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Water Demand Management and the water-food-climate nexus in the Middle-East and North Africa region

Water Demand Management Research Series

By the Regional Water Demand Initiative in the Middle East and North Africa

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IDRC CRDI

IFAD Enabling poor rural people to overcome poverty

Canadian International Development Agency

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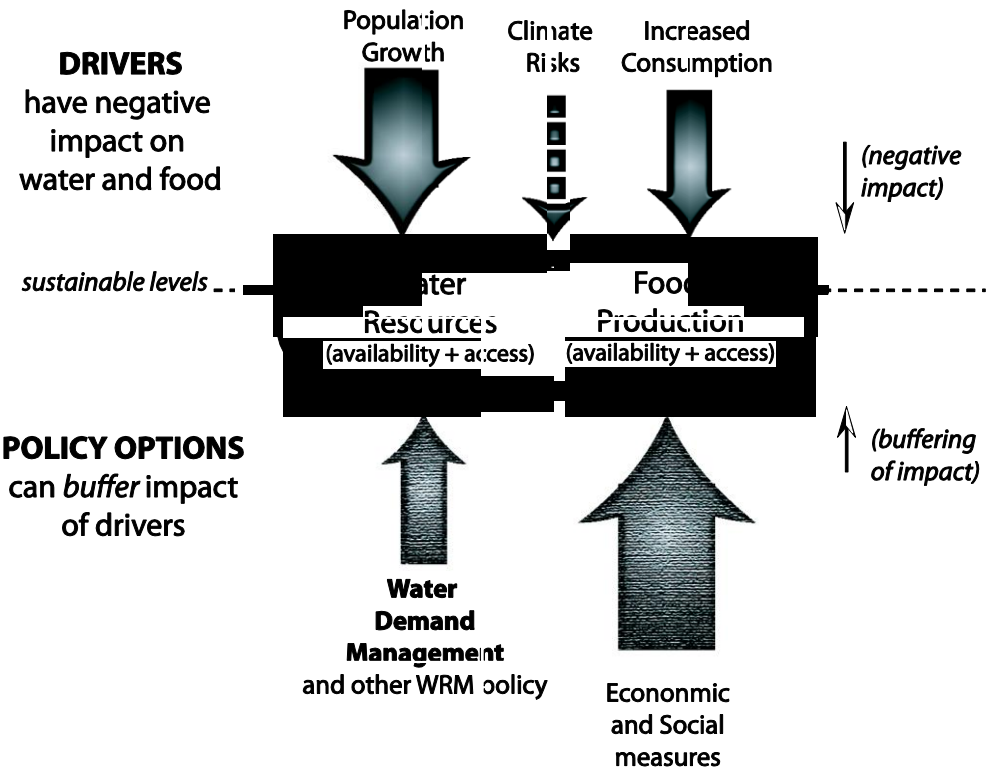
Acronyms

°C	degrees Celsius
A1F1, A2, etc.	specific SRES scenarios, related to different economic and social futures
AR4	Fourth Assessment Report (which uses the SRES emissions scenarios)
FAO	UN Food and Agriculture Organisation
GTZ	Gesellschaft fuer Technische Zusammenarbeit
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
m3	cubic metres of water
MCM	Million cubic metres of water
MENA	Middle East and North Africa region
NAPA	National Adaptation Plan of Action
NGO	Non-Governmental Organization
WaDI*mena*	IDRC programme to promote water demand management
SLR	Sea Level Rise
SRES	Special Report on Emissions Scenarios (report prepared for IPPC)
UNFCCC	United Nations Framework Convention on Climate Change
WDM	Water Demand Management

Executive Summary

This study explores the potential for Water Demand Management (WDM) to respond to climate-induced pressures on water and food availability throughout the Middle East and North Africa region. It considers the interdependency of the water-food-climate nexus through extensive review of the latest climate projections, and current state of water resources availability and food security for Morocco, Algeria, Tunisia, Egypt, Lebanon, Syria, Palestine, Jordan and Yemen. As a water policy option, WDM is conceived to act as a 'buffer' against anticipated future climate risks, as well as against the greater and more immediate pressures from increased population and consumption patterns, as shown below. Economic and social policy options are also considered as potential key buffers, but beyond the scope of this study.



The strain imposed by the drivers is borne by water and food systems that are already highly stressed. The bulk of the select MENA states suffer from physical water scarcity, inequitable distribution both domestically and internationally, and limited institutional and adaptive capacity. Drought is generally held to be the most significant climate risk in the region, especially in terms of impact on livelihoods. Projected temperature increases for the region are for 0.5 to 1.5°C for the period 2020-2029, and 2.5 to 5.5°C from 2029 until the end of the century (IPCC 2007a). Decreases in precipitation in the order of 15 to 20% have been projected for the next fifty years, and surface water run-off is projected to drop by 10 to 30% throughout most of the MENA region by 2050 (Milly, et al. 2005).

With roughly 80% of water in the region consumed by crops (FAO 2009b), the effects of climate change are likely to be felt first and foremost in the agricultural sector. Sustained long-term drying can lead to a reduction in arable land, and higher temperatures may lead to increased evapotranspiration (tempered by increased

humidity and CO_2 levels). The projected reduction in yields throughout the MENA region is thus even higher than the global average – about 33% in rice, 7% in wheat, 8% in Maize and 4% in millet (Nelson, et al. 2009: Table 3).

With its focus on equitability and sustainability, Water Demand Management is identified as a preferred policy response to the water-food-climate challenges, in both the short and the long term. Over forty specific WDM interventions are tested for relevance to each of the three components of the nexus. The interventions and termed '***best-fit'*** intervention types and classed in five categories: Food trade; Changing consumption patterns; Environmental; Agronomic; and International Cooperation. The earliest incorporation of these WDM interventions into national water, food and climate policy is the primary recommendation of this study. The report highlights a number of other observations and recommendations, a selection of which follows.

Integrated water-food-climate policy is key to addressing the interdependence of the three systems. Policy that serves to address only one of the three can have unintended negative impacts on the others. Isolated policy is both ineffective and unnecessary: the 'best fit' water and food demand management options available are beneficial to the entire nexus.

Policy-makers must also consider the political economy, outside the water and agri-food sectors. The current political economy exacerbates the negative effects of the climate, population and consumption drivers, through pricing signals that favour unsustainable and inequitable practices. Economic and fiscal policies (e.g. trade and insurance) designed to counteract the current emphasis may serve to mediate variability. National water-food-climate policy should therefore also coordinate with ministries of finance and trade.

Notions of *national water, food and climate 'security' must be reconsidered.* Supply-side solutions in most of the MENA countries are exhausted, with limited further scope for dams, deeper boreholes, or foreign agricultural land acquisition. The food and/or water security that a supply-side paradigm may ensure in one country is fleeting, and likely to come at the cost of food and water *in*security in another country (or at a later date, in the same country). A broader approach to water, food and climate security would consider the interaction of each sector within the political economy in which it occurs, over the long-term.

The water-food-climate nexus is global. Climate risks, food trade and water resources derive from far beyond national borders. The fundamentally international character of the water-food-climate nexus can lead to strengthen or harm international relations. There is considerable benefit to be gained from improved international and transnational cooperation that would strengthen regional markets of food and (virtual) water, as well as regional or global frameworks to address the climate impacts.

The 'best-fit' WDM interventions should be incorporated into water, food and climate policy without further delay. The five WDM interventions discussed here (and several others discussed in detail in the report) found to be relevant to all three elements of the

water-food-climate nexus are ‘best fits’ for a range of national policies. National policy-makers in MENA countries are strongly advised to prioritise such interventions (and the general approach) when devising their national climate change adaptation plans, and national water and food policy.

1 Introduction

This study explores the potential for Water Demand Management to respond to climate-induced pressures on water resource availability and food growing conditions throughout the Middle East and North Africa region, and in select countries in the region. The nexus of water, food and climate is introduced in this section, and explored through review of the latest regional and national climate projections, and data on water and food availability, in Section 2. The scope for Water Demand Management (WDM) to respond to the pressures is gauged through tests of the relevancy of the WDM interventions to each of the three elements in the nexus, in Section 3. The study concludes with specific recommendations and observations for national water, food and climate policy-makers.

1.1 Rationale for the study

The primary climate changes anticipated in the Middle East and North Africa (MEAN) region are decreased precipitation, less intense and shorter and more erratic rainy seasons and generally higher temperatures (see Section 2). Other climate-related risks include coastal saline intrusion and extreme weather events. Combined, these climate changes are expected to lead to less available freshwater resources and poorer food growing conditions. The ability of a state to respond to the risks or events will depend very much on their capacity to adapt to changes, or to plan ahead to reduce dependencies and thereby avoid vulnerabilty. In other words, states prepared for future uncertainties can increase their resilience (or decrease their vulnerability) to the effects of climate change through proactive, rather than reactive, water and food policy planning.

Most national water policies in MENA follow a reactive 'supply management' approach to water resources – where a country's demand for water is met through continuously sourcing new supplies. Desalination is the increasingly favoured way to meet water demand, but the supply-side response also includes ever-deeper wells to mine renewable or (increasingly often) fossil aquifers, and reaching for the few remaining rivers that are not already depleted. Apart from perpetuating reactive planning, the supply-side approach leads to additional fossil fuel consumption and greenhouse gas emissions.

Managing the *demand* for water (and food) is suggested here as the preferred alternative, and Water Demand Management as a policy that may operationalise it. The rationale is that states and communities that can manage their water and food demand will be in a position to reduce their overall water consumption, thereby either 'buffering' the expected impacts or by avoiding them altogether. The reasoning follows previous investigations that assert that WDM is a strategic and effective adaptive strategy to current and future water resource management challenges (e.g. Arafa, et al. 2007: 15), a view endorsed recently by a poll of over one thousand 'sustainability experts' (Schneider 2010).

Research goals and questions

The goal of this study is *to investigate to what extent can WDM serve to counter the anticipated effects of climate change on water and food availability in the MENA region*.

To that end, the following research questions are examined: a) What are the effects of expected climate changes on water and food availability?; and b) What is the potential role of WDM within policy aimed at improving water resources management, food security, and climate change adaptation?

The study hypothesises that expected changes in climate will increase aridity throughout the region within this century, reduce freshwater resources availability, and decrease food growing conditions. WDM is hypothesised, furthermore, to assist with adaptation to projected climate changes and to benefit water availability and food production.

1.2 Methodology and limitations

This study makes use of the extensive secondary sources of data: primarily published scientific and policy reports, and peer-reviewed articles. The extensive bodies of literature on food security, water resources and climate change have been scrutinised, and the data most relevant to the water-food-climate nexus and to the Middle East has been sorted, processed and analysed. The research team has been supported by peer experts in each of the water-food-climate fields, as well as by the IDRC WaDI*mena* team.

A number of factors related to the study's methodology bound its reliability and utility. First, the bulk of the data provided is through review and analysis of published literature. While there are numerous reports published relevant to each element of the water-food-climate nexus, many more that are currently in progress or that are not intended for publication have not been consulted. Second, the reliance on secondary data has been corroborated with experts related to the topics through an internal and external peer-review process. Consultation with experts from MENA countries has been limited, such that national contextualisation does not run deep. Third, the geographic scope of the report is very broad indeed. Analysis has been maintained primarily on biophysical factors of water, food and climate at the regional level. Country-level analysis and socio-economic and political considerations related to access to water and food is provided where possible, but is not emphasised. Finally, the MENA region here is composed of nine countries – Morocco, Algeria, Tunisia, Egypt, Lebanon, Syria, Palestine, Jordan and Yemen. The omission of countries contiguous with the selected group of countries (e.g. Libya, Saudi Arabia) presents particular challenges for regional environmental assessments. 'Palestine' is furthermore seen as a particular case, in the sense that the ongoing Israeli occupation of the West Bank and Gaza compromises the data available for analysis, as well as the feasibility of recommendations made.

1.3 Definitions

Water Demand Management

IDRC defines Water Demand Management as *any practice or policy implemented which results in water being used in a more efficient, equitable and sustainable way*. The focus on efficiency, equitability and sustainability is elaborated upon in Brooks (2003), and developed to included six pillars of WDM policy: technical, economic, social, institutional, financial, and political. Alternative definitions and critique of the approach is provided in Section 1.5.

Food Security

A common definition for food security is provided by FAO (2009c: 8): "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Household food security is the application of this concept to the family level, with individuals within households as the focus of concern." The FAO's annual *State of Food Insecurity* reports set the foundational conceptual basis of food security, counted in four elements: food availability (i.e. food production); food accessibility (the ability of people to obtain food); food utilization (the nutritional value of food); and food systems stability (stability of supply and access, and emergency coping capacity) (FAO 2009c).

The main focus of this study is on the most basic element – that of food production, at the national level. To the extent that it is feasible, the crucial element of food accessibility (at the national level) is drawn into the analysis, and assessed primarily through levels of food imports. Food use and systems stability are not discussed at further length.

Climate Change and Climate Risks

The term 'climate change' is used throughout the report to refer to long-term changes in climate, beyond the levels of 'natural variability' that would be expected during a 30 year period, and which have an anthropogenic cause (due to greenhouse gas emissions). Shorter-term variability such as seasonal or intra-seasonal rainfall variability are referred to by their specific nomenclature. Climate risks are used to describe the environmental hazards associated with aspects of climate change and their potential significance for societies vulnerable to the hazards.[1]

1.4 The Water-Food-Climate Nexus

Changes in climate are one of many pressures on future water resources management and food production. The related threats of population growth and increased consumption rates that accompany wealthier lifestyles are considerably greater in the short to medium term, and are expected to be compounded by climate change in the long term. Climate change impacts must therefore be framed within their wider socio-economic and political contexts.

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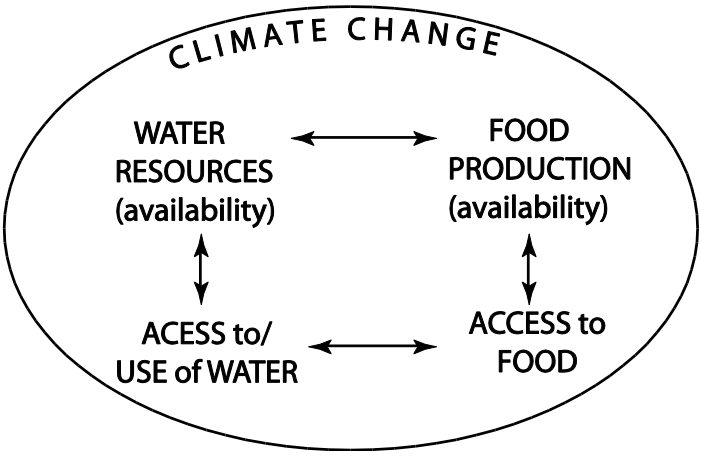
[1] Risk' is understood here in relation to hazards and vulnerability, – i.e. that populations exposed to a hazard are at risk if they are also vulnerable to the effects of the hazard (Wisner, et al. 2004).

Conceptualising the water-food-climate nexus

Water is seen by many to be 'at the heart of both food security and climate change'. Each of the three environmental resources or phenomena – water, food and climate – are highly inter-dependent and impact upon each other, but in unequal measure. That is, changes in climate are expected to affect food security and water resources significantly more than food security and water resources will affect climate change.[2]

In keeping the three factors in mind, it is crucial to distinguish between the biophysical traits of *water resources availability* and *food production*, and the more socio-economic traits of water and food *accessibility.* The nexus involves the three traits at different levels, as shown (in relation to the national level) in Figure 1.1.

Figure 1.1 A simple conceptualisation of the water-food-climate nexus. Changes in climate are expected to affect the a) biophysical traits of *water resources* and *food production*, and b) the more socio-economic traits of *access to water* and *access to food.*

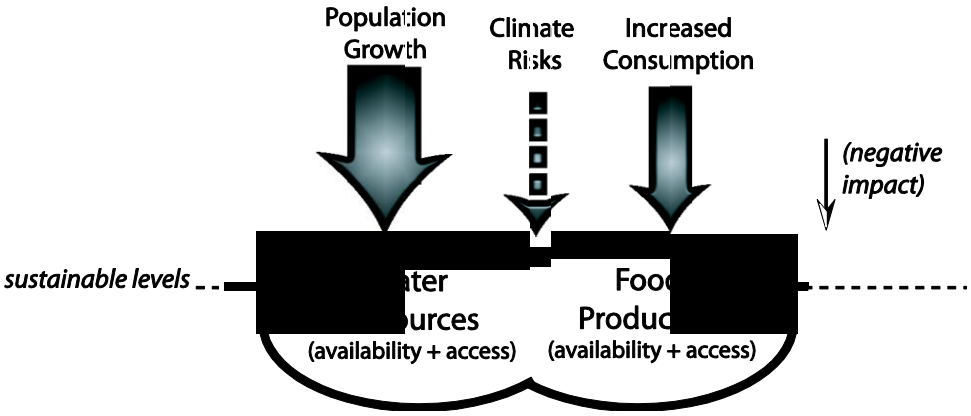


Climate change, and more immediate pressures on water and food

A more useful conception of the nexus between water-food-climate is offered in Figure 1.2. The figure shows the direct negative impact of the three main constraints of water resource and food availability, and potential indirect impact on the related issues of access to water and food. It also relates the significance of the climate change driver to population growth and increased consumption rates.

Figure 1.2 Primary drivers of reduced water and food availability at the national level, shown to push beyond sustainable levels. The dashed line representing climate risks reflects the high level of uncertainty; the width of the arrows indicates relative magnitudes in the short to medium term.

[2] It is noteworthy that roughly 10 to 12% of total global anthropogenic emissions of greenhouse gases, are related to agriculture (FAO, 2009). The carbon footprints of desalination plants and hydroelectric reservoirs should also figure into the analysis of the impact of water use on climate change.



