative energy technologies may be an attractive option for Lebanon given the potential of obtaining international financial support through mechanisms such as the Clean Development Mechanism, and the challenges in matching supply and demand in energy which mirror those in the water sector. MEW includes a Centre for Energy Conservation, which appears to have an important role in policy formulation.

The National Meteorological Service is under the Ministry of Public Works and Transportation, but none of their experts were listed in the contributing experts to the SNC.

As in Jordan and Egypt, UNDP is also financing the development of Lebanon's Third National Communication to the UNFCCC through the Ministry of Environment. No evidence was found of activities to develop a national climate adaptation strategy.

Water

There is a considerable amount of activity in this sector, although little concrete information could be found in English or French. The range of institutions involved is quite extensive, and potentially confusing. Within the Lebanese Government MEW is the key stakeholder in terms of policy and (at least for now) capital expenditure, operations and management of water supply and wastewater. Four subnational water establishments under the *tutelage* of MEW are in principle responsible for service provision in their geographic areas, but are currently restricted to water supply. The Litani River Authority (LRA) and the Council for Reconstruction and Development (CRD) are also involved in the implementation of major projects and works. The LRA is responsible for implementing a master plan for the river, and manages irrigation projects and hydraulic works along the length of the Litani Basin. CRD plans and develops infrastructure for water supply and wastewater treatment. A number of other organisations are responsible for monitoring water quality, including the Ministries of Environment, Public Health, and Interior, whilst the MEW's new Centre for Water Conservation and Management is intended to have a role in policy development and capacity building. Municipalities also have a statutory responsibility for building and maintaining certain wastewater treatment facilities.

On the donor side, the European Union and World Bank are significant investors in infrastructure along with international finance institutions such as the European Investment Bank, the Islamic Development Bank, Kuwait Fund, Arab Fund for Economic and Social Development, and European Investment Bank. The Italian Cooperation, Japanese International Cooperation Agency, and AFD are also involved in infrastructure investments. German agencies including GIZ and BGR are perhaps the most active bilateral institutions involved in technical assistance. UNDP currently supports MEW by funding the creation of the Centre for Water Conservation and Management and the development of a groundwater database.

Agriculture

Work on improving efficiencies in agricultural water consumption is supported by UNDP, IFAD, and the EU SWIM program through the Ministry of Agriculture, and projects also include floodwater harvesting and soil and water conservation. Within the Ministry of Agriculture the Green Plan – a public authority with a mandate that includes services in the development of irrigation networks – appears to be under-capacitated, and the SNC calls for it to be strengthened (Ministry of Environment 2011). It is unclear what major policy initiatives are under way in the agricultural sector.

4.2.3 Research

A number of regional and international workshops on climate change and water have been organized in Lebanon by ESCWA, universities, NGOs, and foreign embassies, and have been well attended by Lebanese academics. Lebanese academics from several universities and research centres were involved in the development of the SNC, and a number of researchers listing climate change amongst their research activities were identified during this assessment. However, there is little evidence of empirical studies or published research from the Lebanese research community. It appears that far more work is conducted on the political economy of water than quantitative research on water vulnerabilities, perhaps reflecting the nature of challenges on the ground in Lebanon.

The American University in Beirut has a project funded by the International Development Research Centre on the management of coastal aquifers in the context of saltwater intrusion due to over-exploitation and rising sea levels. The project is working with two municipalities in the Beirut and Mount Lebanon area and is in the process of participatory identification of pilot adaptation projects with local communities. The AUB project has attracted interest from the authorities and is negotiating additional funding to extend the project to additional communities. AUB are also developing a project with funding from USAID and the US National Science Foundation on integrated water resources management and adaptation with three possible pilots in the Litani basin related to maximizing crop yield and water conservation.

4.2.4 NGO activities

The most notable NGOs engaged in climate awareness activities are IndyAct and the regional office of Greenpeace. IndyAct is leading the Arab Climate Campaign urging Arab governments to show leadership on climate change, and has a good regional network including cooperation with 350.org in Cairo. The Heinrich Bolle Foundation also runs a regional Climate Leadership Program from its Beirut office.

Some other NGOs with a broader interest in environmental or natural resource issues have activities touching on climate change, both in awareness raising and in practical action. The Association of the Friends of Ibrahim Abd El Al, the Association for the Development of Rural Capacities, and CARITAS have activities on participatory work with rural agricultural water users. Greenline, The Lebanese Association for Energy Saving & for Environment, l'Association T.E.R.R.E. Liban and a few others run climate-related awareness campaigns.

4.2.5 Gaps

Institutions, Policy and Political Will

As has been noted throughout this assessment, there appear to be significant institutional and policy challenges forestalling substantive progress. A lack of leadership, coordination between fragmented institutions, shortages of qualified staff, a lack of policies, plans and strategies, challenges in implementing agreed policies, and poor enforcement of water regulations are all symptoms of an incoherent and dysfunctional institutional environment.

