Water and Food Security in the Arabian Gulf

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WATER AND FOOD SECURITY IN THE ARABIAN GULF

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THE EMIRATES CENTER FOR STRATEGIC STUDIES AND RESEARCH

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Through these and other activities, the ECSSR aspires to engage in mutually beneficial professional endeavors with comparable institutions worldwide, and to contribute to the general educational and academic development of the UAE.

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First published in 2013 by
The Emirates Center for Strategic Studies and Research
PO Box 4567, Abu Dhabi, United Arab Emirates

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Website: http://www.ecssr.ae

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ISBN: 978-9948-14-622-3 hardback edition
ISBN: 978-9948-14-623-0 paperback edition
ISBN: 978-9948-14-624-7 electronic edition

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ABBREVIATIONS AND ACRONYMS

ACSAD	Arab Center for the Study of Arid Zones and Dry Lands
ADB	Asian Development Bank
ADFD	Abu Dhabi Fund for Development
ADFEC	Abu Dhabi Future Energy Company (Masdar)
ADWEA	Abu Dhabi Water and Electricity Authority
AED	UAE Dirhams
AFESD	Arab Fund for Economic and Social Development
APRP	Arabian Peninsula regional Program (ICARDA)
ASEAN	Association of South East Asian Nations
AWGI	Asian Water Governance Index
bcm	billion cubic meters
CPI	consumer price index
CPI	consumer price index
DHS	(US) Department of Homeland Security
F&V	fruit and vegetables
FAO	(UN) Food and Agriculture Organization
FOB	free on board
GDP	gross domestic product
GHG	greenhouse gas
GSFMO	Grain Silos and Flour Mills Organization
GWP	Global Water Partnership
ha	hectare
HDI	Human Development Index
IAEA	International Atomic Energy Agency
ICARDA	International Center for Agricultural Research in Dry Areas

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ICARDA	International Center for Agricultural Research in the Dry Areas
IDWA	Index of Drinking Water Adequacy
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
INCO-NET	international cooperation network
IRGC	Iranian Revolutionary Guard Corps
IWP	Institute of Water Policy (National University of Singapore)
IWRM	integrated water resource management
IWRM	integrated water resources management
KAISAIA	King Abdullah Initiative for Saudi Agricultural Investment Abroad
KFAED	Kuwait Fund for Arab Economic Development
lpcd	liters per capita per day
LPI	Logistics Performance Index
mcm	million cubic meters
MDG	Millenium Development Goals
MED	multiple-effect distillation
MGD	(UN) Millennium Development Goals
MSF	multi-stage flash distillation
mt	metric tons
MWA	Metropolitan Waterworks Authority (Bangkok)
NAT	normal accident theory
NRW	non-revenue water
NUS	National University of Singapore
NWP	national water policy
NWRP	national water resources policy

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OECD	Organization for Economic Cooperation and Development
PFI	public finance initiative
PPP	public–private partnership
PPP	purchasing power parity
PPWSA	Phnom Penh Water Supply Authority
PUB	Public Utility Board (Singapore)
QNFSP	Qatar National Food Security Program
R&D	research and development
RO	reverse osmosis
RoR	rates of return
RSB	Regulation and Supervision Bureau
SCADA	supervisory control and data acquisition
SNG	FAO Sub-regional Office for the Gulf Cooperation Council States and Yemen
SSR	self sufficiency ratio
UFW	unaccounted-for water
UNESCO	United Nations Economic, Social AND Cultural Organization
UNICEF	United Nations Children's Fund
UNPD	United Nations Population Division
WFP	World Food Program
WHO	World Health Organization
WMD	weapons of mass destruction
WTO	World Trade Organization

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FOREWORD

With a rapidly growing world population, rising food prices and increasing scarcity of water resources, food and water security have emerged as among the most serious challenges facing today's governments, including those of the GCC.

Arabian Gulf countries do not have sufficient natural water resources, and mainly rely on sea water desalination to satisfy their requirements. Natural food supplies in these countries are scare and face increasing degradation. Therefore the states of the region depend on food imported from abroad, which renders them vulnerable to social and economic instability stemming from fluctuations in world food production, basic commodity prices, and changes in commercial policies.