MENA populations are growing rapidly (estimated by 2030 at roughly 30% for Tunisia and Lebanon, to roughly 75% for Syria), and wealth-driven increases in consumption patterns are also on the rise (refer to Figure 2.4). Numerous studies demonstrate that the long-term desiccation takes a back seat to socio-political and economic drivers, at least in the short-term. Globally, population and economic development over the next 25 years is expected to have a far greater influence on the water supply-demand balance, when compared against the projected impacts of global mean climate change (Vörösmarty, et al. 2000). Conway et al. (1996) obtained similar results in a study of the effects of future driving forces (changes in climate, land use and water demand) in the Nile Basin on water availability in Egypt.[3]

The relatively greater short and medium-term significance of population growth and consumption patterns on water and food availability emphasise the need to set climate risks in context. That context includes the socio-economic conditions and water and food demand for each country, as well as domestic and international policy and politics that enable or prevent policy options. The socio-economic and political drivers are likely to continue to outweigh climate change over the next few decades, though climate risks may fall into the same range of magnitude in the long term. Some of the IPCC emissions scenarios predict the threat of rapid climate change by 2050, meaning that climate change issues not currently high on the priority list of policy-makers may be so in the decades ahead.

Water resources availability, water use and climate change

The importance of distinguishing between water availability and food production on the one hand, and access to water and food, on the other, becomes evident when considering the potential impact of climate change on *sustainable* water use. Climate change can directly affect water resources and food production levels, while WDM

[3] In their examination of water use in the context of income, water efficiency, water productivity and industrial production, Alcamo et al. (2003) found that the growth of the domestic sector (urbanisation) was the most dominant factor in increasing water use and stress in future decades. Similarly, Arnell (2004) finds that differences in the population projections would have a greater impact than differences in climate on the number of people living in water-stressed river basins, when modelled for the Special Report on Emissions Scenarios (SRES). Ashton (2002) concludes that even in the absence of climate change, present population trends and patterns of water use indicate that African countries will exceed the limits of their economically usable, land-based water resources before 2025.

policy influences water (and food) use. The potential outcomes that would derive from different scenarios for climate change and water policy are suggested in Figure 1.3. The effects of changes in climate are presented simplistically as an overall and gradual reduction in water availability.

Figure 1.3. Conceptual representation of the expected effects of climate change on the range of trajectories of sustainable water availability or use. Water Demand Management can influence water use to remain under sustainable limits. Changes in climate are presented simplistically as an overall and gradual reduction in water availability (lower dashed line), though increased variability is expected to create more frequent periods of water deficit, and will not be so linear.

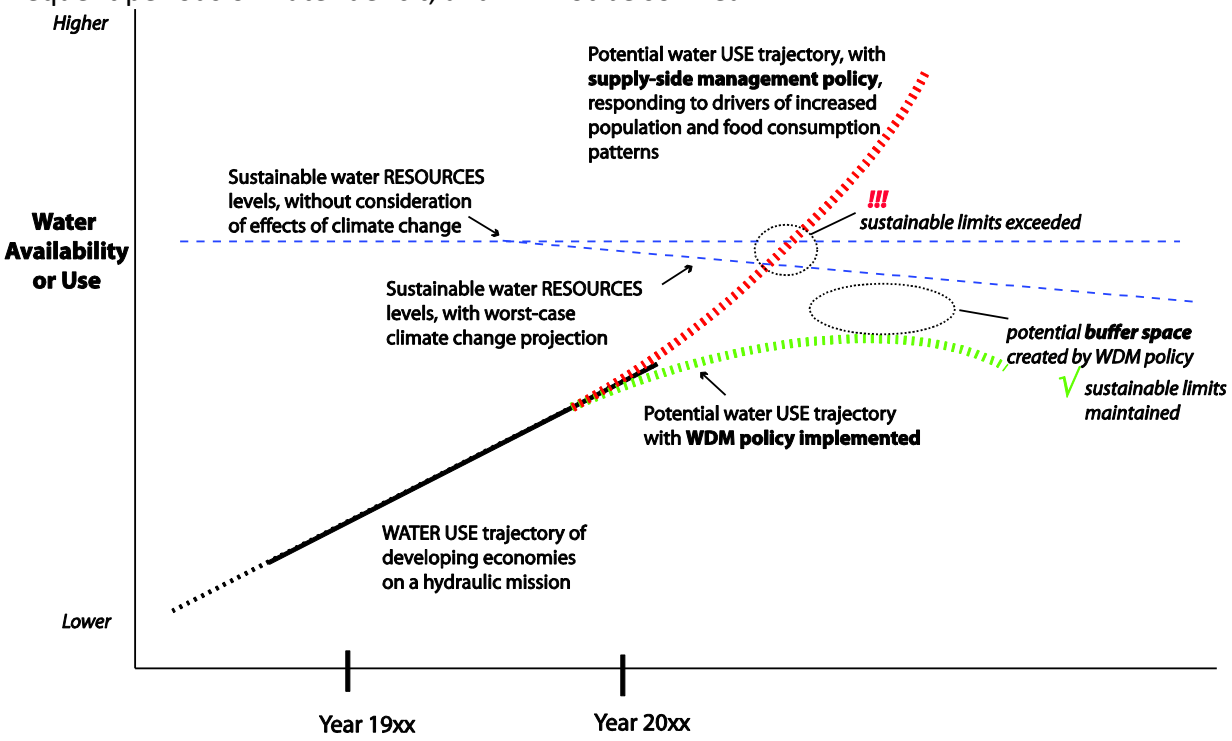


Figure 1.3 indicates that under the currently dominant supply-side management paradigm, sustainable limits of the resource will be exceeded at an undetermined point in the future, even with no expected changes in climate. If changes in climate do decrease water resource levels (or food growing conditions), the sustainable limit will be exceeded *earlier*. The figure also suggests that if demand-side management is implemented, water use levels can be kept at or below sustainable limits. National level water use will in a sense thus be 'buffered' from the effects of climate change.

1.5 Water Demand Management

Principles of Water Demand Management

At its very broadest, water demand management (WDM) is a policy option for the water sector that emphasises making better use of developed water sources (Winpenny; 1997: 297 in Turton (1999a)) or a reduction of use of existing developed sources, rather than the development of new ones. The breadth of the concept allows multiple aspects

of WDM to be interpreted – and implemented.[4] The previously-mentioned IDRC definition that is used throughout the study is amongst the broadest.

Misconceptions related to the WDM principle of 'efficiency'

Interpretation and implementation of the broad sense of WDM tends to favour one of the three main principles, with a discernible emphasis on the principle of efficiency (see e.g. GWP (2005)). Increased efficiency is generally understood in technical or economic terms. Water efficiency programmes and projects in agriculture would include switching from surface to drip-irrigation techniques, increased use of hothouses, pricing water at an economic value closer to cost, etc. The intention is to increase productivity, i.e. more 'crops per drop' or 'dollars per drop' (Allan 2007b). It is based on the assumption that yields will be maintained or even increased with the same or a reduced amount of water (see e.g. Vince 2010).

The idea that increased efficiency leads to less water use is hotly debated, however. In areas where water (not land) is a limiting factor, for instance, there is evidence that the same or increased volumes of water will be used to plant expanded agricultural area.[5] This is the case in Yemen (Lichtenthaler 2002, Ward and al Aulaqi 2008) and to some extent, in Egypt. Even in areas where land (and water) are limited, there is no evidence that increased agricultural productivity leads to reduced water use, as increasingly technical farming methods ensure that ever-more crops can be grown in ever-tighter spaces. Such is the case with hothouse food production in the Jordan River Valley (Abed Rabboh and Jabarin 2008).

Attention devoted to the equitability and sustainability principles of WDM has been relatively weak in comparison to efforts at improving efficiency. In principle, market mechanisms (e.g. pricing signals) could be used to determine water allocations. Markets in areas rife with bottlenecks are not typically effective in practice, and depend furthermore on well-regulated and effective policies in related sectors. Social inequity is a common result, including in terms of access to water. As such, achieving equitable allocation of water resources cannot purely be the domain of technology or economics, but requires interventions in and consideration of the social and political economy. The idea is to manage different – and oftentimes competing – sectors of society through negotiated processes to ensure equitable distribution at sustainable levels.[6]

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[4] Many definitions of WDM are on offer. Good work on the subject is recommended in Turton (1999b), Brooks (2006, 2007), and Arafa (2007).

[5] Seckler et. al. (2003), furthermore, point out that "While the potential for saving water through increased efficiency is substantial, it is not as large as might be thought… Many of the problems of water-resources management today are due to the implementation of false, erroneous or misapplied concepts of efficiency in water-resources policy and management" (Seckler, et al. 2003). See also discussion in Molle (2008).

[6] Work done on the equitable and sustainable principles of WDM has led to the approach of 'soft paths' to water management. Developed in large part by David Brooks, the soft path approach for water management includes a) treating water as a service rather than an end in itself; b) ensuring ecological sustainability; c) conserving quality as well as quantity; and d) 'backcasting' – which relies on managers choosing first the situation they would like to achieve and then determining the steps required to get there (Brandes, et al. 2007, Brooks, et al. 2009).

Types of WDM interventions

There are numerous types of interventions under the broad definition of WDM. Apart from the most well-known interventions – i.e. reducing losses in irrigation distribution networks or crop selection – a number of other potential interventions are frequently evoked (see e.g. Bates, et al. 2008: Table 3.4). Six pillars of WDM policy are identified to capture the breadth of interventions: technical, economic, social, institutional, financial, and political. With a view to testing the relevance of each type of intervention for relevance to the water-food-climate nexus, Table 1.1. assembles the bulk of these, classified under each of the six pillars.

Table 1.1 Inventory of Pillars, Types and Examples of WDM interventions. Collated from numerous sources.

Pillar	TYPE	EXAMPLES
Technical	Improved water use efficiency	Loss reduction in water distribution networks, irrigation networks through repairs
		More efficient types of irrigation (drip-irrigation)
		More efficient growing methods, i.e. hothouses
		Wastewater re-use for agriculture
		Irrigation water re-use/irrigation and drainage improvement
		Irrigation canal lining
		Improved operations and maintenance (O&M) of water delivery systems
		Emergency drought measures
	Knowledge base	Monitoring of water use, water quality, etc
		Investigations into sustainable limits of aquifers
		Investigations into severity of climate risks / expected impacts of climate change
	Agronomic	Changes/diversification in crop production (e.g. shift towards less water-intensive crops)
		Increased yields through fertiliser, pesticide application + modified crops
		Increased use of drought-resistant seeds
		Improved rainfed/dryland farming techniques
		Improved permaculture (e.g. Jordan)
	Environmental	Expansion of rainwater harvesting
		Watershed management(comprehensive approach including technical, social and economic issues)
		Restoration of aquatic habitats and ecosystem services
Economic	Food Trade	Multi-lateral or Bi-lateral food trade agreements
		Establishment of regional food markets
		Promotion of equitable food trade principles ('food sovereignty') or promotion of green water trade
	Water Markets	Tariffs and subsidies (to encourage more 'crops per drop' (efficiency)
		Green and Blue water credits scheme
	Economic measures	Diversification of the economy (water use prioritised towards industry and services)

		Long-term/planned economic growth and development
Social	Empowering stakeholders	Building WUAs, Water Boards, etc
		Improving local production systems to promote socio-economic development
	Consumption changes	Urban water conservation campaigns
		Changing food consumption patterns [Food demand management]
	Population policies	Family planning/control
		Migrations (moving people out of river banks)
Institutional	Empowering stakeholders	Improved managerial and technical capacity of water and agriculture government ministries, researchers
		Agency with explicit responsibility for WDM
	Legal reform / legislation	Agricultural water conservation legislation
		Decentralisation of domestic water supplies
		Development of strong institutional framework for WDM
		Water rights frameworks
	Regulation	Water use and consumption regulation
Financial	Financial	Insurance to farmers for poor-yield seasons
		Cost-recovery (and cost-sharing) measures for farmers
		Social protection to individuals
Political	International Cooperation	Basin-wide water management [International River Basin Management]
		Location of water storage beyond national borders (in the case of transboundary river basins)
		Transboundary cooperation
		Enhanced regional political and economic integration / Diversification of political or trade alliances

A brief scan of the interventions inventoried in Table 1.1 reveals that some of the interventions are specific only to the water component of the water-food-climate nexus, and may not be directly relevant to national agricultural and food policy or to changes in climate. The institutional or legal measures relating to the development of a rigid institutional framework for the water sector, for example, are not expected to independently serve to adapt to changes in climate. Technical and economic WDM interventions that might lead to less water use – such as improved efficiency or increased food imports – *are* on the other hand expected to help adapt to anticipated changes in climate, and to bear directly on food security. Many other types of interventions lie in between the two. Evaluation of the scope for each type of WDM intervention for relevance to climate risks and food policy is thus facilitated by categorisation of the interventions as suggested in Table 1.2. Testing of the relevancy of each WDM intervention to the water-food-climate nexus is conducted in Section 3.

Table 1.2 Categories of WDM Interventions.

I	WDM Interventions highly relevant to counter effects of expected climate risks, and to increase food security
IIa	WDM Interventions relevant to counter effects of expected climate risks, but not to increase food security
IIb	WDM Interventions relevant to increase food security, but not to counter effects of expected climate risks
III	WDM Interventions relevant to water resources management, but not directly to climate risks or food security.

WDM in the MENA region

The limits to the uptake of WDM principles into policy and practice in the MENA region are well-known. While there is certainly a long way to go with implementation of the policy, there have been achievements both at the local and national levels that are important to bear in mind.

The principles of WDM have been taken up for instance at the national level in some cases. The 2008 – 2022 Water Strategy of Jordan, for instance, states clearly as one of its goals for 2022 that "water tariffs within and outside the water sector should support water demand management" (HKJ 2009: 2-2). The government of Tunisia is beginning a water audit of its largest water consumers, in a bid to manage demand (Laamrani, pers. comm. Nov 2009). The Kingdom of Morocco has plans to transform its agricultural sector towards more drip irrigation between 2009 and 2017. The Kingdom of Saudi Arabia has decided in 2008 to outsource its practice of irrigating cereals (Laamrani, pers. comm. Nov 2009). Perhaps most significantly, the government of Syria has recently declared an end to horizontal extension of irrigation until 2027, in a reversion of its heavily subsidised agricultural sector (Droubi 2008).

Efforts to implement WDM practice at the community level have served to improve the livelihoods of several communities throughout the MENA region. In Ouled-Bessem (Algeria), treated wastewater from a local treatment plant is being used for supplemental irrigation of cereal crops, increasing crop yields and incomes (IDRC 2008). In Farafra Oasis, Egypt, traditional practices in managing groundwater are being documented and assessed to help local communities develop an integrated, participatory water management plan. In Jordan, treated greywater from dormitories at Mu'tah University is being reused for local agriculture. In Tafilalet, Morocco, reservoir-based drip irrigation—a system using saline water instead of fresh water—is being tested to validate equipment performance, uniformity of irrigation, effect on soil salinity, crop tolerance, and crop yields. Researchers in Sana'a, Yemen, are testing refinements to the traditional practice of using mosque grey water to improve crop yields and conserve groundwater, with the aim of improving livelihoods of poor urban farmers.

Despite the particular local-level successes, and the partial official uptake of WDM principles into national policy of some MENA governments, practice around the MENA region continues to follow a supply-side management paradigm. Each country is

developing or has plans to exploit what little water remains (e.g. the Toshka project in Egypt, dams on the Yarmouk river for Jordan and Syria, dams on the Litani and Hasbani rivers in Lebanon, etc), while desalination is becoming an increasingly popular option (e.g. the Red Sea-Dead Sea Canal, for Jordan, Israel and Palestine). Water 'needs' are created in large part by vested agricultural business interests, and direct implementation of WDM or food management policy is typically not a politically feasible option (see discussion in Section A1, Appendix A).

Implementation of WDM at the national level is further hampered by policy harmonization issues. Water policy is generally not coordinated with food and agricultural policy, which engenders tensions between ministries and renders both the water resources and the population that depends upon them for food more vulnerable. The problems with the policy are further compounded in some MENA countries by the fact that many water resources are shared with other countries. If the anticipated changes in climate are negative for both water availability and food growing conditions as expected, the need to undertake WDM policy seriously and to coordinate food and water policy both at home and abroad becomes imperative.

2 Climate Change, Water and Food in the MENA region

This section reviews the bulk of recent literature on climate change, water resources and food production in the MENA region. For the latter two it emphasises the element of international trade. The analysis is generally kept on a regional level, though country level data and analysis is provided, where possible.

2.1 Climate Change Projections and Risks

Consideration of how climate may change over decades and centuries most commonly involves the use of projections from global climate models. Projections are not predictions, and they are subject to considerable uncertainty. Confidence in future projections declines at higher spatial resolution. As such, regional and national scale results will be mediated by local topographic and weather conditions (e.g. proximity to coast, altitude). Generalisations even at the sub-national level can be problematic, and the local context must always be borne in mind. Saline intrusion is a much greater risk to livelihoods of the residents of Gaza than it is to the land-locked residents the West Bank's, whose main concern of drought (UNDP-PEQA 2009), for instance. Sea-level rise is of much greater concern to Nile Delta farmers (El-Raey 2009) than it is to farmers in upper Egypt.

General trends in climate change projections for the MENA region and in select MENA countries

A summary of the recent climate studies and the IPCC 4th Assessment Report main findings for the MENA region is presented in Table A1, Appendix A. Unlike some parts of the world, climate models show considerable agreement for the Mediterranean region. Inconsistencies within each sub-region are noted within Table 2.1, but general trends remain. Overall, there is reasonable climate model agreement on future patterns of *increasing temperature*, *decreasing precipitation*, and *higher inter-annual variability* throughout most of the MENA region (see e.g. Giorgi and Lionello 2007).