Makdisi (2007) concludes that the underlying problem is the lack of requisite political will. In his analysis, the political system is based on sectarian and clientalist considerations, relies on power-sharing among the country's elite, and sectarian proportionality in political representation, civil service appointments, and allocation of public funds. The result is a deeply entrenched system of patron-client relationships rather than viable government services, inefficiencies due to unqualified people being appointed to public sector positions, and disincentives amongst political elites for reform. He also asserts that the tendency to consider the water sector in terms of national security has reduced opportunities for public participation in water policy (Makdisi 2007).

Research

There are extensive gaps in research covering the whole range of climate change and water concerns, from climate modelling to social vulnerability assessments, gender, climate economics and policy, and adaptation. Gaps in long-term data may limit opportunities for modelling approaches, and institutional problems may inhibit opportunities to translate research into policy. However, there remain substantial areas of potential work in adaptation experiments that could be exploited by the available pool of expertise in Lebanon, and used to create pressure for evidence-based policy and initiatives.

The Third National Communication is a potential opportunity for the Lebanese government to commission in depth research from national experts on impacts, vulnerabilities and adaptation, although it is not clear if this intended.

Financing

The SNC estimated short costs for tackling climate problems as between 1.5 and 3 billion USD, and to that must be added the costs of addressing existing deficits in water supply, wastewater systems, human health, and water equity (Ministry of Environment 2011). Capacity building for proposals development to international sources such as the Adaptation Fund could help prepare Lebanese authorities to access funds.

4.3 Entry points for ACCWAM

Pilot Project

No pilot project proposal has yet been received for Lebanon, although the idea of working on the artificial recharge of coastal aquifers has been suggested. To place it in context, this is an idea that has been considered in the Beirut area for some time. However, the major challenge is sourcing the recharge water. Water is too scarce in the area to be diverted from existing demands. Agriculture in the area is limited and agricultural wastewater would not provide the required quantities. Municipal wastewater could provide sufficient quantities, but would need to be treated. The Beirut and Mount Lebanon Water Establishment have a plan to construct two treatment facilities with a combined cost of 4 to 6 million USD, but so far have not secured financing. There is also the question of whether – assuming water of sufficient quality for recharge was available – recharge would provide the most effective economic and social returns on the use of water.

It is recommended that ACCWAM assess the "Climate Change and Saltwater Intrusion along the Eastern Mediterranean: Socioeconomic Vulnerability" project at AUB as a potential vehicle if the pilot focuses on coastal aquifers. It is already active in the Beirut and Mount

Lebanon area and is based on a community participatory methodology which includes socioeconomic analysis of climate vulnerabilities.

Capacity Building

The limited amount of information available during the review makes assessing the capacity needs of MEW with respect to climate change very uncertain. Section 4.1.2.5 identified a number of knowledge needs identified as priorities by the National Water Strategy and the SNC. These include improved downscaled climate projections, watershed water balances assessments in terms of projected climate change, and the development of management plans including climate dimensions.

Assuming that ACCWAM will make downscaled climate projections available, it seems likely that a key area of capacity building within MEW could in understanding and translating climate projections into impact and vulnerability models, and understanding and managing uncertainty. MEW staff may also benefit from capacity building on planning, monitoring and evaluating adaptation. Given the institutional challenges in Lebanon's water sector, some reflection on the potential role of autonomous versus planned adaptation may also be beneficial.

Policy

The principal policy process that should be targeted is the development of the Third National Communication, which is funded by UNDP and implemented by the Ministry of Environment. It is recommended that ACCWAM ensure that experts, researchers and MEW and MoE officials involved with the TNC are engaged in project activities in order to maximise opportunities for including ACCWAM results and perspectives in the final document. In principle, identification of an adaptation option or initiative in the National Communications is important in obtaining future financial and institutional support for implementation.

MEW is the principal stakeholder that ACCWAM will engage with in Lebanon, but it is unclear whether there are any major policy processes underway. ACCWAM might consider assessing the potential for updating the National Water Strategy to include vulnerabilities to climate change.

Awareness and Civil Participation

The NGO sector in Lebanon appears well mobilized and active, although not so many actors were identified working in climate change specifically. Civil organisations working at a local community level were hard to identify, although there does appear to be good capabilities for such work. IndyAct and Greenpeace both appear to have capacity for national and regional awareness raising activities.