In terms of impact on livelihoods, the highest risk from changes in climate is generally held to be drought.[7] Other risks include coastal flooding and coastal saline intrusion due to sea level rise, heat waves, flash flooding, and increasing frequency in storm events. A brief summary of further climate change projections and risks in the MENA region is provided in Appendix A, Section A2.

Table 2.1 Summary and qualitative ranking of relevance of major climate risks to countries in the MENA region. Based on regional climate model projections, national communications to the IPCC, and authors' estimates.

Climate Risk	*Morocco*	*Algeria*	*Tunisia*	*Egypt*	*Jordan*	*Lebanon*	*Syria*	*Palestine*	*Yemen*
Increasing temperatures	✓✓	✓✓	✓✓	✓	✓	✓✓	✓✓	✓✓	✓
Decrease in precipitation	✓✓✓	✓✓✓	✓✓✓	✓	✓✓✓	✓	✓✓	✓✓✓	✓✓✓

[7] The authors acknowledge that drought – like scarcity – also has important socio-economic causes and should not be separated from water *use* (Maidment 1994).

Variation in precipitation	✓✓ ✓	✓✓✓	✓✓✓	✓	✓✓✓	✓✓ ✓	✓✓✓	✓✓✓	✓✓
Extended and more frequent droughts	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓	✓✓	✓✓✓	✓✓✓
Extreme events/ storms	✓✓	✓	✓	✓	✓✓	✓	✓	✓	✓✓✓
Sea level rise	✓✓	✓✓	✓✓✓	✓✓✓	✓	✓✓	✓✓	✓✓✓	✓✓

Projected importance: ✓✓✓ High; ✓✓ Medium; ✓ Low.

Morocco

The Moroccan Initial National Communication to the IPCC (Kingdom of Morocco, 2001) is based on projections of a temperature increase between 0.6 to 1.1°C and a decrease in average annual rainfall volume of 4% by 2020 (compared to 2000 levels).[8] The Atlas Mountains control the pattern of rainfall within Morocco, creating convective thunderstorms in the north and west which are projected to increase in frequency and intensity due to increased ocean and land temperatures (Kingdom of Morocco, 2001). This delays the drying trend in the northwest of Morocco, but projections suggest a drying phase by about 2070, leading to an increase in the frequency and intensity of droughts- particularly in the south and east of the country (Gommes, et al. 2009). The gradually increasing aridity is expected to have negative impacts on agricultural yields.

Algeria, Tunisia

A decrease in total available water resources in Algeria is projected at 10-15%, by 2020 (Kingdom of Morocco 2001). The IPCC in AR4 projects within the 'Mediterranean and Europe' a decrease in precipitation of 4 to 27% and a 'very likely' decrease in the number of precipitation days (Christensen, et al. 2007). The IPCC AR4 also concludes that the largest warming will occur during the summer months, making it 'very likely' that the increase in maximum summer temperatures will be more than the average[9] (Christensen et al., 2007). Other impacts include a reduction in relative humidity due to the proportionally larger continental warming (compared to maritime warming), whilst spring warming is 'very likely' to cause earlier snow melt and enhanced evaporation, and therefore a reduction in soil moisture in the summer (Christensen et al., 2007). The IPCC AR4 projected sea level rise of 38 – 55cm would lead to increased salinity in the lagoons and lowest coastal marshes and aquifers within Tunisia (Republic of Tunisia 2001).

[8] The A2 scenario created the largest effects - a 20% decrease in precipitation by 2050 and -40% by 2080. The timing of precipitation may also shift, so that less rain falls during the traditional peak precipitation periods, i.e. spring and autumn, and more intense rain events occur in the winter. Temperature changes also vary spatially, with the A2 scenario projecting an average of over 3°C warming over the entire country by 2080 (IFAD 2009), but incorporating a warming of up to 5°C in the east and mountain zones (Gommes, et al. 2009, see also Kingdom of Morocco (2001)).

[9] A large role in these impacts is played by atmospheric circulation, namely more easterly and anticyclonic flow in the summer causing less precipitation, though thermodynamic factors due to the increased average temperatures are also influential (Christensen et al., 2007). The largest impact when combining these projections for the SEM region is the prevalence of drought and extreme temperature days.

Egypt

Sea level rise is also one of the primary concerns for Egypt, particularly as the Nile Delta is expected to continue to subside. The inundation of the low-lying coastal areas is thus expected, with salinisation affecting the Nile and local aquifer water quality.[10] The Egyptian initial national communication project does not include any regional specific models for temperature or precipitation responses. The spatial variability of the precipitation response is most startling in Egypt - a decrease of up to 50% is projected for northern areas in summer, whereas a wetting trend is projected in the southern regions (Christensen et al., 2007) (though these large per cent changes are small in absolute terms). There is no model agreement on the effects of climate change on Nile River flows, as both decreases and increases are projected (Conway 2005) (with corresponding positive or negative impacts on electricity production from the High Aswan Dam (Beyene, et al. 2010)).

Palestine

The UNDP-PEQA's 2009 *Analysis of the Climate Change Situation in the Occupied Palestinian Territory* (UNDP-PEQA 2009) quotes the IPCC AR4 findings for the Mediterranean region, where the Southeastern Mediterranean region will be subjected to annual average temperature increases between 2.2 and 5.1°C, and to precipitation decreases of 10% in 2020 and 20% in 2050 (Christensen et al., 2007). The UNDP report also emphasises how the Israeli occupation restricts access to water, movement and economic development, thereby compromising the ability of Palestinians to adapt to expected climate changes.

Lebanon

Regional studies carried out for Lebanon project an expected doubling of the 1990 CO2 level by 2060, temperature increases of 1.7°C by 2020 (2.7°C by 2050 and 4.1°C in 2080), and precipitation decreases of -39mm in 2020[11] (-48mm in 2050 and -99mm in 2080) (Government of Lebanon 2002). The resultant decreases in water resources and increase in evapotranspiration is expected to be felt primarily in Lebanon's freshwater springs, where quantity and quality will become an even greater issue than they are currently. The resultant decrease of net usable water resources from a 1.2°C rise has been estimated at 15%, for instance (Bou-Zeid and El-Fadel 2002). Climate change impacts particular to Lebanon include the retreat of the tree line in mountainous areas due to changes in soil water and temperature- an upward shift of 300m is projected by 2020, increasing to 700m by 2080. Rising sea levels are also a threat to the large areas of coast between 1.5 and 2.5m, with concerns of saline intrusion for the major coastal municipalities of Tyre, Saida, Beirut and Tripoli (Government of Lebanon 2002).

Jordan

The future scenarios modelled for Jordan over the period 2005 to 2050 show an average increase in temperature of less than 2°C, where the warming was found to be stronger during the summer months of the year (Fayyad 2009). The minimum temperature

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[10] One projection of severe significant sea-level rise (> 2metres) suggests a related decrease in the country's GDP by 4 to 15% and in its agricultural sector by 10 to 30% (El-Raey 2009: Figures 3 and 4).

[11] Scenario based on the assumption that CO2 emissions will continue to increase at 1% per annum.

warming trends are found to be more significant than the increasing maximum temperature trend. Precipitation trends are highly variable. Jordan has ratified both the 1994 UNFCCC and the 2003 Kyoto protocol, and is planning a second 'national communication' on climate change adaptation (HKJ 2009).

Syria

A scoping study of research required to evaluate climate risks in Syria briefly discusses the climate risks faced by Syria. Hoff (2009) notes that over-subscribed water abstraction rates in parts of the country are likely to be exaggerated with increased needs and anticipated climate change. The general warming trend is also expected to affect rainfall variability, with a shift from snowfall to rain, and earlier snow melt. The country is furthermore expected to endure the same impacts of climate change on agricultural production as other Eastern Mediterranean countries.

Yemen

The Yemeni National Adaptation Programme of Action (NAPA) projects temperature changes for Yemen similar to those of the Eastern Mediterranean countries (an increase between 1.7 and 2.7°C in summer and 1.4 - 2.5°C in winter, by 2050. Precipitation projections for Yemen are more varied, with one model creating negative results and the other two positive results (Republic of Yemen 2009). Changes in the delay between rainfalls and in inter-annual variability are also projected (Republic of Yemen, 2001).[12] The IPCC AR4 regional studies for East Africa (which includes Yemen) supports the investigations, by showing a spatial variation in the precipitation response proportional to distance from the coast (meaning the north of Yemen would become yet drier).

2.2 Water Resources

Water resources and availability in MENA has been covered in many reports, notably SIWI (2007), World Bank (2007, 2009b), and FAO (2009b). A snapshot of the situation is provided in Appendix A, Section A3.

National and international water resources and availability

Seen from the regional perspective, the climate, population pressures and extensive use of water for irrigation create a picture of general regional water *in*security. The effects of the population and consumption drivers and physical scarcity are worsened by 'second-order scarcity' – that is, the economic, social, and political and institutional factors that keep the resources from being sustainably managed or equitably distributed.[13]

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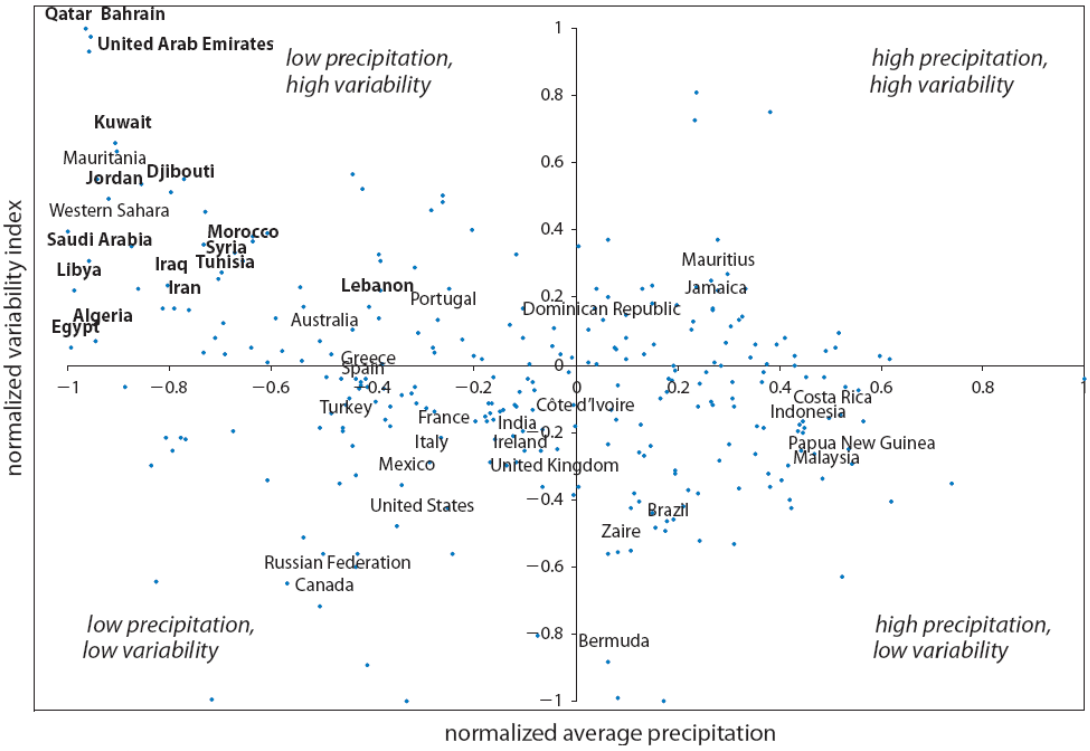
[12] Changes in cloudiness, as well as intensity of wind and frequency of high temperatures. The UKHI model predicts a decrease in cloud cover that correlates with its projections for a decrease in precipitation. Yet, "[c]ontrary to UKHI, the ECHAM3TR scenarios projected cloud cover to increase in the range of 1 to 18% for the four seasons. In between to the two scenarios, the OSU estimated cloud cover to decrease during spring and summer and to increase during autumn and winter" (Republic of Tunisia, 2001: 63).

[13] Second-order scarcity is analogous to 'economic scarcity', the term used by the FAO.

MENA countries are particularly vulnerable to climate-induced changes in precipitation owing to the combination of high variability and low precipitation across the region, as Figure 2.1 shows. If future decreases in long-term annual precipitation levels combine with increased inter-annual variability, as climate models project, the trajectory of MENA counties can be expected to be plotted moving further towards the upper left hand quadrant, towards the hot and dry Gulf countries. Such a trajectory would result in increasing water scarcity, characterised by prolonged droughts, approaching an arid climate, similar to present day UEA, Qatar and Bahrain.

Figure 2.1 Precipitation rates and variability in the MENA region [shown in Bold]. The trajectories of each select MENA state is further towards the upper left-hand quadrant. (World Bank 2007: Figure 1.2) .

The Unusual Combination of Low Precipitation and High Variability in MENA Countries



Source: Authors' calculations based on data from the Tyndall Centre (a consortium of the Universities of East Anglia, Manchester, Southampton, Oxford, Newcastle, and Sussex). See http://www.cru.uea.ac.uk/~timm/climate/index.html.

Note: The chart plots 289 countries (or other political entities) against average precipitation and the related coefficient of variation (standard deviation divided by the mean) in the period 1961–90. These variables have been normalized to range in the (–1, 1) interval, where –1 corresponds to the minimum, 1 to the maximum, and 0 to the mean.

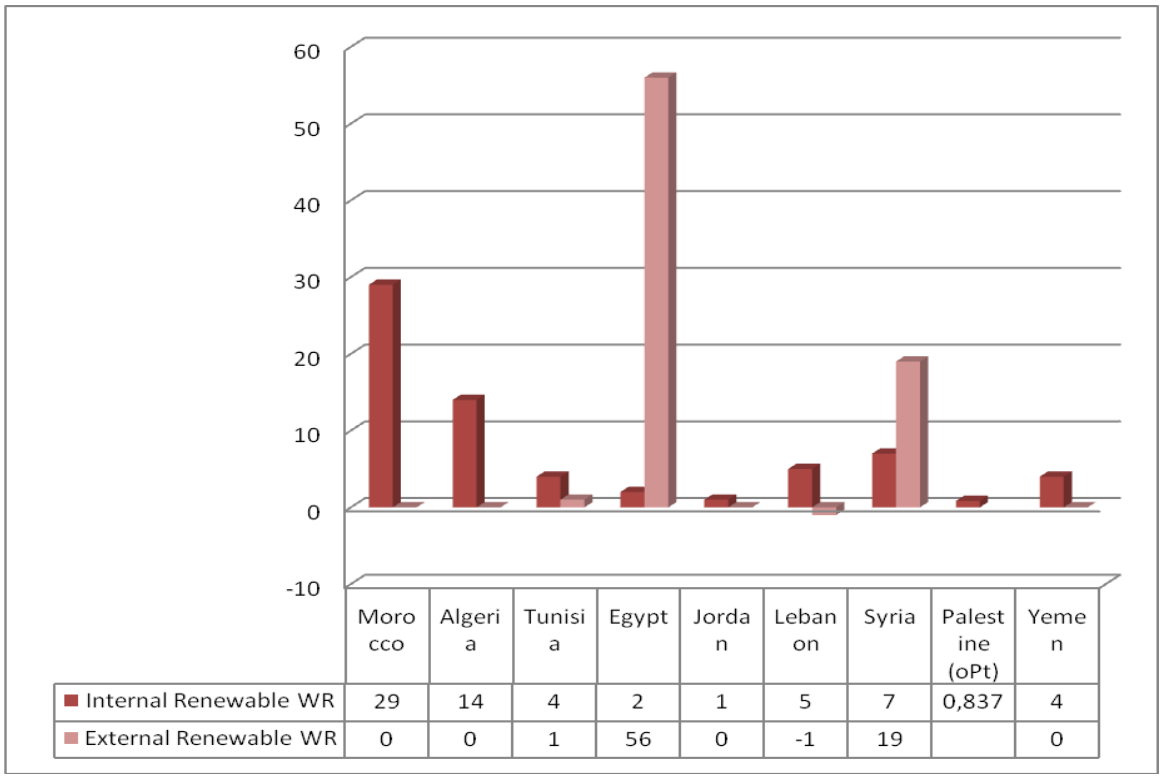
Freshwater availability varies widely by country in the North Africa sub-region. Figure 2.2 shows the *internal*[14] and *external*[15] renewable water resources (surface and groundwater) for the MENA countries. In North Africa, it is clear that Morocco is endowed with the greatest internal water resources (over one-third of which is

[14] Total internal renewable water resources refers to the long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation.

[15] External renewable water resources refers to the sum of the total natural external surface water resources and the external groundwater resources.

groundwater). The picture changes dramatically, however, when considering external water resources.

Figure 2.2 Internal and 'Actual' Renewable Water Resources for North Africa (km3/year). 'Actual' includes external sources. The negative value for Lebanon corresponds to water shared with downstream countries on the El Assi (Orontes) and Al Kabir rivers. Based on FAO (2009b).



	Morocco	Algeria	Tunisia	Egypt	Jordan	Lebanon	Syria	Palestine (oPt)	Yemen
Internal Renewable WR	29	14	4	2	1	5	7	0,837	4
External Renewable WR	0	0	1	56	0	-1	19		0

In the Eastern Mediterranean, Syria and Lebanon are seen to be considerably more favourably endowed than their neighbours, in both surface and groundwater.[16] Jordan and Palestine are the water poorest in this region, with physical and second-order water scarcity issues of a most serious degree (Haddadin 2001). Groundwater abstractions in Gaza are estimated to be up to *twice* the sustainable limits, for example (Almasri 2008). Of particular interest in this sub-region is the relatively much greater share of groundwater availability, especially within each country. The bulk of water available in Jordan and Palestine is groundwater, while in Syria and Lebanon it is nearly half, and in Yemen up to one quarter.

Figure 2.2 shows that although Egypt is not endowed with substantial internal water resources, it in a sense is compensated by the international freshwater resources of the Nile.[17] Water availability in Egypt is thus particularly acute to water management practices, needs and climate changes *outside* the MENA region (i.e. in Ethiopia and the Great Lakes region).

[16] The scale obscured localised issues, notably abstraction-induced droughts in Syria for instance (see e.g. IFRCRCS 2009).

[17] The natural flow of the Nile forms 95% of the Egyptian water budget, with the remaining 5% composed of rain falling on the coastal areas, plus reserves of groundwater aquifers (Tolba and Saab 2009).

Exogenous flows from the Euphrates River (primarily Turkey and partly Iran) mean that water security for Syria and Iraq is also determined to a degree by water use, water policy and climate changes outside of its boundaries. The same is true of water availability in Palestine, which has no access to the over-allocated Jordan River (el Musa 1997). Jordan's main water sources are all transboundary – the Jordan River (shared with Israel, Syria, Lebanon and Palestine), the Yarmouk River (shared with Syria) and the Disi aquifer (shared with Saudi Arabia). The state of international hydropolitics ensures that the hegemony in each basin retains the lion's share of the water (Zeitoun and Warner 2006) – a fact that will influence any future collective action required to address climate change.

Dealing with the impacts of climate change on water resources

While surface water run-off throughout MENA is grossly projected to decrease by 10 to 30% by 2050 (Milly, et al. 2005), the local context often betrays general trends – and any country's ability to adapt. Certainly, water resource managers will have a difficult time adjusting to the additional uncertainty. Efforts to reconcile pressing water resource management needs (and budgets) with uncertain climate futures may follow either of two approaches, according to Dessai and Hulme (2004). The first, led by the climate change science community, is to interpret future climate projections to current needs, in a "top-down", global to local manner. The alternate approach is to address current (water) challenges through a "bottom-up" view linking local challenges to global (climate) concerns.

Water resource managers and policy-makers are likely to prefer and follow the second approach to reconciling future global uncertainties with current local realities. The 'bottom-up' approach provides an opportunity to deal with actual water-related issues and pressures, and will also allow for greater flexibility within existing governing structures. Such flexibility will furthermore help in dealing with the potential socio-economic implications of the effects of climate change on water resources, as shown in Figure 2.3.

Figure 2.3 Socioeconomic implications of climate change impacts on water resources in select Middle Eastern countries. Bou Zeid and Fadel (2002).

Impact	Iraq	Israel	Jordan	Lebanon	West Bank and Gaza	Syria
Increased industrial and domestic water demand	++	+	+	++	+	++
Increased agricultural water demand	+++	++	+	+++	+++	+++
Water resource equity decline	+++	++	+++	++	+++	+++
Flood damage	+++	+	+	++	+	+
Water quality damage	+++	+++	+++	+++	+++	+++
Hydropower loss	+	+	+	++	+	+
Ecosystems damage and species loss	++	++	+	+++	++	++
GDP reduction (%)	3–6	1–2	1–2	2–5	2–5	4–7

Source: Bou-Zeid and El-Fadel 2002.

Note: + = insignificant; ++ = moderate; +++ = high.

The potential impact on water resources on GDP ranges from 1 to 7 percent. The breadth of the range may reflect the diversity and resilience of each country's economy, suggesting again that solutions to water problems are often found 'outside the watershed' (see Appendix A, Section A1). Water resource managers and policy-makers will be obliged to interact with other sectors, including the ministries of finance, environment, and trade (which is discussed at greater length in Section 3).

2.3 Food Security

With an understanding that total food production of a country does not reflect distribution or total consumption of food within it, the concept of 'food security' was broadened in the 1970s beyond the consideration simply of food production levels. Food trade – and the extent to which countries import food – is a particularly key component of food availability. Food security in the MENA region is explored in this section primarily through the role of food imports. A comprehensive overview of food imports for the MENA region and each country is provided in Section A3, Appendix A. Climate changes and risks are seen to affect food security directly through food availability, and indirectly through access to food.

Drivers and constraints of food security in the MENA region

Recent reports identify trends that raise relatively new concerns about food security in MENA countries. Hunger and malnutrition is rising, mainly due to insufficient daily nutritional intake and imbalanced diets, which stem in part to food distribution issues[18] (IFAD 2009). Domestic food production, mainly cereals, had been declining since the 1990s, and at least 50% of the calories consumed are imported, meaning greater vulnerability to agricultural commodity prices (UNDP 2009).

The majority of MENA countries cannot rely on a policy of food self-sufficiency, as they are not in a position to satisfy demand solely through domestic production. Population and consumption levels stress food needs as they do fresh water requirements. Increased consumption of water-intensive food, such as meat, will of course impact both sectors. Meeting future food demand is hampered throughout MENA in general, for a number of reasons:

- Vast arid expanses, with limited arable land or scope for expansion of agricultural production (especially cereals);
- Limited and fixed water resources available within each country (Section 2.2); and
- Limited scope for increasing agriculture efficiency.

Food production, virtual water imports, and food consumption patterns in MENA countries

Food production levels for the individual MENA countries are provided in Table 2.2. While each produces a combination of cereals, roots, tubers, pulses and meat, cereals

[18] The 2008 food price spike "is associated with an additional four million undernourished people in Arab countries" (IFAD 2009: xii).

remain the majority crop in all but Lebanon and Jordan. Egypt is by far the biggest producer, with Morocco and Syria in a middle band of producers.

Table 2.2 Average food production,[19] 1999 – 2001 (1000 metric tonnes) (WRI 2003).

Average Production	Morocco	Algeria	Tunisia	Egypt	Jordan	Lebanon	Syria	Palestine	Yemen
Cereals	3,492	1,819	1,581	19,657	50	95	3,390	n/a	679
Roots and Tubers	1,195	1,071	311	2,439	125	308	419	n/a	192
Pulses	248	41	84	545	6	41	235	n/a	--
Meat	580	528	242	1,395	134	121	353	n/a	--

All MENA countries rely to a considerable extent on food imports. The Maghreb countries and Yemen all depend more than 50% on imports to satisfy their cereal needs alone. Lebanon and Jordan are extreme cases, depending on over 88% and 97% on cereal imports. The notable exceptions to the considerable dependency are Egypt (with roughly 34%) and Syria (roughly 22%) cereal import dependency. The findings suggest the possibility of regional 'bread baskets', a point that is returned to in Section 3.

The importance and political implications of food imports in the MENA countries may also be gauged by considering virtual water 'imports', and water footprints. Table **2.3** shows how much water each country 'imports', through the import of crops and livestock.

Table 2.3 Virtual Water Imports in crops and livestock (1,000 million m3) (Chapagain and Hoekstra 2003, Hoekstra and Hung 2005). No period given.

	Morocco	Algeria	Tunisia	Egypt	Jordan	Lebanon	Syria	Palestine	Yemen
Virtual water imports in crops	5,5	9,8	3,9	16,035	4,5	0,7	-4,4	unavail.	1,4
Virtual water imports in livestock	0,3	1,1	0,3	2,897	0,6	1,3	0,3	unavail.	0,2
Total Virtual Water Imports	**5,8**	**10,9**	**4,2**	**18,932**	**5,1**	**2**	**-4,1**	unavail.	**1,6**

Table **2.3** shows that virtual water imports in the Maghreb countries, Jordan, Lebanon and Yemen are in the same order of magnitude – about 4,000 million m3/y. Egypt's relatively heavier water footprint is explained primarily by its relatively much greater population, but also by its heavy dependence on Nile River flows. More than half the total water needs of Jordan, West Bank and Gaza are already imported in the form of net food imports (World Bank 2007), following trends similar to other Arab countries in the Gulf region.

Syria is the only exception to virtual water 'imports' in the whole MENA region. As Table 2.3 shows, Syria is in fact a net virtual water 'exporter'. This may be due primarily to its previous national food policy of food self-sufficiency, and holds considerable

[19] "Average production" of cereals refer to the amount of cereals produced in a given country or region each year. Data relate to crops harvested for dry grain only.

implications for food stability and security – particularly, as discussed, during periods of global food trade price spikes.

Projected population growth and consumption patterns of MENA countries
Demand for food in the MENA region is expected to increase substantially along with growth in population and income. The associated change of food consumption patterns and increasing purchasing power will manifest itself in an number of ways. The demand for cereals might be expected to grow proportionally, though as IFAD predictions from food balance models shown in Figure 2.4 reveal, this is not exactly the case.

Figure 2.4 Growth projections – population, income and cereal imports in % (2000-2030). Based on IFAD (2009: Table 3.1) . *No data for Palestine or Yemen.*

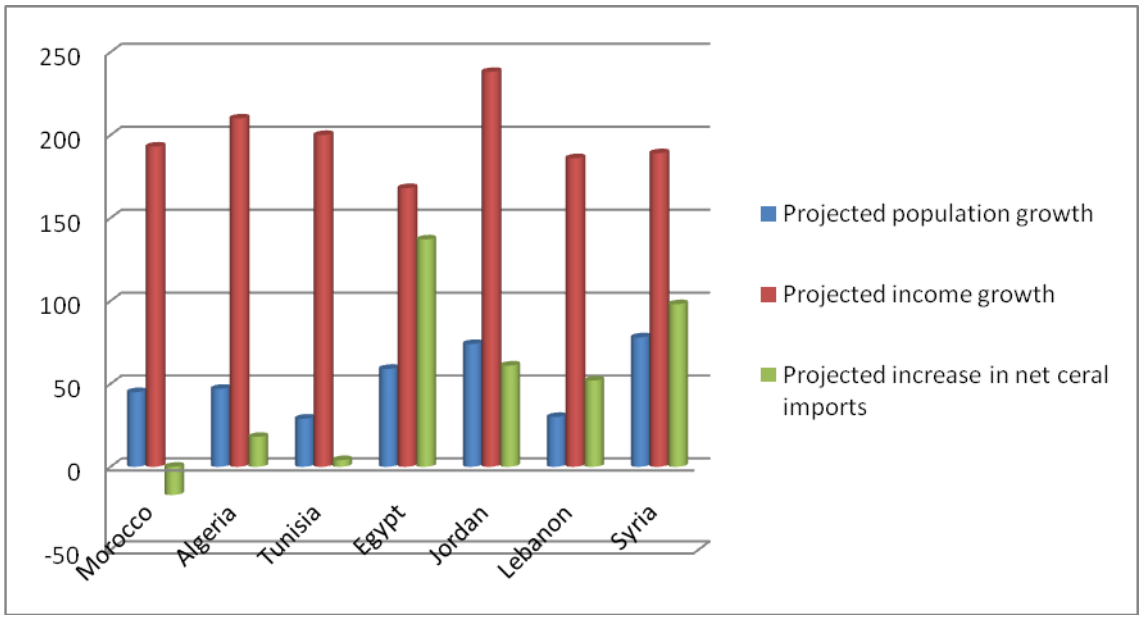


Figure 2.4 highlights that the MENA countries will all experience significant population growth by 2030 – between roughly 30% (Tunisia and Lebanon) to roughly 75% (Syria and Jordan). A secondary factor in terms of increasing food demands in the next 30 years is related to income growth. The income growth for all MENA countries for the period 2000-2030 for which there is data available is projected at about 200%. Related demand for food – not only cereals – is expected to increase to an even greater (but uncertain) extent.

How the select MENA countries will be able to meet these demands through national production and imports is the crucial question. The projections of Figure 2.4 suggest that the three Maghreb countries will not substantially increase their net cereal imports. Algeria is projected to increase food cereal imports by 18%, and Tunisia by 4%. Morocco is projected to decrease its current level of cereal imports (though as production peaked from 2000 to 2003, imports are expected to rise again FAO (2008b)). Cereal imports by Egypt, on the other hand, are projected to rise by over 130%, thereby increasing dependence on external sources. The Eastern Mediterranean countries are also each projected to substantially increase their net cereal imports for the period 2000 to 2030, with Lebanon at 48%, Jordan 61%, and Syria 98%. The risks associated

with the increased dependence on food imports are discussed at greater length in Appendix A, Section A4.

Projected impacts of climate change on agricultural production and food security

Changes in climate can affect food production in a number of ways. Sustained long-term drying can lead to reduced arable land while also affecting the biological, chemical and physical aspects of food growth. Higher temperatures lead to increased evapotranspiration from plants, although this may be offset by the direct effects of higher CO2 levels which tend to improve plant water use efficiency (through reduced stomatal opening).

Crop production is directly affected by other climatic changes and risks as well. The increasing probability of less frequent but more intense rainstorms will lead to a decreasing rate of absorption of water into the soil. The decrease in absorption leads to a diminished rates of aquifer recharge, and hence reduced water resource availability for both direct consumption and irrigation. Decreases in agricultural yields follow soil desiccation, inducing higher water demand, and the creation of a negative feedback cycle. A further stress on aquifers will be the increasing sea level rise causing salinisation – a particularly acute issue for regions dependant on crops fed by coastal aquifers, such as the Gaza Strip and the Nile Delta (Brown and Crawford 2009).

The combined effects of anticipated climate change and food production in MENA is significant. The 2009 IFPRI study *Climate Change- Impact on Agriculture and Costs of Adaptation* (Nelson, et al. 2009) projects the expected changes in production of rice, wheat, maize, soybeans and groundnuts and increasing food price, as shown in Table 2.4.

Table 2.4 Climate Change effects on crop production by 2050 (by weight and percentage), no CO2 fertilisation. (Nelson, et al. 2009: Table 3). Based on A2 SRES emissions scenario.

Agricultural product	South Asia	East Asia and the Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	Sub-Saharan Africa	Developed countries	Developing countries	World
Rice									
2000 (mmt)	119.8	221.7	1.1	14.9	5.5	7.5	20.4	370.3	390.7
2050 No CC (mmt)	168.9	217.0	2.6	17.8	10.3	18.3	20.3	434.9	455.2
2050 No CC (% change)	41.0	–2.1	143.0	19.9	88.0	145.6	–0.2	17.4	16.5
CSIRO (% change)	–14.3	–8.1	–0.2	–21.7	–32.9	–14.5	–11.8	–11.9	–11.9
NCAR (% change)	–14.5	–11.3	–0.8	–19.2	–39.7	–15.2	–10.6	–13.6	–13.5
Wheat									
2000 (mmt)	96.7	102.1	127.5	23.5	23.6	4.5	205.2	377.9	583.1
2050 No CC (mmt)	191.3	104.3	252.6	42.1	62.0	11.4	253.7	663.6	917.4
2050 No CC (% change)	97.8	2.2	98.1	79.1	162.7	153.3	23.6	75.6	57.3
CSIRO (% change)	–43.7	1.8	–43.4	11.4	–5.1	–33.5	–7.6	–29.2	–23.2
NCAR (% change)	–48.8	1.8	–51.0	17.4	–8.7	–35.8	–11.2	–33.5	–27.4
Maize									
2000 (mmt)	16.2	141.9	38.0	80.1	8.2	37.1	297.9	321.3	619.2
2050 No CC (mmt)	18.7	264.7	62.7	143.1	13.1	53.9	505.1	556.2	1,061.3
2050 No CC (% change)	15.4	86.5	65.0	78.7	59.8	45.3	69.6	73.1	71.4
CSIRO (% change)	–18.5	–12.7	–19.0	–0.3	–6.8	–9.6	11.5	–10.0	0.2
NCAR (% change)	–8.9	8.9	–38.3	–4.0	–9.8	–7.1	1.8	–2.3	–0.4
Millet									
2000 (mmt)	10.6	2.3	1.2	0.0	0.0	13.1	0.5	27.3	27.8
2050 No CC (mmt)	12.3	3.5	2.1	0.1	0.1	48.1	0.8	66.2	67.0
2050 No CC (% change)	16.0	52.2	78.3	113.0	128.0	267.2	60.0	142.5	141.0
CSIRO (% change)	–19.0	4.2	–4.3	8.8	–5.5	–6.9	–3.0	–8.5	–8.4
NCAR (% change)	–9.5	8.3	–5.2	7.2	–2.7	–7.6	–5.6	–7.0	–7.0
Sorghum									
2000 (mmt)	8.4	3.1	0.1	11.4	1.0	19.0	16.9	43.0	59.9
2050 No CC (mmt)	9.6	3.4	0.4	28.0	1.1	60.1	20.9	102.6	123.5
2050 No CC (% change)	14.3	9.7	300.0	145.6	10.0	216.3	23.7	138.6	106.2
CSIRO (% change)	–19.6	1.4	–2.7	2.3 0.3		–2.3	–3.1	–2.5	–2.6
NCAR (% change)	–12.2	6.7	–10.4	4.3 0.7		–3.0	–7.3	–1.5	–2.5

Source: Compiled by authors.
Note: The rows labeled 2050 No CC (%) indicate the percent change between production in 2000 and 2050 with no climate change. The rows labeled CSIRO (%) and NCAR (%) indicate the additional percent change in production in 2050 due to climate change. For example, South Asia sorghum production was 8.4 mmt in 2000. With no climate change, South Asia sorghum production is predicted to increase to 9.6 mmt, an increase of 9.6 percent. With the CSIRO scenario South Asia sorghum production in 2050 is 19.6 percent lower than with no climate change.

CSIRO = Commonwealth Scientific and Industrial Research Organization (Australia); NCAR = National Centre for Atmospheric Research (US). met = million metric tonnes.

The net effect of the projected decrease in food production is expected to be a drop in calorie availability in 2050 to lower than the 2000 level and increasing child malnutrition (Nelson, et al. 2009). Within MENA the daily capita calorie availability is predicted to decrease by 3.6%, the equivalent of 2 million malnourished children.

Table **2.4** indicates a reduction in each of the basic food staples throughout MENA, with a drop of production of about 33% in rice, 7% in wheat, 8% in Maize and 4% in millet.[20] The drop in production in wheat in MENA is considerably below the projected global drop (of about 25%), due in part to the predicted regional aridity trend.