Regional Aspects

Lebanon has expertise that ACCWAM could exploit at a regional level. The Issam Fares Institute for Public Policy and International Affairs at AUB has been developing work on climate change for a number of years, and has an interest in developing a regional think-tank style policy fora on climate and adaptation, which could be of interest to ACCWAM. There are also two 'regional' centres for water and environment at the University of Notre Dame and St Joseph University that could be assessed for potential contributions. Lebanon is also host to several NGOs that aspire to regional leadership, including IndyAct and the Arab Forum for Environment and Development, both of which have strong networks and apparently good capacities.

5. Analysis

5.1 Regional trends in water and adaptation

With arid environments and rapidly growing and urbanising populations, MENA countries face serious challenges in coming decades, and the projected impacts of climate change on water will further stress this picture. Their ability to adequately address these challenges will not be helped by weak governance and institutions across the region. Each of the three countries assessed in this study has issues with untransparent and unparticipatory decision-making systems, in which vested interests are able to shape or obstruct water policy. Bureaucracies are also under-resourced, and implementation of activities and institutional reform typically takes longer than anticipated and/or fails to achieve intended targets.

In the water sector, these issues appear to have a more significant impact on results than any deficits in technical expertise. In general there is a good pool of technical expertise on water in the region. However, expertise on social, institutional economic, and policy aspects of water studies are under-developed by comparison to engineering, and these deficits do appear to have an impact on water planning. Water Strategies exist for each of the reviewed countries, but it is unclear how realistic each of these plans is. Egypt's plan appears to be self-contradictory in some respects; Jordan's plan appears to have little support from political and social elites; Lebanon's water institutions faced delays and obstacles in getting their strategy approved.

With this context it is unsurprising that governments in the region have been slow in responding to climate change, particularly given the urgent development demands in poor MENA countries and the access to desalination technologies in rich ones. The time scales and uncertainties surrounding climate change do not appear to have instilled any sense of urgency.

However, the last three years have seen a considerable growth in activity on climate change adaptation, principally led by the UN system, especially through the Spanish MDG Achievement Fund. Second National Communications to the UNFCCC have been completed in Jordan (2009), Egypt (2010), Lebanon (2011), as well as in Algeria (2010), Bahrain (2012), Morocco (2010), Saudi Arabia (2011), and the UAE (2010)[4, 5]. The UN system is supporting efforts to develop National Adaptation Strategies in Egypt and Jordan, and a number of sectoral adaptation strategies across the region. With Least Developed Country Status, Yemen, Sudan, and Djibouti filed their National Adaptation Programme of Action in 2009, 2007, and 2006 respectively[6]. UNDP has been the central institution in these efforts, and is also supporting the regional Water Governance Programme for the Arab States, which includes a focus area entitled Vulnerability and Adaptation of the Water Sector to Climate Change. Key areas of activity are developing vulnerability assessments, developing national climate adaptation strategies, and mainstreaming climate adaptation in to water sector plans. The Regional Economic Commissions for West Asia and Africa (ESCWA and

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[4] Available from: http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

[5] Gaps still remain: Yemen and Tunisia have filed no communication with the UNFCCC since 2001, Djibouti since 2002, and Sudan since 2003. Syria didn't complete their First National Communication until 2010, or Qatar until 2011. Oman, Libya, Iraq and Kuwait have never filed a UNFCCC Communication.

[6] Available from: http://unfccc.int/cooperation_support/least_developed_countries_portal/submitted_napas/items/4585.php

UNECA) have begun leading activities in policy coordination. UNECA has established the African Climate Policy Centre to act as a think tank for the African Union, whilst ESCWA is engaged in similar activities – including through ACCWAM.

Aside from the UN system and GIZ, other key donors include the World Bank, which is preparing a regional program for technical assistance on climate change adaptation and mitigation though Mediterranean Environmental Technical Assistance Program (METAP), aimed primarily at institutional strengthening across the region. The Bank also have a cooperation programme with NASA on capacity building for improved water resources management which will develop decision support tools, run training workshops, and includes key components in Jordan and Lebanon. The World Bank has also been supporting work on climate change and cities in the MENA region, and a report is due soon.

Other donors have regional capacity building activities on water, although not necessarily framed in terms of climate change. USAID has a regional program on water in the Middle East which supports work on infrastructure, irrigation system improvement, water resource management capacity building, and a regional network which draws on technical expertise from the US. On a regional scale European Union engagement is mainly through the Euro-Mediterranean Partnership's Horizon 2020 Initiative, which includes a program on solar energy and significant investments in pollution reduction, including wastewater treatment and recycling.

The European Commission is also the leading regional actor in research funder through the Seventh Programme Framework (FP7). FP7 projects involve large consortia of research institutions, and in many Mediterranean-focused projects these include partners from MENA institutions. Historically such consortia projects have not focused on building capacity in southern partners and have made limited contributions to evidence-based policy making in developing countries, although the EC is continuing to try addressing these points in the next framework programme, also named Horizon 2020. FP7 research projects on climate change have mainly addressed projections and impacts, with limited work on understanding vulnerabilities and adaptation. Nonetheless, the quality of the climate modelling and impact scenarios done in these projects is generally very high, but fails to reach MENA policy makers. The Canadian International Development Research Centre (IDRC) has a stronger grounding in vulnerability and adaptation research, and a global program on Climate Change and Water with projects in Lebanon and Egypt. However, MENA appears to be excluded from its new Global Adaptation Research Program, and IDRC has little capacity to develop activities on climate change adaptation and water in the region at present. The GLOWA-Jordan River project, funded by the German Government, produced a substantial body of research between 2001 and 2011, but is now closed.

The Consultative Group on International Agricultural Research (CGIAR) is the most significant regionally-represented implementer of agricultural research. Historically this has mainly been based through the International Centre for Agricultural Research in the Dry Areas (ICARDA), but headquarters in Aleppo, Syria have been closed and the office is currently dispersed to offices in Cairo and Beirut. The International Water Management Institute and the WorldFish Centre, both of which conduct high quality research on climate change, have offices based in Cairo. CGIAR research programs in the region relevant to climate change and water include the Water, Land and Ecosystems Program (includes work on the Nile, Tigris, and Euphrates Basins) and the Dryland Systems Program (which focuses on risk management and innovation systems).

Other actors on the regional stage include intergovernmental bodies such as the Centre for Environment and Development in the Arab Region and Europe (CEDARE), NGO networks such as the Arab Forum for Environment and Development (AFED) and the Arab Network for Environment and Development (RAED), and NGOs and campaigning groups such as Friends of the Earth Middle East, the International Union for the Conservation of Nature (IUCN), IndyAct, and 350.org. Many of these actors are adding climate change to their portfolio of activities in response to funding opportunities.

However, despite this upsurge of activity, regional expertise and capacity remains low. The increase in donor funding has so far resulted in limited tangible outcomes or commitment from governments.

5.2 Regional knowledge and capacity development needs

MENA is significantly understudied in terms of climate change. The region is not well served by the IPCC as it falls in between, and on the periphery of, three assessment regions: Africa, Asia, & Europe. Italy and some other Mediterranean countries have argued for a Mediterranean assessment region that would including MENA, but this was deemed unfeasible due to the overlap of some nations (e.g. France) between the Mediterranean and other regions. In the words of a senior IPCC official:

> *"MENA is not covered directly, and despite obvious vulnerabilities does not appear to have much knowledge, much data, or much internal or external interest. It is a gap from IPCC's perspective"* (Confidential source, pers. comm.)

Table 5.1 Sample of search terms results on Google Scholar. (Retrieved July 2nd 2012.)

Search terms + COUNTRY	Egypt	Jordan[7]	Lebanon	Kenya
"climate change"	33 600	37 000	11 900	37 200
"climate change" precipitation	11 300	12 400	2 560	11 900
"climate change" model	27 700	28 200	8 340	30 300
"climate change" RCM	230	314	69	303
"climate change" "vulnerability assessment"	788	514	268	1 160
"climate change" adaptation	14 700	12 900	3 840	19 300
"community based adaptation"	91	56	11	287

Of the studies reviewed during this assessment, few quantitative or empirical studies on climate change were authored by MENA researchers. The literature on climate vulnerability and adaptation was also quite minimal, and especially in the case of Lebanon almost entirely qualitative and desk-based. Table 5.1 presents a sample of search term results in research literature from Google Scholar[8] for the three countries of this assessment by comparison to Kenya. On average climate change in Lebanon receives about a third of the attention that it does in Jordan, Egypt or Kenya. Climate change in Kenya consistently receives more attention than in the MENA nations. Research on regional climate models,

[7] Jordan may receive an artificially high number of hits as there is at least one well-published climate researcher with the surname "Jordan'

[8] http://scholar.google.com

adaptation, vulnerability, and community based adaptation all receive significantly higher attention in Kenya.

Projecting Climate Impacts

There are obvious gaps in capacity for climate modelling in the region. Climate models are expensive to develop and maintain, and require expert staff and powerful computing infrastructure. The levels of uncertainty inherent in climate projections mean that owning just one model is not much use, so there is a disincentive for investment by governments. Outside MENA some researchers are interested in the region, particularly as a testing ground for precipitation models, but it tends to attract less funding for regional climate modelling than Africa, Asia or Latin America. The challenges with access to and availability of consistent time-series data and high uncertainties of precipitation projections in arid areas are also obstacles for researchers.