The Inter-governmental Panel on Climate Change projections confirm the pessimistic inequitable picture of the future. 2004 projections based on IPCC scenarios suggest that lower cereal yields due to the effects of climate change in developing economies will be matched by higher yields in industrialised economies, such that the global output remains unchanged. As Parry et al. (2004) state, the balanced outcome comes as a cost, for being "achieved through production in the developed countries (which mostly benefit from climate change) compensating for declines projected, for the most part, for developing nations. While global production appears stable, regional differences in crop production are likely to grow stronger through time, leading to a significant polarisation of effects, with substantial increases in prices and risk of hunger amongst the poorer nations, especially under scenarios of greater inequality (A1FI and A2)". (Parry, et al. 2004: 53).

The implications these expected changes have for national food policy are far-reaching indeed. When considered with the projected increase in consumption patterns, wealth and food imports, the general decrease in food production in MENA countries due to changes in climate emphasises the need for carefully considered national food policy. The drivers may result in increased dependence on food imports or agricultural land acquisitions (and stress on national water resources), for those MENA countries that can afford this option. The pressures could in theory also lead to greater regional cooperation, with Syria and Egypt, for instance, becoming the MENA breadbasket (the concept generally reserved for Sudan, though with its own set of concerns – see Appendix A, Section A4). Considering the current and projected level of food production and imports, the benefits of improved international cooperation to achieve food security is as clear as it is to achieve national water security

[20] The figures compare with estimates of reductions of crop production in Egypt by year 2050, as collated by Abou Hadid (2009: Table 1): rice - 11%; wheat – 4.8 to 17.2%; maize – 14 to 19%.

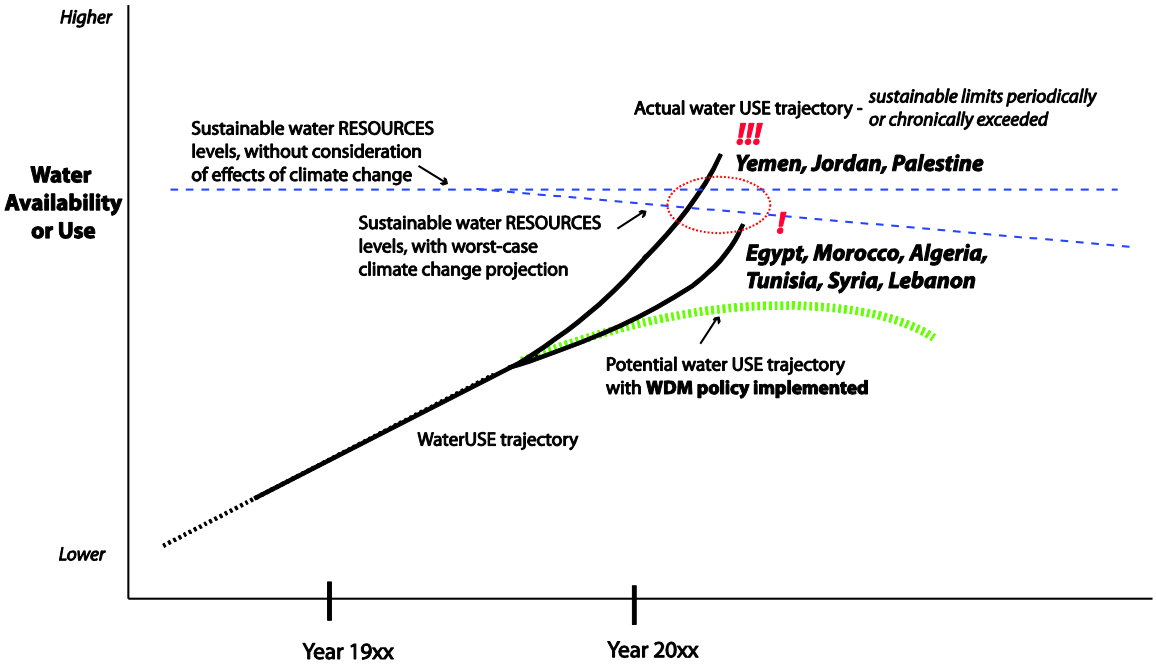
3 WDM and the Water-Food-Climate Nexus

This section interprets the extent of the relevance of Water Demand Management to the water-food-climate nexus for MENA countries, and for the MENA region. The vulnerability of individual MENA countries is first briefly evaluated in terms of water availability and food security. The potential for Water Demand Management policy to counter the pressures on the water-food-climate nexus is then explored. Specific types of WDM interventions that are found relevant to all the three elements of the nexus are highlighted, and a case is made for their uptake into national policy related to water resources, food security and climate change adaptation.

3.1 Water Resources Availability and Food Security in MENA Countries

Reflecting the findings of Section 2.2, Figure 3.1 indicates that in terms of water *use*, Egypt, Tunisia, Algeria, Morocco, Syria and Lebanon are operating near the sustainable limits of availability. Yemen, Palestine and Jordan are use close to and in some cases beyond the sustainable limits.

Figure 3.1 Indicative diagram of water resources availability and use, for select MENA countries. Food security not considered, here.



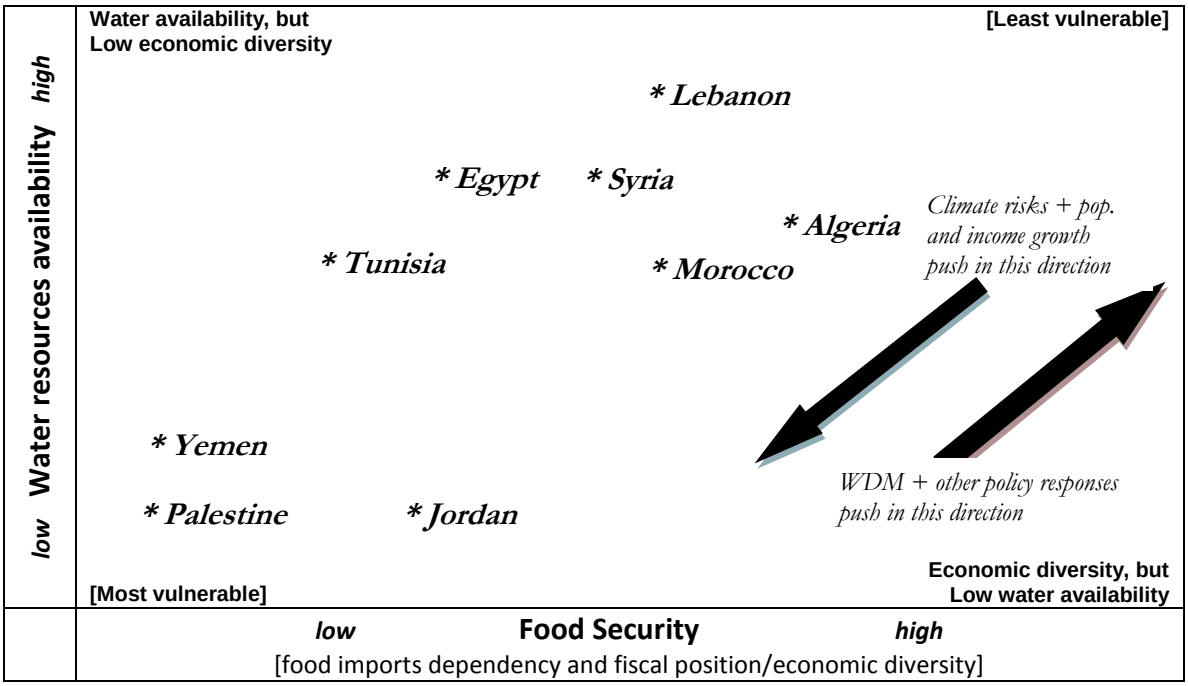
The common feature of note is that most MENA countries also have limited scope to increase the efficiency of use of their endogenous water resources (with Syria as exception (Hoff 2009)). As a result, the MENA countries have a limited scope to increase their national agricultural production and increase their levels of food self-sufficiency. Considering further that much of the water available is transboundary, the vulnerability of each country is undermined, as is the importance of international trade and cooperation.

As mentioned, Egypt, Jordan, Syria and Yemen have each officially incorporated WDM principles into national water policy, though implementation lags considerably behind.

It may be coincidental that (apart from Palestine) the 'worst-off' countries in terms of chronic scarcity of water (or food crises, in the case of Syria) are also those that have begun to adopt WDM. The partial or official uptake of WDM principles there may reflect a rational response to crises, and/or sustained donor interest in promotion of WDM. With greater implementation of the policy and with time, it may be expected that the water use curves of these countries begin to follow the dashed downward curve trajectory of WDM in Figure 3.1. The case is clearly made for the other countries to learn from the gravity of the problems of the others, and change trajectory before crises worsen.

The relatinshiop between water resources availablility and food security is inidcatively presened for each country in Figure 3.2. Food security here is used in the sense of a combination of food production and (in)dependency on food imports, and level of economic diversification in relation to food trade markets (similar to 'fiscal position' of Appendix A, Figure A4).

Figure 3.2 Indicative relative plots of water resources and food security within a context of climate change, for select MENA countries. Food security here is taken to mean a combination of food production and dependency on food imports, and level of economic diversification in relation to food trade markets (see Section 2).

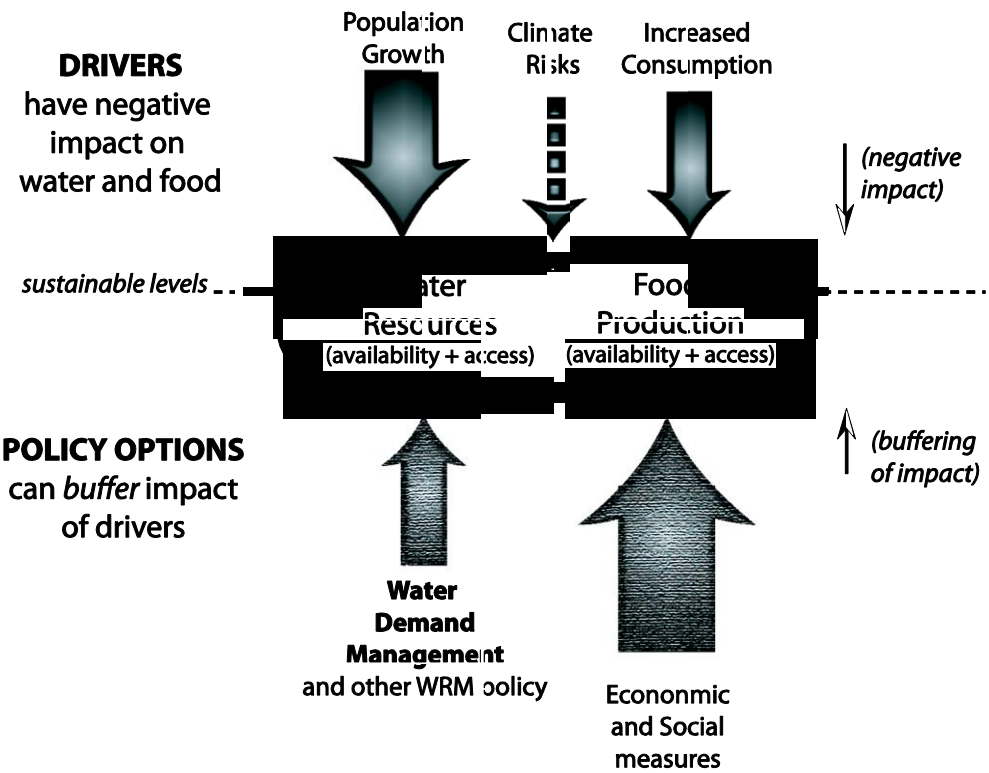


The drivers of population and consumption growth will tend to push the countries towards even more vulnerable positions of decreased water resources availabliliyt, and greater food insecurity. The extent to which WDM may serve to counter the constraints and provide greater resilience, at least to the climate drivers is, the issue considered following.

3.2 Revisiting the Water-Food-Climate Nexus

The potential policy responses that act on water resources availability and food production are added to Figure 1.2 in Figure 3.3 below. Combined, these policy 'buffers' may serve to increase availability both in terms of water resources and food production.

Figure 3.3 Drivers constraining and policy responses buffering water and food availability. The dashed line representing climate risks reflects the high level of uncertainty; the width of the arrows indicates relative magnitudes in the short to medium term.



There are two features to note from Figure 3.3. The first is the strength of climate drivers relative to population growth and increased consumption patterns. The rate of growth in both population and consumption patterns in the select MENA countries is considerable (see Figure 2.4). Income growth is expected to grow by 200% across the select MENA region, and is likely to entail similarly dramatic increases in food consumption, with the growing middle economic class changing their diet towards greater consumption of meat, cereals and other water-intensive food staples (see also UNDP (2009)). The strain on water and food is direct, in the short term as well as in the long term. By comparison, climate risks are expected to take on a relatively more significant role in the medium to long term.

The second feature relates to the relative strength of the policy options to counter the drivers. Just as climate risks are posited beside more significant drivers, so WDM is situated in Figure 3.3. alongside possibly much more significant policy options that exist 'outside the watershed' (Allan 1998, USBR 2005) – termed 'economic and social measures'.

Economic measures aimed at responding to reduced water and food availability (such as pricing signals, insurance, etc) can act in two broad sectors: national political economy, and trade (at the regional or global level). A country's 'fiscal position' (see Appendix A, Figure A4), and degree of economic diversification are found to be key to the ability of a country to adapt to anticipated climate risks, and population and consumption increases (IFAD 2009, Allan in press). Furthermore, given the substantial (and increasing) level of dependence of most MENA countries on food imports (Figure 2.4), solid international terms of trade are also key to reducing pressures on national and individual water and food availability. Equitable terms of trade would ensure a MENA country the ability to balance, on the one hand, national food production with local food growing conditions and water resource availability, and, on the other hand, to use the regional or global markets to reduce rather than to increase freshwater deficits. Additionally, steps taken to reduce the exposure to the global food trade market volatility (see Section 3.4) would also help to avoid the impacts of future global food trade and price crises.

Foreign agricultural land acquisitions is a particular economic measure that requires greater consideration for their potential positive or devastating consequences. Egypt, Syria and Jordan are already engaged as investors in agricultural land abroad. As noted in Appendix A, Section A4, however, land acquisitions also carry notable concerns, particularly in poorly-regulated contexts (Cotula, et al. 2009). MENA countries would do well to consider the concerns, particularly those that might host investor countries. IFAD suggests responsibility lies with the investor, stating that for truly 'positive-sum' arrangements, "it is imperative that the investor country protect the recipient country's citizens from nationalization or expropriation, labour abuses, and loss of their own food security" (IFAD 2009: 48).

Social measures designed to reduce the pressure of decreased water and food availability of the most vulnerable segments of society are aimed at individual resilience and consumption patterns. The strengthening of safety nets under the right conditions, for example through social protection programmes, can directly improve living conditions for millions of individuals through access to safe water and sanitation or to local food markets, in a way that water resource management cannot. Similarly, family planning services and campaigns aimed at the reduction of consumption or change of food consumption habits ('food demand management') might be effective (IFAD 2009: xi). The equity component of WDM reinforces the food policy responses of social nets, and this latter issue is returned to as a WDM intervention in the following section. WDM interventions can be considered a 'no regrets' option in general, with particular aspects of it quite effective indeed.

3.3 'Best-fit' WDM Interventions to the Water-Food-Climate Nexus

This sub-section categorises the multiple types of WDM interventions in terms of relevance to countering climate risks, and increasing food and water availability. The categorisation of WDM interventions provided in

Table 1.2 is recalled.

I	WDM Interventions highly relevant to counter effects of expected climate risks, and to increase food security
IIa	WDM Interventions relevant to counter effects of expected climate risks, but not to increase food security
IIb	WDM Interventions relevant to increase food security, but not to counter effects of expected climate risks
III	WDM Interventions relevant to water resources management, but not directly to climate risks or food security.

Insofar as they are relevant to all aspects of the water-food-climate nexus, the interventions classed into the 'Type I' category are considered to be the 'best-fit' WDM policy interventions. The categorisation of each WDM intervention, based on relevance to key indicators of water and food availability, as well as relevance to decreasing the effects of the key climate risks, is presented in Table 3.1.