Where modelling has been done it is usually limited in scope, based on just one or two emission scenarios, and less than four GCMs or just one or two RCMs. The development of RCM approaches for the region has been limited, yet the coarse resolution outputs from GCMs can be meaningless in the context of complex geography such as found in Lebanon. Projections and models of future runoff also need more development, a particular challenge in the Nile due to the complexities in the Basin's hydrology. All these practical constraints mean that the results of existing climate studies must be treated with caution.

Rather than investing funds in modelling, it is more advisable and cost-effective for regional governments to focus instead on gaining access to climate projections produced elsewhere. Initiatives such as the Coordinated Regional Climate Downscaling Experiment (CORDEX)[9] and PRECIS[10] have been established to provide RCM outputs. ACCWAM's intention to work with ESCWA and ACSAD to provide such models is appropriate in this context. There is also a need for the provision of downscaled sea level rise projections to assist with vulnerability assessments of inundation and saltwater intrusion in coastal areas. There is very high quality work being done through FP7 research projects, and ACCWAM could play a useful role in linking these researchers with regional policy makers.

However, there is a need for capacity building amongst researchers and officials on the use and interpretation of climate projections in developing impact and vulnerability assessments. There is also a need to develop research and decision-support tools to model impacts and vulnerabilities in particular sectors using the outputs of climate models as input data, for example in assessing agricultural impacts, or changes in streamflow or water demand. Expertise in the interpretation of climate projections would also assist in the development of adaptation plans and mainstreaming adaptation in water sector plans, particularly in terms of managing uncertainty.

Governments can also do more to make data more freely available to researchers. Where climate data exists it can sometimes be regarded as a commodity or as a security issue. In addition, meteorological records exist across MENA from colonial times, but have not been digitised or standardised.

Vulnerability Assessment

Very limited work has been done on assessing vulnerability to climate impacts in the region, particularly in terms of identifying or prioritising vulnerable groups or impact pathways.

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[9] http://www.meteo.unican.es/en/projects/CORDEX
[10] http://precis.metoffice.com/

The majority of vulnerability assessments that have been conducted are broadscale, in the sense of projecting per capita water resources at some future date for a whole country, or losses in particular crop types. Very few assessments have been made of how climate change will affect the livelihoods of groups such as farmers or specific communities in terms of income or health.

In part this can be explained as due to researchers and officials thinking that certainty in climate projections is a prerequisite for detailed studies on vulnerabilities. Vulnerability is usually understood as a function of a subject's exposure, sensitivity, and capacity to adapt to a particular hazard. This approach is well accepted by the IPCC and leading climate change experts. However, can be interpreted to imply that without detailed knowledge of the subject's exposure (e.g., the magnitude of changes in temperature or water availability) it is not possible to assess vulnerability.

Considerable work can be done in conditions of climate uncertainty by using social and gender vulnerability assessment approaches. These inventory livelihood systems and capitals of communities and attempt to identify impact pathways that might render them vulnerable. As an example, research in a remote area of rural Morocco identified pregnant women as particularly vulnerable to increased flooding from climate change, as roads leading to hospitals would be made impassable. As a result of this finding, donors and the government invested in a rural midwifery project to ensure that a trained volunteer midwife would be within walking distance of each home in the area. It is notable that no studies on gender and climate change were identified during this assessment.

Simple social vulnerability analyses can be used to identify relatively cheap measures to adapt and improve resilience whilst making positive contributions to development – so called 'no-regrets' strategies. However, there is limited capacity for this kind of work amongst MENA researchers and NGOs, and limited support or interest from states. Research using these approaches is relatively inexpensive, and a program conducting a series of assessments across a representative sample of communities could quickly begin highlighting priorities for action.

In terms of specific sectors, whilst water and agriculture both require considerably more research to be done, the impacts of climate change on health remains a large gap, not just in MENA. Economic assessments of climate change impacts and vulnerabilities are also scarce in the region.

Adaptive Thinking

There is little empirical or theoretical grounding in adaptation to climate change in MENA. Whilst there are numerous approaches to conceptualising adaptation, three useful distinctions in this context are between planned and autonomous adaptation, between anticipatory and reactive adaptation, and between adaptations in institutions and adaptations in technology.

Planned adaptation is the result of deliberate policy decision, based on evidence or expectations of change, and agreement that some form of action is required. Planned adaptations usually progress in top-down fashion, starting with policies and investments, and are typical of the public sector. Examples include the provision of large infrastructure projects, development of early warning systems, or implementation of regulations governing groundwater abstractions, and the water sector plans and adaptation plans reviewed during this study are typical of the process. By contrast, individuals, the private sector, and communities can act independently through autonomous adaptation that may be short-term. Examples of autonomous adaptation might be farmers experimenting with and selecting new crops or cropping patterns, or purchasing refrigerators to prevent food spoilage. Autonomous adaptations are generally cheap for governments, but rely on people having adequate knowledge and not facing economic or institutional disincentives.

Adaptation initiatives in MENA identified during this review were almost entirely planned, or revolved around the development of plans. There is very little knowledge regarding autonomous adaptation in MENA, other than some studies on responses of farmers to increasing water scarcity. There is also a capacity gap in terms of governmental support for autonomous adaptation by citizens, and, in general, extensive bureaucracy and policy is thought to inhibit autonomous adaptation in the region. However there are a limited number of examples where efforts to develop more enabling environments are underway. The Government of Morocco, for example, is attempting to reform finance laws and streamline bureaucratic procedures that would allow individual farmers to purchase crop insurance from banks, and is reducing the bureaucratic hurdles farmers face in accessing drip irrigation technologies.

Anticipatory adaptation is usually associated with planned adaptation, in that it should occur before the impacts of climate change are obvious. Reactive adaptation, by contrast, happens after impacts are evident, and is often associated with autonomous adaptation. The water strategies reviewed during this assessment are typical of anticipatory measures to increasing water scarcity, except that they generally fail to account for climate change impacts. Given that these plans govern investments worth hundreds of millions of dollars in infrastructure with expected lifespans of decades, this is a significant source of risk, and could lead to the need for increased expenditures in reactive adaptation. The exposure of existing and planned infrastructure to climate change impacts has been raised in the context of the Aswan High Dam, and wastewater systems in Lebanon. There is a need to systematically evaluate the risks in existing infrastructure and to update national water plans to include climate dimensions in order to anticipate climate change induced hazards and plan accordingly. Other donors such as UNDP and the World Bank are active in this area, but gaps remain.

The most significant distinction is between institutional or technological adaptation. Technological solutions to problems are generally easier to implement than changes in behaviours, rules, and norms (institutions). However, technologies rarely solve problems in unsupportive institutional contexts. In the MENA region, strong institutions are less common than they are in developed countries. Organisations are likely to have fewer resources; institutional arrangements for dealing with complex policy problems are generally weak; adaptive management processes are unlikely to be in place; legal frameworks may be insufficient for taking action; and both formal and informal institutions may have challenges with leadership, accountability, and building constituencies for meaningful and appropriate adaptation. In some areas communities may not rely on public services and institutions at all, either because of problems in access or shortfalls of institutional resources. Particularly where decision-making processes are lengthy and based on patronage - which can be just as true with respect to community level institutions as it can of the state - vulnerable people are required to be self-reliant. A program such as ACCWAM cannot directly address these challenges, but it can promote debate, discussion, and raised awareness through inclusive networks, public events, and awareness raising, all of which can support improved outcomes.

Despite these challenges in delivering public services, NGOs and civil organisations tend to be highly constrained, and by comparison to Africa few researchers are skilled in participatory approaches. The literature review found very few examples of community-based or participatory climate adaptation initiatives in MENA, with the majority supported by IDRC's research programs. NGOs active in community development may represent the best opportunity to spread expertise and practise in this area.

Capacity to assess and reform institutions in the MENA region is limited, particularly in terms of reforming interactions and participation between the state and wider society. In the documents reviewed for this assessment there was a general preference for technological adaptations and limited assessment of accompanying measures such as agricultural extension. There was extensive coverage of institutional issues in the Egyptian National Water Plan and the Lebanese Second National Communication, although there will be considerable challenges in enacting the proposed reforms.

Institutional Capacities

Adaptive management and the management of uncertainty in planning is a key area for capacity building. Adaptation is inherently uncertain and adaptation measures have no guarantee of success. Allowing experimentation, learning from and sharing experiences, admitting mistakes, and obtaining multiple perspectives on potential problems and solutions are therefore all important aspects of institutional capacities for adaptation. However, these are rarely characteristics of public organisations, especially in MENA. Establishing participatory monitoring and evaluation frameworks for projects and initiatives, and strengthening capacity for evaluative thinking and processes within institutions can be an important entry point to building adaptive capacity.

In addition to national institutions, substantial regional networks exist within MENA, including on desertification, pollution reduction, knowledge sharing in agriculture, and the management of transboundary rivers. Existing networks offer relatively straightforward options for mainstreaming adaptation activities. However, the relatively recent – and still ongoing - emergence of climate change adaptation as an area of activity in MENA also means that many organisations may not be aware of their potential roles and responsibilities in implementing and mainstreaming adaptation, or that these roles have not been properly defined or agreed upon. Regional and national institutional networks could be evaluated for potential contributors to adaptation, and to identify where raised awareness is required and options for reducing barriers and constraints in participating in adaptation.