Table 3.1 Relevance of specific WDM interventions to food concerns, water concerns and climate risks.
✓ = relevant; -- = possibly relevant; X = not relevant. [Typesetters to determine how best to present this table in published form]

			Direct relevance to **increasing**:					Direct relevance to **countering the effects of**:					CAT.
			Biophysical traits and Socio-economic issues					Climate risks					
Pillar	**Type**	**Examples**	Food Production	Food Growing conditions	Water Availability	Access to Water	Access to Food	Droughts / aridity	Variation in precip'n	Decrease in precip'n	Temperature: increase	Sea-level rise	
Technical	**Improved water use efficiency**	Loss reduction in water distribution networks, irrigation networks through repairs	✓	X	--	--	--	X	X	X	X	X	IIb
		More efficient types of irrigation (drip-irrigation)	✓	--	--	--	--	X	X	X	X	X	
		More efficient growing methods, i.e. hothouses	✓	X	--	--	--	X	X	X	X	X	
		Wastewater re-use for agriculture	✓	X	✓	--	--	X	X	X	X	X	
		Irrigation water re-use/irrigation and drainage improvement	✓	X	--	--	--	X	X	X	X	X	
		Irrigation canal lining	✓	X	--	--	--	X	X	X	X	X	
		Improved operations and maintenance (O&M) of water delivery systems	X	X	--	--	X	X	X	X	X	X	
		Emergency drought measures	--	X	--	--	--	✓	✓	✓	--	--	
	Knowledge base	Monitoring of water use, water quality, etc	--	--	--	--	--	X	X	X	X	X	IIb
		Investigations into sustainable limits of aquifers	✓	X	--	X	X	X	X	X	X	X	
		Investigations into severity of climate risks / expected impacts of climate change	✓	✓	✓	X	X	X	X	X	X	X	
	Agronomic	Changes/diversification in crop production (e.g. shift towards less water-intensive crops)	✓	X	✓	--	--	X	X	X	X	X	I
		Increased yields through fertiliser, pesticide application + modified crops	✓	X	X	--	--	X	X	X	X	X	
		Increased use of drought-resistant seeds	✓	X	X	--	--	X	✓	✓	X	X	
		Improved rainfed/dryland farming techniques	✓	✓	✓	--	--	✓	✓	✓	✓	X	
		Improved permaculture (e.g. Jordan)	✓	✓	✓	--	--	✓	✓	✓	✓	X	
	Environmental	Expansion of rainwater harvesting	✓	✓	✓	--	--	X	✓	✓	X	X	I
		Watershed management(comprehensive approach including technical, social and economic issues)	✓	✓	✓	✓	✓	✓	✓	✓	--	--	
		Restoration of aquatic habitats and ecosystem services	✓	✓	✓	--	--	✓	✓	✓	✓	✓	

Economic	Food Trade	Multi-lateral or Bi-lateral food trade agreements	✓	X	✓	X	--	✓	✓	✓	X	X	I
		Establishment of regional food markets	✓	X	✓	X	✓	✓	✓	✓	X	X	
		Promotion of equitable food trade principles ('food sovereignty') or promotion of green water trade	✓	X	✓	X	--	✓	✓	✓	X	X	
	Water Markets	Tariffs and subsidies (to encourage more 'crops per drop' (efficiency))	✓	X	--	✓	✓	X	X	X	X	X	III
		Green and Blue water credits scheme	X	X	--	--	X	X	X	X	X	X	
	Economic measures	Diversification of the economy (water use prioritised towards industry and services)	✓	X	--	--	--	X	X	X	X	X	IIb
		Long-term/planned economic growth and development	✓	--	--	✓	✓	X	X	X	X	X	
Social	Empowering stakeholders	Building WUAs, Water Boards, etc	X	X	--	--	--	X	X	X	X	X	IIb
		Improving local production systems to promote socio-economic development	✓	--	--	--	✓	X	X	X	X	X	
	Consumption changes	Urban water conservation campaigns	X	X	✓	--	X	✓	✓	✓	✓	X	I
		Changing food consumption patterns [Food demand management]	✓	✓	X	X	--	✓	✓	✓	✓	X	
	Population policies	Family planning/control	X	X	✓	✓	✓	X	X	X	X	X	IIb
		Migrations (moving people out of river banks)	X	X	✓	--	--	X	X	X	X	X	
Institutional	Empowering stakeholders	Improved managerial and technical capacity of water and agriculture government ministries, researchers	X	X	X	--	--	X	X	X	X	X	III
		Agency with explicit responsibility for WDM	--	X	✓	✓	X	X	X	X	X	X	IIb
	Legal reform / legislation	Agricultural water conservation legislation	✓	x	✓	--	--	X	X	X	X	X	IIb
		Decentralisation of domestic water supplies	X	X	--	--	--	X	X	X	X	X	
		Development of strong institutional framework for WDM	--	X	✓	✓	X	X	X	X	X	X	
		Water rights frameworks	X	X	--	✓	X	X	X	X	X	X	
	Regulation	Water use and consumption regulation	X	X	✓	✓	--	X	X	X	X	X	IIb

Financial	**Financial**	Insurance to farmers for poor-yield seasons	--	X	✓	--	✓	X	X	X	X	X	**III**
		Cost-recovery (and cost-sharing) measures for farmers	✓	X	--	--	--	X	X	X	X	X	
		Social protection to individuals	✓	X	✓	✓	✓	X	X	X	X	X	
Political	**International Cooperation**	Basin-wide water management [International River Basin Management]	✓	✓	✓	--	--	✓	✓	✓	✓	✓	**I**
		Location of water storage beyond national borders (in the case of transboundary river basins)	✓	X	✓	--	--	✓	✓	✓	✓	✓	
		Transboundary cooperation	✓	X	✓	--	--	✓	✓	✓	✓	✓	
		Enhanced regional political and economic integration / Diversification of political or trade alliances	--	X	--	--	--	✓	✓	✓	✓	✓	

Of particular note from Table **3.1** is the fact that none of the WDM pillars are related solely to climate risks (Category IIa). The finding reinforces the transferability of WDM as a broad and 'no regrets' policy response. Of greater interest are those types of WDM interventions that are relevant both to countering the effects of expected climate risks and to increasing water availability and food security. These are found to come from the economic, social and political pillars, that is food trade, consumption patterns, international cooperation, and agronomic or environmental interventions.

3.4 'Best-fit' WDM Interventions in the MENA region

This sub-section discusses the 'best-fit' WDM interventions in greater detail. Their general applicability suggests that they should be considered without delay for inclusion into policy related to water resources management, food security or climate change adaptation[21] (i.e. National Adaptation Plans of Action (NAPAs)).

WDM interventions related to Food Trade

Multi-lateral or bi-lateral trade agreements

Projected cereal imports of MENA countries vary considerably (Figure 2.4), with cereal imports for Egypt, Lebanon, and Syria (and, likely, Palestine and Yemen) projected to rise between roughly 50% and 150% between 2000 and 2030. Unfavourable trade arrangements for countries with a high degree of dependency on food imports renders them vulnerable to the price volatility of the food market. Countries that also have a high dependency on external water resources are yet more vulnerable (e.g. Egypt, Syria, Jordan and Palestine). While the terms that govern food imports are thus particularly important to these latter countries, they are considered of fundamental importance to all MENA countries. The 2009 IFAD report *Improving Food Security in Arab Countries* suggests a number of innovative methods by which MENA countries may reduce their exposure to food market volatility[22]:

- Improvement of procurement systems (through i.e. review of national procurement legislation and systems (tendering, transaction-risk mitigation, etc));
- Hedging of food price risks by using formal risk markets to insure transactions, futures contracts, swaps and loans, and other financial mechanisms;
- Improvement of logistics in the imported food supply chain (trucking and warehousing, etc);
- Forecasting of price shocks, by increasing and improving monitoring of world and regional cereal supply (e.g. the regional food security monitoring system proposed by the League of Arab States);
- Stockpiling of food e.g. in warehouses, or in other countries, in relation to expected and actual production; and
- 'Virtual stockpiling', through financial instruments that lock in supply at fixed prices.

(IFAD 2009: Ch 6).

[21] The call is consistent to that of the Water and Climate Coalition – see WCC (2010).

[22] The same report also makes specific recommendations for shifting macro-economic policies towards safety nets to ensure better *access* to food.

Establishment of regional food markets
Interestingly, the MENA region is generally independent in terms of fish and vegetable (and to a lesser extent, meat) production (see Appendix A, Section A4). There may thus be scope for specific MENA countries to become 'food baskets' (if not *bread* baskets) for the region, should a regional approach and the related dependency risks be desired and politically feasible. The most likely MENA candidates in this regard would be Lebanon or Syria (with the latter already a net virtual water 'exporter' (Table 2.3)). With the MENA region dependent on cereal imports as a whole, any 'bread basket' that could temper production, supply or climatic shocks will certainly be located outside the region. Due to its considerable land and water resources, Sudan has been identified as a potential breadbasket for the Arab world, at least so long as "massive improvements in productivity and infrastructure" (IFAD 2009: 20) were to prevail.

Innovative food and 'green' water trade arrangements
Favoured terms of food trade can also address water concerns. Food produced through rainfed agriculture ('green' water) may serve to reduce regional water deficits, while irrigated crops ('blue' water) may perpetuate them. Pricing signals that encourage the former and discourage the latter can thus form an important part of an integrated water-food-climate policy. Thus fruit and potatoes grown through irrigation in dry (or drying) regions (e.g. the Toshka project in southern Egypt, the Jordan River valley) would be disadvantaged in favour of the same crops grown through rainfed farming in Lebanon or Morocco, for instance. The potential role for 'green' water to modulate regional deficits is made clearly in Allan (2007a, 2007b) and gaining substantial interest (see ISRIC (2008), Aldaya (2008), Hoff (2008)). The importance of the role of 'green' water trade is highlighted by its consideration by the World Trade Organisation, the implications of which are discussed at length in Hoekstra (2010).

WDM interventions related to Consumption Patterns
Food production and consumption patterns ('food demand management')
Managing food consumption may be the most robust of all WDM interventions, for directly reducing dependence on both food and water systems domestically, and internationally. Public awareness campaigns targeting obesity (see e.g. Brichieri-Colombi 2003) or water-intensive diets (e.g. primarily vegetarian as opposed to meat-based) are likely to be more effective if implemented over a long-term. Study of the savings to be had throughout the entire water/food production system – from 'field to fork' (see e.g. Lundqvist et al. (2008)) – will also help in this regard.

Urban water conservation campaigns
A reduction in volume of water used is clearly a most effective 'buffer' against the drivers of Figure 3.3. Most if not all major cities in MENA countries have undergone water conservation campaigns (including the rehabilitation of water networks and public awareness campaigns). Water crises in urban centres are felt perhaps most acutely in Ta'iz (Handley 2001, Lichtenthaler 2002) and Amman (Jabarin 2007, Abed Rabboh and Jabarin 2008). With over 70% of water consumed in the agricultural sector, however, any gains through reduced domestic consumption will be relatively minor.

Agronomic WDM interventions

The agricultural sectors in several MENA states suffer from what Huq and MacGregor (2009) call "systemic vulnerabilities". As they state, "existing poor levels of rural economic development and, specifically, agricultural innovation are expected to compound and exacerbate negative impacts caused by climate challenges. These are due to poor delivery of new technologies, poor scalability of good agricultural practices, weak enabling institutions, and a lack of private sector innovation." As inefficiencies abound at the later stages of the food production chain, specific agronomic WDM interventions may help build resilience to the inherent vulnerabilities.

Diversification of crops

Given the importance of the agricultural sector to water resources, the water-food link must remain a key consideration to policy-makers. Water conservation efforts in the irrigated agricultural sector is most effective through replacement of water-intensive with less water-intensive crops. Natural species such as olive trees and date palms are more suited to particular growing conditions in MENA than many of the crops actually produced, for example. This is particularly relevant in Gaza, where citrus orchards have squeezed out date palm forests. The production of bananas, citrus fruit or potatoes through irrigation in the Jordan River Valley or in upper Egypt consumes disproportionately large amounts of freshwater (that could be saved through food imported from more humid climates).

Increased use of drought-resistant seeds

Seeds genetically modified to be more tolerant to droughts are being promoted by many as a possible solution for increasing food demands and food security. Advocates include the bio-engineering corporations and private sector considering the advancement a 'second green revolution' (Raney and Pingali 2007, The Economist 2009). Resistance to the developments remains broad, based on uncertainties related to impacts on human health, biodiversity, the livelihoods of farmers, and the hydrological cycle, amongst others.

Improved rainfed / dryland farming techniques

The debate on irrigation efficiency (see Section 1.5) is reflected somewhat in discussions on the potential for greater yields from dryland farming. The potential in Sub-Saharan Africa has been widely studied (see e.g. Appelgren, et al. 2000, IWMI 2007), and is seen as a potential way of ensuring both food and water security. Success with the methods in Australia have not been replicated in North Africa (Chatterton and Chatterton 1996), due in part to institutional or ideological resistance. Considerably more effort to harmonize the local food markets and economy with the variability of rainfed farming is required to ensure the potential of improved rainfed yields is achieved.

Environmental WDM interventions

Effective watershed management

Environment-related WDM interventions relate to the 'sustainability' pillar of WDM policy. Ecologically-based watershed management may serve to counter some of the difficulties with implementation of inter-sectoral Integrated Water Resources Management (IWRM) (see e.g. Molle 2008). 'Sustainable water resources management'

has been suggested as a way of shifting the focus of IWRM to principles of sustainable and cohesive environmental, social, economic and institutional structures (Hepworth 2009, Hepworth and Dalton 2010).

Restoration of aquatic habitats

Efforts to restore rivers and wetlands are generally held also to restore the local hydrological cycle, potentially increasing water resources availability (though this depends entirely on local topographic, climatic and hydrologic conditions (see e.g. Bruijnzeel 2004). The replenishment of the lower Nile through excess flows from the Aswan dam that are currently diverted to the Toshka depression (and contributing to the subsidence of the Nile Delta, compounding the effects of sea-level rise) is one potential application. Efforts to restore the Jordan River as a partial alternative to the much larger Red Sea – Dead Sea Canal project (FOEME 2010) is another.

WDM interventions related to International Cooperation

Quite apart from the considerations of improved food trade, 'political' WDM interventions can also serve to buffer against the drivers worsening water availability and food growing conditions. The high level of dependence of MENA countries on external water resources (Figure 2.2) obliges careful attention to be paid to effective transboundary water cooperation. Efforts at improving cooperation on transboundary river basins have met with varying levels of success, however.

Transboundary cooperation

Because of the scale of climate risks, basin-wide approaches are likely to be much more effective as a response than are isolated national efforts. As Wilk and Wittgen (2009) note, "It is particularly important that the river basin perspective becomes much more prominent in NAPAs, and that mechanisms are put in place to stimulate greater cooperation between transboundary countries on adaptation measures" (Wilk and Wittgren 2009). This is particularly relevant to Egypt, Jordan, Syria and Palestine. The establishment of water-sharing norms might help address the situation. It is of interest that 6 of the 9 MENA countries[23] in question have signed the 1997 UN Watercourses Convention – a much greater proportion than in any other region.

Egypt is the only member of the selected MENA countries involved in an international river organisation, through the Nile Basin Initiative (NBI). Syria and Lebanon have bilateral treaties, informed by international water law, on the el Assi and al Kabir rivers. There is minor informal or significant cooperation with Turkey over the Tigris-Euphrates transboundary water resources. In the Jordan Basin, Jordan and Palestine are committed to but limited by water-sharing agreements signed with Israel. There is otherwise little international cooperation between MENA countries. The distribution of the resources in each case is skewed in favour of the basin 'hegemon'. While 'dealing' with the hegemon and with power asymmetry is difficult, options are available and being considered (see Jägerskog and Zeitoun (2009)).

[23] Jordan, Syria, Lebanon and Tunisia have ratified the 1997 UN Convention, while Yemen has signed it. The Palestinian Authority has indicated their intention to ratify the Convention upon entering the United Nations as a full member.

International River Basin Management

The emphasis on inter-sectoral management promoted through IWRM is rendered more important, if complex, by its expansion at the river basin (or aquifer) level. Application of IWRM would see water infrastructure built in the most suitable hydrological place, rather than simply where it may be politically feasible. Basin-level planning could result in overall increased water and food security at regional level, through benefits shared between riparian states. Dams built in Ethiopia or Sudan for irrigation could benefit Egypt through favourable terms of trade by the food produced through them, for example. The proposed dam on the Hasbani tributary of the Wazzani river could in theory bring about similar benefits for Jordan and Palestine downstream (Comair 2009). Perhaps of even greater significance is the potential that may be derived from groundwater as a buffer (van Steenbergen and Tuinhof 2009) against the drivers. The fossil water of the Nubian Sandstone Aquifer, for example, has been noted for its possible benefits to Egypt and all the Maghreb countries, including Libya (Allan 2007b).

4 Observations and Recommendations

This section captures the key conclusions related to the water-food-climate nexus, and relates the classification of previous sections to observations and recommendations for the consideration of national policy-makers.

General observations

Changes in climate are projected to lead to higher temperatures and lower rates of precipitation throughout the MENA region. Water resources availability and food growing conditions are expected to suffer as a result. Further climate impacts common to MENA countries include more frequent and extended droughts, extreme weather events and sea-level rise. The extent of the risk is highly uncertain, however, and there is significant variation between countries and even within countries.

The effects of climate change are considered one of several drivers of increased stress on water resources and food availability. Increased population and consumption rates are expected to have a significantly greater impact on water resources in the short to medium term. Climate change is expected to compound the pressures in the longer term (one study projects reductions in wheat yields in the MENA region by 7% by 2050, for example (Nelson, et al. 2009)).

Integrated water-food-climate policy is considered key to addressing the interdependence of the three systems. Policy that serves to address only one of the three can have unintended negative impacts on the others. Isolated policy is both ineffective and unnecessary: 'best fit' water and food demand management options available are beneficial to the entire nexus.

A further observation derived from this study is that national water, food and climate 'security' must be reconsidered. Supply-side solutions in most of the MENA countries are exhausted, with limited further scope for dams or deeper boreholes. The food and/or water security that a supply-side paradigm may ensure in one country is fleeting, and likely to come at the cost of food and water *in*security in another country (or at a later date, in the same country). The management of water and food demand is highly beneficial for all MENA countries, and pressing in particular for Yemen, Jordan and Egypt. A broader approach to water, food and climate security would consider the interaction of each sector within the political economy in which it occurs, over the long-term.

Water Demand Management is a policy option to be considered alongside economic and social measures. There are a number of specific WDM interventions that are relevant to all three elements of the water-food-climate nexus. These 'best-fit' WDM interventions may form the basis of any future national water policy, national food policy, or National Adaptation Plan of Action, and specifically include:

- *Food trade* (Multi-lateral or bi-lateral trade agreements; Establishment of regional food markets; Promotion of 'food sovereignty' and green water trade)

- *Changing consumption patterns* (Water conservation campaigns; Food consumption patterns)
- *Agronomic interventions* (Diversification of crops; Increased use of drought-resistant seeds; Improved rainfed/dryland farming)
- *Environmental interventions* (Expansion of rainwater harvesting; watershed management; Restoration of aquatic habitats)
- *International Cooperation* (International river basin management; International water and climate change adaptation programmes; Enhanced regional political and economic integration; Diversification of political and trade alliances).