5.3 Summary - Opportunities for adding value through ACCWAM

5.3.1 Regional Level

- Provide ensemble downscaled climate projections to national ministries and researchers;
- Provide a link between MENA policy makers and the outputs of FP7 research projects;
- Support the provision of downscaled sea level rise projections to assist with vulnerability assessments of inundation and saltwater intrusion in coastal areas
- Identify knowledge exchange opportunities between countries based on matching needs with existing competencies;
- Support efforts to assess climate vulnerabilities and identify adaptation options for neglected communities, particularly those in inland areas reliant on rainfed agriculture and groundwater. The Drylands Reseach Programme of the CGIAR may be an appropriate partner;

- Strengthen analyses of the impacts of climate change on water demand in the municipal and industrial sectors;
- Mainstream understanding of the relationship between climate change, water quality and human health, and support vulnerability assessments and identification of adaptation options where possible;
- Mainstream support for economic assessments of climate change impacts, vulnerabilities, and adaptations;
- Mainstream gender considerations in water sector adaptation;
- Build capacity of researchers and officials on the use and interpretation of climate projections in developing impact and vulnerability assessments;
- Support the development of research and decision-support tools to model climate impacts and vulnerabilities in particular sectors. However, monitor the activities of other donors such as USAID & NASA who are active in this sector to avoid duplication;
- Support the development of adaptation plans and mainstreaming adaptation in water sector plans, particularly in terms of managing uncertainty. However, monitor the activities of other donors such as UNDP who are active in this sector to avoid duplication and look for synergies;
- Build capacity in researchers and NGOs for assessing climate vulnerability, particularly in terms of identifying and prioritising vulnerable groups or impact pathways;
- Strengthen capacity in NGOs and the research community to spread expertise and practise in community based adaptation and participatory approaches;
- Support social vulnerability assessments and community adaptation plans as demonstration activities;
- Support studies identifying and identifying means of reforming institutional, policy and economic barriers to and creating enabling environments for autonomous adaptation in the water sector;
- Develop and share guidelines and develop pilot studies for evaluating climate risks in existing water infrastructure;
- Promote debate, discussion, and raised awareness on climate change and adaptation through inclusive regional networks, public events, and awareness campaigns;
- Evaluate existing relevant regional and national institutional networks to identify options for mainstreaming adaptation in their activities;
- Support cooperation between ESCWA and UNECA on climate activities and knowledge sharing;
- Strengthen capacity for participatory monitoring and evaluation, and implement in pilot projects and ACCWAM initiatives.

5.3.2 Egypt

- Conduct climate vulnerability assessments in the pilot farms and community to indicate specific climate impact pathways, and identify adaptation options;
- Build capacity for community-based adaptation with partnerships of the community, NGOs, researchers, and officials;
- Partner a well capacitated NGO established at the national level with local CDAs;
- Consider options for using solar technology in water pumping;
- Opportunities for regional knowledge sharing may include Jordanian expertise on wastewater recycling and solar power;

- Mainstream climate adaptation in the next National Water Resources Plan, due in 2017;
- Engage with the development process for the Third National Communication to the UNFCC, and ensure that ACCWAM results are included;
- Engage with the UNDP/GEF Coastal Zone Management Project housed at NWRC to gain influence over the drafting of the coastal zone law;
- Following the progress of the National Adaptation Strategy and influence where possible;
- Strengthen capacity in national climate activism groups;
- Engage with officials working in desert communities to identify potential capacity building through the provision of downscaled climate projections;
- The Alexandria Research Centre for Adaptation (ARCA) is one of the only sources of expertise on the economics of adaptation in the region, and could be useful in a regional role.

5.3.3 Jordan

- Conduct climate vulnerability assessments in the pilot farms and community to indicate specific climate impact pathways, and identify adaptation options;
- Develop analyses of the economic and policy basis for solar farming;
- Provide ensemble downscaled climate projections and build capacity on their interpretation and use;
- Strengthen capacity in climate vulnerability assessment and approaches to planning adaptation in NGOs, researchers, and officials;
- Engage with UNDP project incorporating climate dimensions in to the National Water Strategy;
- Share results with and offer technical capacity support to the National Adaptation Strategy project;
- Share results with and offer technical capacity support to the Third National Communication.

5.3.4 Lebanon

- If the pilot project is on the recharge of coastal aquifers, engage with the “Climate Change and Saltwater Intrusion along the Eastern Mediterranean: Socioeconomic Vulnerability” project at AUB;
- Provide ensemble downscaled climate projections and build capacity on their interpretation and use;
- Provide technical support and capacity building in developing climate impacts projections, watershed water balance assessments in terms of projected climate change, and management plans including climate dimensions;
- Strengthen capacity for supporting autonomous adaptation in NGOs, researchers, and officials;
- Assess potential for updating the National Water Sector Strategy to incorporate climate dimensions;
- Share results with and offer technical capacity support to the Third National Communication;
- Assess plans and opportunities for developing a National Adaptation Strategy, and engage if feasible;

- Lebanon could benefit from Jordanian and Egyptian expertise in water engineering and wastewater management;
- 'Regional' academic policy centres and NGOs in Lebanon may be useful convenors of network events.

5.3.5 Strategy Map

Table 5.2 shows a potential strategy map for options given above. The strategy map distinguishes between causal measures over which ACCWAM has direct control, persuasive measures where the program has less control, and supportive measures with greatly reduced control over outcomes. It also distinguishes between measures aimed at individuals (e.g. provide training) and measures aimed at the operational environment (e.g. provide tools).

Table 5.2. Potential strategy map for the ACCWAM Programme

Strategy	Individual	Environmental
Causal	Fund pilot projects; Engage consultants to support officials and NGOs develop plans and activities. Provide ensemble downscaled climate projections; downscaled sea level rise projections.	Provide research and decision-support tools to model climate impacts and vulnerabilities in particular sectors.
Persuasive	Hold informal field visits by officials; Provide training in participatory monitoring and evaluation; the use and interpretation of climate projections; climate vulnerability assessment; adaptation planning; Commission expert studies on the impacts of climate change on water demand; linkages between climate change, water quality and human health; climate change and gender; economic assessments of climate change; climate vulnerabilities of neglected rainfed communities; climate change and gender; barriers to and limits of adaptation.	Promote debate, discussion, and raised awareness on climate change and adaptation through regional and national events; Mainstream adaptation in existing institutional networks; Fund social vulnerability assessments and community adaptation plans as demonstration activities.
Supportive	Strengthen capacity in NGOs and the research community to spread expertise and practise in community based adaptation and participatory approaches; Develop and share guidelines and best practise guides.	Support mainstreaming of adaptation water sector policies and plans; Develop institutional support for national water sectors from ESCWA and ACSAD; Identify knowledge exchange opportunities between countries based on matching needs with existing competencies; Develop a knowledge network of experts on climate change adaptation in the water sector.

5.4 Conclusions and Key Messages

ACCWAM is well situated to influence the evolution of practice and policy for climate adaptation in the water sector of MENA. The programme's regional partnership under the auspices of the League of Arab States (LAS) provides a forum for spreading and sharing technical expertise, adaptation experience, and learning amongst member states and regional organisations. This includes opportunities for engaging and coordinating with the regional activities of organisations such as UNDP and the World Bank on climate change adaptation. However, it is important to recognise that LAS, ESCWA and ACSAD cannot compel or direct member states to particular actions. Rather, their mandate is limited to encouraging best practices. ACCWAM is therefore bound to a strategy of persuasion and supporting the development of a conducive environment to achieve its objectives.

ACCWAM should consider how to best operationalize a supportive and persuasive strategy, recognising that there are limited opportunities for having direct causal effects on adaptation efforts within member states. The principal direct causal option available to ACCWAM is through supporting individual pilot projects in the three Phase 1 countries – Jordan, Lebanon and Egypt. Ideally, a supportive and persuasive strategy would use these pilots not as ends in themselves, but as entry points for engagement and capacity building. In this sense the nature of the specific pilot projects is less important than the opportunity they represent for capacity building.

Growing experience of adaptation around the world indicates that specific adaptation technologies are less important than the processes by which they are identified, selected, implemented and evaluated. More than anything else, adaptation requires the abilities to manage uncertainty, to build partnerships across diverse institutions and societal actors, and to learn and share learning. These three dimensions of adaptive capacity are not characteristic of water management institutions in the LAS region.

ACCWAM therefore should use pilot projects as vehicles to engage officials from water management institutions in partnership development with civil society and research institutions, in assessing and mitigating uncertainty, and developing evaluation and learning frameworks. This can be supported by the use of national and international consultants and experts to conduct 'on-the-job' training and capacity building within each pilot project, and by exchanging experiences and reflections at the regional level. Although ACCWAM is not oriented as a community based adaptation program, framing pilot projects as participatory action research projects based on learning partnerships would be likely to have more significant penetration of key concepts and capacity than pilot projects framed as technical exercises.

At a regional level, ACCWAM can support activities promoting best practice, knowledge sharing, and the development of scenarios, climate projections, and vulnerability assessments. Specific areas appropriate to the regional level are transboundary water resources and the harmonisation of plans and policies where appropriate. Working through the League of Arab States also offers an important opportunity to develop a body of work on creating enabling environments for autonomous adaptation, particularly with respect to rural communities dependent upon pastoralism and rain-fed agriculture.

The key recommendation of this study, therefore, is for ACCWAM to frame pilot projects as entry points for changing attitudes, relationships and ideas and for building capacity through sustained engagement with key actors. These experiences will then provide substantive content to be relayed through the supportive and persuasive processes established at the regional level.

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