As is the case for national solutions, the extent of MENA-regional solutions to respond to the projected pressures is limited. Intra-MENA food trade can help distribute virtual water resources, in theory. Greater increase in food imports from outside of the region are expected for every MENA country, and are driven by limited water and arable land, and a relatively cheap international food trading system. Large-scale exports from any MENA country within the region appears unfeasible in the current political economy (even for Lebanon and Syria). The evolution of food trade towards foreign agricultural land acquisitions is cautioned against in such poorly-regulated contexts, the food insecurity it can create in the host states.

A final observation is that the water-food-climate nexus is *global.* Climate risks, food trade and water resources derive from far beyond national borders. The fundamentally international character of the water-food-climate nexus can lead to strengthen or harm international relations. There is considerable benefit to be gained from improved international and transnational cooperation that would strengthen regional markets of food and (virtual) water, as well as regional or global frameworks to address the climate impacts.

Recommendations

The 'best-fit' WDM interventions should be incorporated into water, food and climate policy without further delay. The WDM interventions found to be relevant to all three elements of the water-food-climate nexus are 'best fits' for a range of national policies. MENA countries are strongly advised to prioritise such interventions (and the general approach) when devising their national climate change adaptation plans, and national water and food policy.

A sustained strategic approach is required to implement the 'best-fit' WDM interventions. Direct implementation of WDM or food management policy is not typically the first politically feasible option. Policy-makers must consider how best to address the resistance to change from groups with interests vested in the status quo, and take a strategic approach to application of WDM. A long-term approach to water-food-climate concerns would address institutional reform, markets and consumer behaviour, and redress of power asymmetry, to name only a few. The approach would necessarily rely upon increased transparency, accountability and the involvement of the public in decision-making.

Food and water policy-makers should *follow a 'bottom-up' approach in linking local realities (and budgets) to future global uncertainties* as suggested in Dessai and Hulme (2004). Water resource and food measures undertaken in this approach are likely to be more effective (and in any case will not contradict) the more abstract 'top-down' approach favoured by the climate science community, which takes future scenarios as the starting point.

Invest in groundwater development and research. Aquifers can store water to help moderate rainfall, climate and food market variability. Improvements in groundwater management are necessary – particularly aquifer recharge rates and quantification of sustainable pumping limits. Effective governance of the hidden resource is furthermore essential to avoid a 'race to the bottom'.

Consider the possibilities of 'environmental diplomacy'. The global character of the water-food-climate nexus obliges careful consideration if international relations. Sustained environmental diplomacy aimed at securing basin-wide cooperation, regional frameworks for action and legal instruments would see water and food policy linked with foreign policy in order to strengthen relations. National support to the development of international environmental and trades standards can also improve the position of MENA countries to deal with current and future resource pressures (e.g. the 1997 UN Watercourses Convention, and conventions related to the UNFCCC process).

Finally, *the water-food-climate nexus should be understood*. Detailed country-level water footprints can provide a useful picture of green water or blue water 'imports' and 'exports'. The potential for water savings through green water in particular will be of foundational importance to stable water-food-climate policy, and may serve to reduce the misunderstandings surrounding common perceptions of water 'efficiency'. More accurate quantification of the relative significance of each component would provide a clearer picture of country-specific issues and opportunities. The social aspects of the nexus internationally (particularly for *access* to water-food) remain wholly unknown, and require particular attention to avoid perpetuation of social inequity.

Appendix A

A1 Political Economy-related obstacles to uptake of WDM - and windows of opportunity

The WaDI*mena* project on WDM in MENA has concentrated on the obstacles preventing widespread uptake of the principles and practices of WDM. The particular political economy of the MENA region is one reason for the limited success. Traditional hierarchies and practices are deep-rooted throughout MENA, and interests invested in the status quo are significant. As everywhere, challenges to the established order are not usually welcome. WaDI*mena* studies on the political economy of WDM have in the past examined this order, in relation to gender (Arafa, et al. 2007); institutional capacity (Brooks and Wolfe 2007); poverty and equity (Tyler 2007) or power asymmetry (Zeitoun 2009). As the implementation of WDM might not always be popular (e.g. the sectoral reallocation of water from farms to industry), it can be directly opposed to the interests of the relevant authorities.

Another factor preventing the immediate uptake of WDM policy is that MENA countries are still on their 'hydraulic mission', and technical control over the water resources remains a main element in the national policies and discourse. Dams, canals, or diversion schemes remain potential symbols of political power.

'Emblematic events' have been noted as potential key moments in which to introduce new policy or change existing ones. 'Windows of opportunity', to borrow Kingdon's phrase, may be created by extended drought periods which lead to evident over-use of water resources (as in Yemen – see Lichtenthaler (2002)), by heat waves and other extreme weather events brought about in part by climate changes, and by radical changes in government.

It is of considerable interest that the three 'worst-off' countries in terms of the water-food-climate nexus - Yemen, Jordan and Egypt – are the MENA countries that have most seriously begun to incorporate the principles of WDM into national water policy (Section 3.1 and Figure 3.1). The recent severe water shortages (in Yemen and Jordan) and food crises (in Yemen, Jordan and Egypt) may thus in a sense have opened up a window of opportunity for uptake of WDM. It is the concern of all that the WDM policy be implemented, and that other MENA countries learn of the benefits of WDM before crises also occur there.

A2 Summary of Climate Change Projections and Risks in the MENA Region

A summary of findings for the MENA region from recent climate studies and the IPCC 4th Assessment Report is presented in Table A1, followed by brief discussion of some of the risks.

Table A1 Summary of projected climate change projections for temperature and precipitation in the MENA region and sub-regions. Except where stated otherwise, results are based on IPCC (2007a, 2007b).

	Temperature	Precipitation
MENA	Mean temperatures are projected to increase by 0.5 to 1.5°C for the period 2020-2029, and by 2.5°C to 5.5°C for the end of the century (2090-2099).	Annual precipitation projected to decrease generally in the region. The IPCC AR4 multi climate model average change is -12% by 2080-2099 for the Southern Mediterranean region..
North Africa	Warming is *very likely* (e.g. >90% confidence) to be larger than the global annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the humid tropics. Models predict that the median temperature increase lies between 3°C and 4°C, roughly 1.5 times the global mean response.	Annual precipitation is *likely* (>80 to 90% confidence to decrease in much of Mediterranean Africa and the northern Sahara, with a greater likelihood of decreasing precipitation as the Mediterranean coast is approached.
Eastern Mediterranean	Warming over the 21st century will be larger than global annual mean warming – between 2.2-5.1 °C according to an optimistic emissions scenario (Scenario A1B). Recent runs of the ECHAM4 and HadCM3 GCMs under the B2 emissions scenario confirm substantial temperature rises of up to 4ºC for the eastern Mediterranean region (Hertig and Jacobeit 2007). Regional climate change simulations undertaken by different models have delivered a surprisingly consistent account of climate change over the Mediterranean. Increases in inter-annual variability of temperatures, along, with mean warming, are also forecast to lead to a greater number of high temperature events (Giorgi and Lionello 2007). The Levant is projected to undergo an increase of 2.5-3.7C in summer and 2.0-3.1C in winter (Brown & Crawford, 2009) 1.5 °C increase in temperature is expected to shift the Mediterranean climate zone 300-500km northwards, increasing aridity (Brown & Crawford, 2009).	Annual precipitation is deemed *very likely* (e.g. >90% chance) to decrease in the eastern Mediterranean – decreasing 10% by 2020 and 20% by 2050 with an increased risk of summer drought. The annual number of precipitation days is *very likely* to decrease in the Mediterranean area. Risk of summer drought is *likely* to increase in the Mediterranean area. The spatial distribution and timing of precipitation is predicted to increase. Annual precipitation rates are deemed likely to fall in the eastern Mediterranean – decreasing 10% by 2020 and 20% by 2050 – with an increased risk of summer drought. with global warming (Khatib, et al. 2008). Decreasing winter participation by 2100 of up to 35% compared to late twentieth century timelines. The GLOWA MM5 run between 1958-1996 and 2007-2045 forecasts a mid-century decrease in precipitation by 100 to 200mm in the northern oPt (above 31ºN) and a shift in the precipitation season into March and April (Khatib, et al. 2008). Significant rainfall declines in the wet (winter) season (-9%) outweighing slight increases in drier summer (+29%) in the Levant (Brown & Crawford, 2009).

Yemen	According to the country's First National Communications to the UNFCCC, Yemen's climate is projected to change significantly over the next 50 years. Temperature across the country is expected to rise between 1.4 and 2.8 degrees Celsius by 2050. Yemen NAPA, 2008	Precipitation and cloud cover patterns are more uncertain – depending on the GCM, rainfall is projected to decrease by about 24% or increase by about 35%. Follow-up regional climatic modelling indicates that rainfall is expected to decrease across the northern regions, leading to increased pressures on the country's delicate agriculture and water resources sectors. Yemen NAPA, 2008

Increases in Temperature

Table A1 shows that projected temperature increases for the region are for 0.5 to 1.5°C, for the period 2020-2029, and 2.5 to 5.5°C until the end of the century (IPCC, AR4, 2007). The increases may either increase or decrease crop yields, depending on more localised climatic factors and farming methods.

Decrease In Precipitation/River Flows

Table A1 shows that climate models project a *decrease in precipitation* in the order of 15 to 20% in the next fifty years, and surface water *run-off is projected to decrease* by 10 to 30% in most of MENA by 2050 (Milly, et al. 2005). The impact of decreased precipitation on aquifer recharge rates is difficult even to estimate, though these are expected to decrease. Progressive decline in precipitation coupled with higher evaporation rates are likely to contribute to the long-term desiccation of parts of the region.

Extended or more frequent drought periods. IPCC global models predict that in future decades the MENA region will become increasingly arid. Droughts are predicted to become both more frequent and prolonged throughout the MENA region (IPCC, 2007, AR4 Synthesis report).

Floods And Other Extreme Events. *Extreme events such as floods, heat waves, and storms* are also projected to rise in frequency and magnitude. At the continental scale, currently one third of people in Africa live in drought-prone areas and are vulnerable to the impacts of droughts (Bates, et al. 2008).

Sea Level Rise. IPCC Climate models *project sea levels rise* by over 0.5 meters by the end of the century, particularly vulnerable coastal areas are in Tunisia, Qatar, Libya, UAE, Kuwait, and Egypt at particular risk (El-Raey 2009, World Bank 2009b).

Coastal Saline Intrusion. The risk of *saline intrusion* is due to both excessive groundwater pumping and reduced rainfall rates (and subsequent reduction in groundwater recharge rates). Morocco, Algeria and Tunisia are particularly vulnerable, affected by the aquifer system of the Sahara Septentrional (Abdelfadel, 2009). Syria, Lebanon and Gaza in the Eastern Mediterranean are also at risk (Vengosh, et al. 2005, Saadeh 2008).

A3 Snapshot of Water Resources and Use in the MENA Region

The water resource situation in MENA may be characterised as follows:

- The MENA region has generally very low water renewable freshwater availability, relative to other regions. FAO Aquastat figures compare the 'actual renewable freshwater resources' for the MENA region at roughly 2,000 m3 *per capita*/y, while for South Asia it is roughly 4,000, Europe 22,000 and Latin America 36,000 (World Bank 2007);
- The region is nonetheless geographically diverse, and *per capita* water availability varies greatly. *Per capita* availability in Syria and Lebanon, for instance, is in the order of 1,400 m3/year, while in Jordan, Yemen and Palestine it is closer to 200 m3/year or much lower;
- There are generally few lakes and few major rivers, but several fossil or renewable aquifers;
- Most of the water bodies are transboundary, meaning physical availability is not always solely a sovereign concern; and
- The bulk of water consumed is in the agricultural sector, estimated across the region at about 80% (FAO 2009b).

Water storage (dams and aquifers)

Dam issues and debates are generally less contentious in the MENA region than elsewhere.[24] MENA rivers are the "most heavily dammed in the world in relation to the freshwater available" (World Bank 2007: xxii), with roughly 85% of the utilisable surface water resources already stored in reservoirs.[25] As such, there is limited scope for construction of future dams, meaning rainfall variability and climate-related risks in the region must be met primarily through other means. The important exception are for the dams built and planned on the Tigris and Euphrates rivers, with the most important related to Turkey's Southeastern Anatolia project affecting Syria and Iraq (see e.g. Warner 2008, Daoudy 2009)

Aquifer storage takes on even greater importance in the region. Groundwater is generally considered less 'vulnerable' to temperature and precipitation-related climate risks, because it is less exposed to the elements (IUGS 2006). There is thus scope for (and interesting work being done on) groundwater to act as a 'buffer' to climate change and precipitation variability (Moench, et al. 2003, IUGS 2006, van Steenbergen and Tuinhof 2009). How aquifer recharge is affected by changes in climate through changes in land-use, however (see Section A1), is an important area requiring ever-greater research. Severe decreases in humidity, for example, could reduce soil moisture levels

[24] The debate over dams that raged in the 1990s was temporarily settled by the 2000 World Commission on Dams report (see e.g. IIED 2001). Surface water storage is a somewhat direct antidote to rainfall variability, and the uncertainty posed by climate risks. Dams and other types of water storage are typical first responses considered in climate adaptation efforts (see e.g. IWMI (2009), ICIMOD (2009), World Bank (2009a)), more so as a 'clean' source of energy, and dams appear to have returned to the 'international development' agenda. See the Water Alternatives special issue *WCD + 10: Revisiting the Large Dam Controversy* (Vol 3, Issue 2).

[25] The figure is substantially affected by the Aswan High Dam of Egypt.

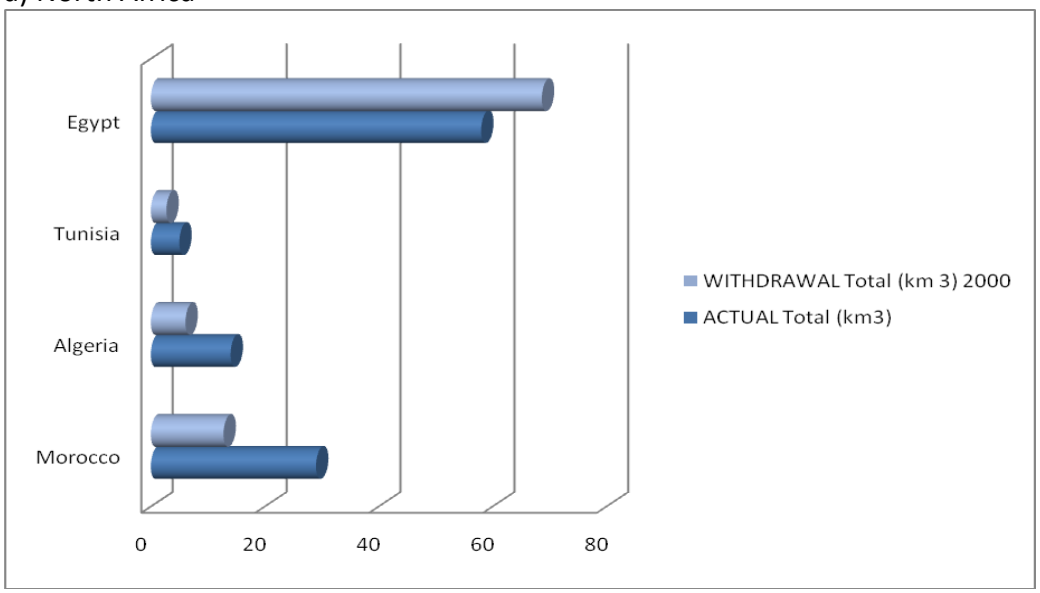
such that recharge to aquifers during rainy seasons may be mildly reduced. Severe increases in humidity may leave the soil more saturated, leading to higher run-off and also to reduced recharge. The mechanisms are not fully understood, but the interest is leading to innovative re-conceptualisation of basin water balances to include the importance, for instance, of soil water (Taylor 2009).

Water use

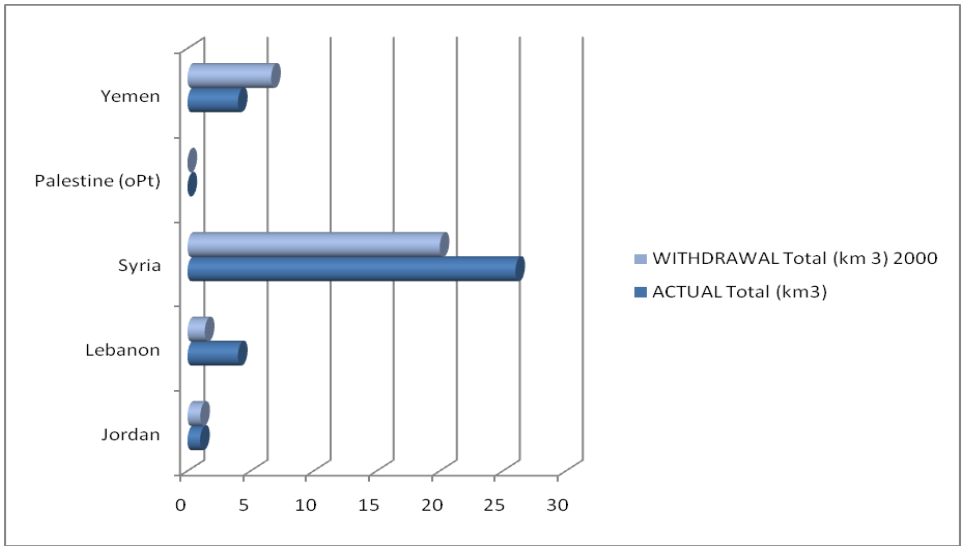
As Figure A1 a) shows, Maghreb countries are using half of their total renewable water resources, which is likely sustainable at the national level. Egypt, on the other hand, is shown to use more water than its available actual renewable resources – unsustainable practice by any measure. Figure A1 a) is somewhat misleading, however. The withdrawal rates do not indicate re-use of water in irrigation as the river proceeded downstream, for example. Egyptian 'external renewable water resources' – which are shown here at 58km3/y, the outcome of the 1959 Egyptian-Sudan agreement – is also not reflective of reality. Egypt has been benefiting from an extended period of high flows (see e.g. Whittington 2004) (as well as from unused quota of Sudan, all of which are stored in the Aswan High Dam).

Figure A1 Comparison between actual renewable resources and withdrawal. Based on FAO (2009b).

a) North Africa



b) Eastern Mediterranean and Yemen



The most striking data of Figure A1 b) is that Yemen and Jordan are withdrawing more than the estimated sustainable limits of the resource. The problem of over-abstractions in Yemen is well-known (Handley 2001, Lichtenthaler 2002, NWSSIP 2008, Ward and al Aulaqi 2008), and the difficulties with implementing water-reduction or WDM policy in Yemen has been attributed to political economy issues such as institutional capacity and internal or domestic power relations (see e.g. Arafa, et al. 2007, Brooks and Wolfe 2007, Zeitoun 2009). Jordan's over-use is attributed to substantial pumping by Jordan River farmers, coupled with low overall availability to begin with. While water use in Lebanon falls short of water availability, water use in Syria is very near the sustainable limits.

As is the case for MENA generally, North African countries devote the majority of their water to the agricultural sector. The range is from 65% in Algeria, to 90% in Morocco. Water use by sector in the Eastern Mediterranean and Yemen replicates the predominance of agriculture seen in North Africa. More than two-thirds of the water resources extracted there are withdrawal for agriculture, while in Yemen and Syria the sector accounts for 95% of total use.

A4 Overview of Food Security and Food Imports in the MENA Region

Some of the most ambitious water infrastructure built in the MENA region was driven to meet domestic food self-sufficiency (World Bank 2007). The tendency for decision-makers to sanction the discourse on national food self-sufficiency for political purposes is well acknowledged. The unacknowledged reality remains, however: that MENA countries are already highly dependent on food imports for their national food demands or to meet physical or second-order water scarcity (Allan 2001).

The magnitude of food imports into the MENA region is massive.[26] The region is the largest net importer of cereals in the world, as shown in Figure A2. Most MENA countries import at least 50 percent of the food calories they consume (FAO 2008b).

Proponents of food trade as a solution to either food security or water scarcity (e.g. Allan 2001, FAO 2009a) emphasise the benefits of low-cost staples (especially wheat) on the global food trade market. States that have maintained policies aimed at being food self-sufficient (e.g. Syria and Saudi Arabia, until recently) have missed out on these benefits. At the same time, such states have been less directly affected by recent (2007-2008) global agricultural commodity and food price shocks (IFAD 2009). In any case, the evident concerns of following either a strict policy of food imports dependency or of national food self-sufficiency have been challenged by expanding levels and reach of food trade globally. The extent of food imports in the MENA region is such that the debate can no longer be separated from discussions of water availability.[27]

Figure A2 Global cereal trade (million metric tons, 2007). The diagram shows that "Arab countries" as a block are the largest importers of cereals in the world. Adapted from FAO 2008 in IFAD (2009: Fig 1.1).

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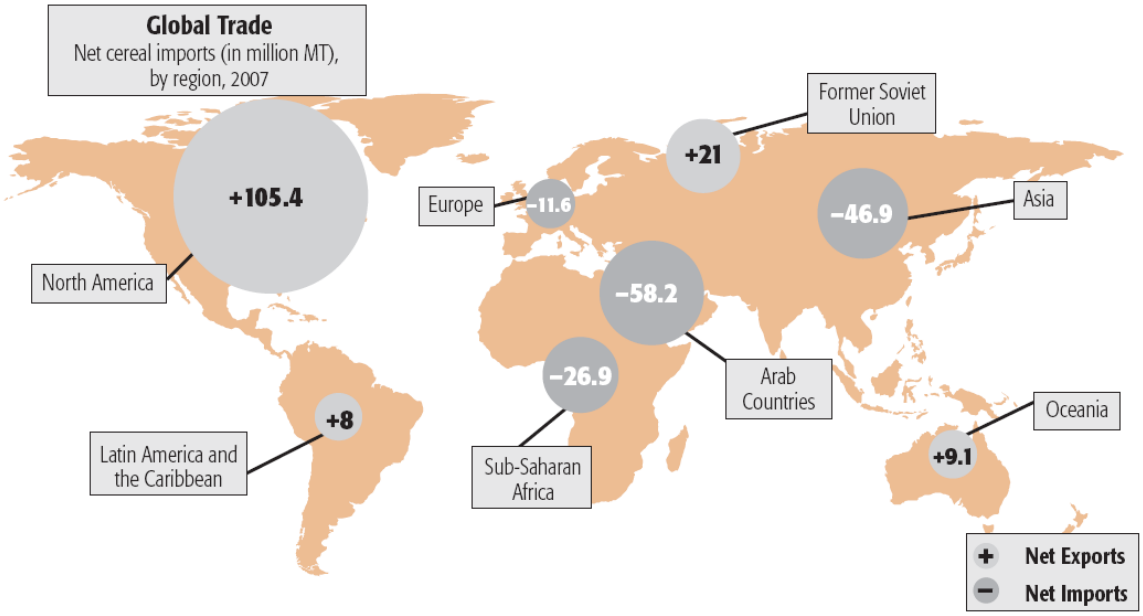
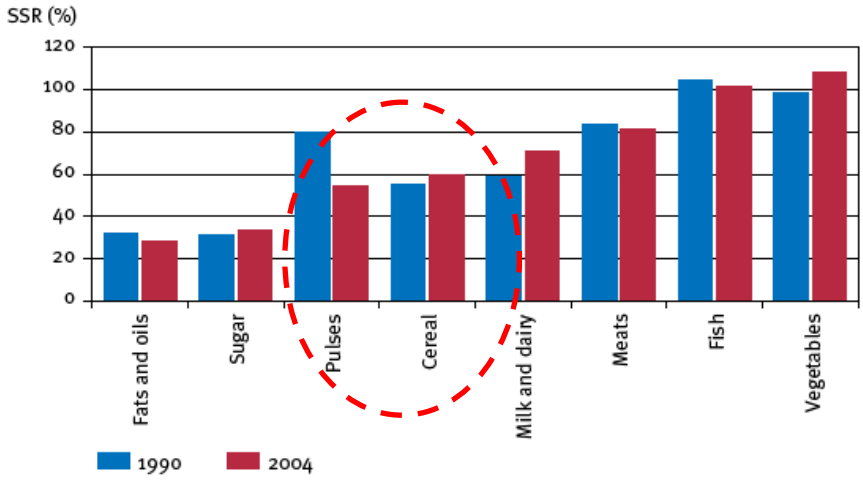
[26] Between 1998 and 2004 Egypt, for example, imported roughly 30,000 Mm3/y in the form of crops and livestock – the equivalent to nearly 1/3 of the Nile river itself, measured at the Sudan-Egypt border (Zeitoun, et al. 2010).

[27] 'Food sovereignty' was introduced as a term that describes the access to food along with access to land, water, genetic resources and knowledge[27] (Via Campesina, 2006). It grew from a view of food as a human right, and out of concern for the benefit of subsistence farmers to "prevent the effects of subsidised exports, food dumping, artificially low agricultural prices and other negative elements of the agricultural trade model" (Lee 2007). Proponents of food sovereignty assert that the agricultural produce should be exempt from the normal regulations of global trade regimes such as the WTO.



Most MENA countries have pursued food security through a combination of domestic production and food imports. As such, all MENA countries – apart from Syria – are net importers of virtual water. As Figure A3 shows, the regional self-sufficiency ratio for cereals has remained from 1990 to 2004 at about 60%, and for pulses the ration has decreased from 80% to under 60%. The figure also shows that MENA countries are generally independent of trade, in terms of fish and vegetables.

Figure A3. Self-sufficiency ratios in major food commodities in the "Arab Region" (%), by type, 1990-2004. UNDP (2009). [can the colours of this image be changed (request of external reviewer)]



Source: UNDP/AHDR calculations based on AOAD 2008 (in Arabic).

Note: The self-sufficiency ratios in the AOAD database are calculated by dividing food produced by food available for consumption (both measured in mega tons).

The dependency of MENA countries on cereals is expected to continue during the coming decades. Overall cereal demand in "Arab countries" is projected to be about 160 million Metric tonnes by 2030, while production is estimated to be at less than 80

million, maintaining the 100% gap between production and demand that has endured at least since the year 2000 (IFAD 2009: Figure 3.1) .

Global projections for consumption of cereals and meat in the Arab countries support the predictions of increased dependence on food imports. "The IMPACT model, created by IFPRI (2008a), and an FAO model (2006a; 2008d) are both food-balance models that project future food demand and supply throughout the world" (IFAD 2009: 17). Meat and milk consumption is also expected to rise, by 104 percent and 82 percent respectively (IFAD 2009: 17). The projected drops in domestic food production associated with the effects of climate change (roughly 7% in wheat by 2050, discussed following) will exacerbate the dependency.

Food security or insecurity through global food trade?

The global food price spike in 2008 revealed that national food security is not derived solely from the global food market. [28] While food trade provides invisible solutions to water stress to governments throughout the MENA region, there are a number of concerns associated with increased dependence on food imports.

First, the shock in agricultural commodity prices in the international market (from mid 2007 to mid- 2008) has had strong impacts in the MENA political economies, generating serious concerns on future food security policies in these countries (IFAD 2009, Johnston and Bargawi 2010). This crisis may be considered an epiphenomena or an exceptional event, but recent rising prices in 2009 (The Economist 2009) are again generating concern of economic impacts on countries which are highly dependent on food imports.

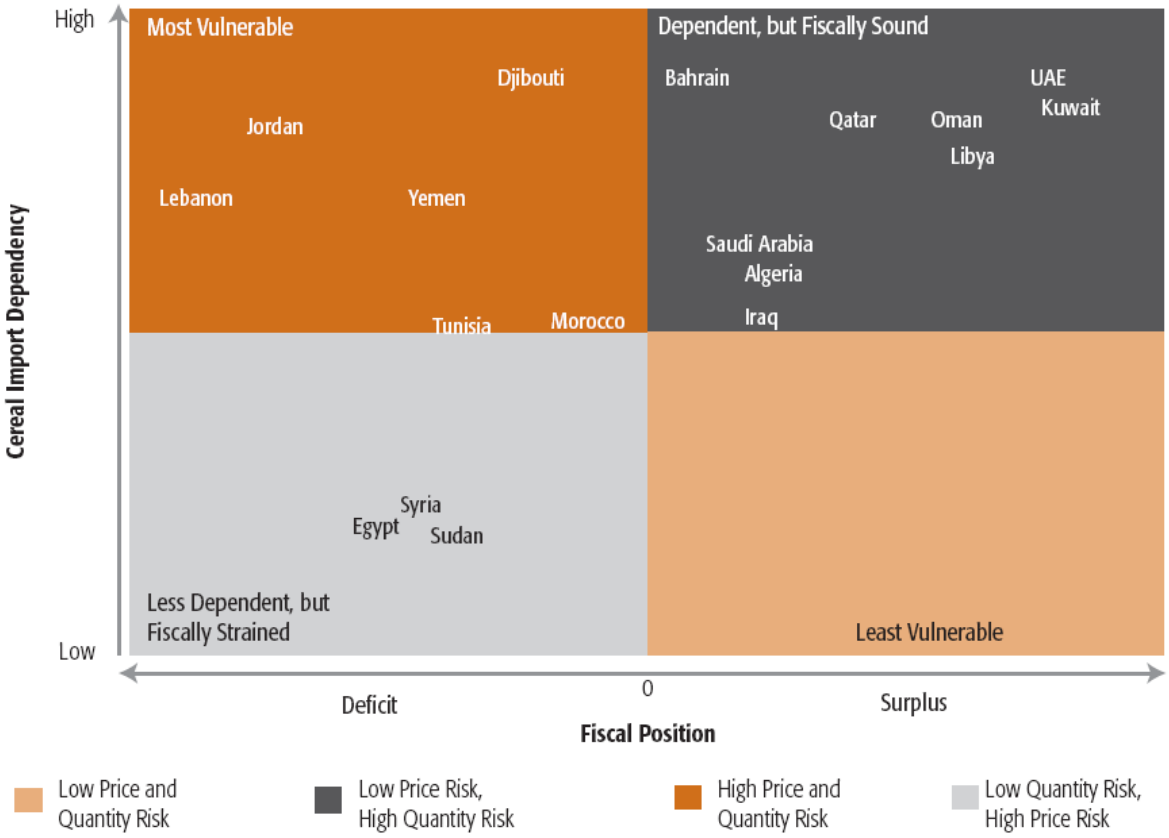
The second concern related to food imports is the decreasing global cereal production and growth since the 1980s, and in particular in the last decade. Shift of land use from cereal production to bio fuels, for example, has been widely credited for contributing for the decreasing surplus of cereals in the global markets (IFAD 2009). An associated concern is the impact of climate change on food growing conditions. As discussed in Section 2.3, the fact that reduced yields around the equator will be compensated by increased yields at higher latitudes is of little benefit to the MENA region.

A third concern with heavy reliance on food imports is the state of the economy of the less wealthy MENA states. Figure A4 shows that those countries least vulnerable to price spikes in the global food market (e.g. Kuwait, UAE, Oman) are either oil-rich and fiscally sound, or less dependent on cereal imports in the first place. The option of reliance on food imports for less economically secure states is considerably more risky.

Figure A4 Arab countries with High cereal import dependency and large fiscal deficits are most vulnerable at the macro level (2007 fiscal balances – percentage of GDP, 2005 cereal balances – metric tons) IFAD (2009: 15). No data available for Palestine.

[28] The detrimental effects of the food price spike of 2008 on Egypt in particular are well-noted (Johnston and Bargawi 2010). Syria's low level of food imports at the time, and Palestine's chronic subsidiarity to the Israeli economy has led to alternate impacts for these latter countries.

Figure 2.4: Arab Countries with High Cereal Import Dependency and Large Fiscal Deficits are Most Vulnerable at the Macro Level *(2007 Fiscal Balances–percentage of GDP, 2005 Cereal Balances – metric tons)**



Source: Authors. Adapted from FAO, 2008b; IMF, 2008; World Bank, 2008b.
Note: Cereal import dependency is measured by net cereal imports/total cereal consumption.
* 2007 fiscal balances were drawn from the IMF. The most recent FAOSTAT data on cereal balances is for 2005.

Another concern with heavy reliance on food imports is the inequitable terms of trade that persist between the wealthy producing nations and the less wealthy importing nations. As documented in FAO (2005) and George (1986), for example, subsidies (e.g. the EU Common Agricultural Policy) have generated terms of trade favourable to the wealthier states, even following recent reforms (see Section 3.4).

More on foreign agricultural land acquisitions

In attempts to reduce exposure to the concerns about food imports, some MENA countries have recently started investing on growing food outside their national borders on lands acquired for that purpose (von Braun and Meinzen-Dick 2009). Informally known as 'land grabs', acquisition of agricultural land by one state for the production of food in another state is gaining popularity. Saudi Arabia, United Arab Emirates, Qatar, and Jordan, Syria and Egypt have already significant foreign direct investment in land in countries such as Sudan, Ethiopia, Tanzania, Indonesia and Pakistan (Cotula et al. 2009).

Once considered the potential "breadbasket of the Arab world" (Kaikati 1980), Sudan is again the stage of large-scale investment from its Arab neighbours. In the case of Egypt, the development of agricultural land in Sudanese territory has occurred since the

independence of Sudan in 1956, although the interest in agriculture development (in particular wheat) had been increasing since the 2007-2008 food crisis (Sudan Tribune 2008). In 2008 Syria and Jordan resumed previous land agreements with Sudan. Syria had since 2002 a Special Agricultural Investment Agreement with the Sudanese government, comprising a 50-year lease over a land area of 12,600 ha (Cotula et al. 2009). Newspaper reports state that Jordan resumed a 1998 agreement, including the rights over 25,000 ha of land for crops and livestock (Jordan Times 2008b, 2008a)

Foreign agricultural land acquisitions can be seen as simple extensions of existing food trade arrangements, and are often promoted as 'win-win' solutions. So long as the economic arrangement is properly regulated, the logic goes, the host country can benefit from investment and labour, turning its competitive advantage in favourable growing conditions, into currency. In discussing the opportunities provided, a recent IFPRI report notes that "[w]ell-designed foreign direct investment could embed transfers of knowledge and institutional strengthening into the investment and related trade flows, thereby improving productivity in the target countries of these investments. In the longer run, a healthy trade relationship could grow out of such investment islands, building trust in trade, at least on a bilateral basis and potentially more broadly, in an increasingly volatile world food system." (von Braun and Meinzen-Dick 2009: 4).

A number of concerns over the practice have been raised, however. Amongst these are recognition that with inadequate regulation, the distribution of benefits will remain primarily with the investing country and with the ruling elites of the host country. The apparent loss of sovereignty by the host state over land purchased by the investing state raises furthermore concerns about the latter's food demand being satisfied ahead of the needs of the host countries.[29]

GTZ proposes a number of steps that both countries must put into place to ensure the creation of a positive-sum outcome: Creation of a reliable information base and transparency; review of existing international legal framework; development and implementation of international guidelines and policies; policy dialogue with partner governments in DC, investor countries, banks, funds and the private sector; Strengthening of civil society in its controlling and negotiating function; development and implementation of national land policies and laws in the partner countries; registration of land rights as an important element of comprehensive land reforms; and establishment and implementation of sustainable land use management (GTZ 2009). Such conditions are not currently in place at national or international levels, for any of the MENA countries. As such, both investor and host MENA countries should take pause for concern before considering land acquisitions as a food or water policy.

[29] In a most extreme case, the purchase by South Korean company Daewoo of 1.3 million hectares for food production in Madagascar is credited in part for contributing to political tensions that led to the coup d'état in 2009 (Cotula, et al. 2009).

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