In keeping with the ECSSR's mission to examine vital global and regional issues, and its recognition of the need to develop solutions and strategies to maintain water and food security, the Center convened its 17th Annual Conference under the title: *Water and Food Security in the Arabian Gulf* on March 26–27, 2012 in Abu Dhabi, hosting a group of distinguished experts from various academic and professional backgrounds.

This book comprises a valuable collection of the papers presented at the conference. They address strategic dimensions of water security in the Arabian Gulf region through an examination of the current state of water resources, geopolitical dimensions of water scarcity, the future water supply–demand balance and the impact of population growth on water resources, and both national and regional water security policies. The papers also discuss food security and challenges to global food supplies, as well as the food strategies adopted by the GCC countries, and the implications of various developments in the food market for the states of the Arabian Gulf region.

It is fitting at this juncture to express my gratitude to all the speakers for their participation in the ECSSR 17th Annual Conference.

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Their papers, compiled in this volume, comprise essential reading for all those concerned with the future of food and water security in our region in the coming years. I would also like to commend the efforts exerted by the ECSSR's editors, as well as the team of translators, proof-readers and type-setters who worked to produce this book in its present form.

Jamal S. Al-Suwaidi, Ph.D.
Director General
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INTRODUCTION

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Achieving Water and Food Security in the Gulf

Water is increasingly being viewed as one of the most important renewable resources worldwide. Increasing populations and growing economies, coupled with a changing global climate, have led to an increase in water demand around the globe. However, there are large variations in the amounts of water available to nations and regions, and growing concern surrounding the uncertainty associated with these supplies, due in large part to natural and human impacts on the water cycle.

According to recent studies cited by Nadim Farajalla in this volume, global demand for water will be 40 percent higher by 2030—a trend that is mirrored in the six countries of the GCC. The combined population of the Gulf states increased from about 30 million to nearly 44 million between 2002 and 2010; however, their demand for water over roughly the same period has increased at a rate of about 17 percent—nearly 2.5 times their population and GDP growth rates. The current trend in the GCC countries of increasing demand with a constant supply of freshwater is simply not sustainable, and unless a major shift in controlling demand occurs, water scarcity will become a major obstacle to development in the region.

The need for alternative sources of fresh water has also been aggravated by the large influx of guest workers and significant improvements in the quality of life among Gulf populations. Therefore supplies are augmented by alternative sources—mainly desalinization, which meets most of the needs of these countries. However, this comes at a great financial cost as it is an extremely energy intensive process.

Despite its high financial and resource costs, many see desalination as the only viable means of ensuring water supply in the region. Hussein Amery argues that increasing reliance on desalination technology will be the most effective way of augmenting current supplies, despite the security risks associated with this option. While desalination plants are susceptible to natural hazards, mechanical failures and sabotage, they provide the Gulf states with an 'upstream-like' status in terms of their water resources, with all the security and stability this provides. Hence, he argues, the geopolitical and security benefits of desalination are greater than the potential costs.

Water scarcity derives from a variety of factors, from physical shortages, pollution of fresh water, lack of infrastructure, and fast population and economic growth, to inefficient water use and competition for water among different sectors. However, it has also been widely acknowledged that the majority of countries have enough water to maintain high human development if they manage their resources appropriately; water crises can often therefore be blamed on a failure of water policy and governance.

Waleed Zubari argues that whereas in the past water security in the GCC countries was only a matter of securing and protecting sufficient reserves for their populations and agricultural sectors, it is now a domestic issue primarily dependent on good governance and water resources management, and a vital element in these states' paths toward sustainable development. The GCC countries are heavily dependent on water for their development activities, but major industries continue to consume water irrationally and inefficiently, and there is generally a low awareness regarding water wastage in society. However, solving water issues, writes Zubari, is the responsibility of government, not consumers. Achieving water security requires radical intervention in the social and economic environment of the GCC countries, accompanied by improved governance to change the prevailing culture of wastage.

In facing water shortages around the world, Peter Rogers emphasizes the distinction between available water 'supplies' and human-moderated water 'resources.' This is particularly important in countries such as those of the GCC typically labeled as "water scarce." Rogers points out that even for those relatively well-watered regions such as Europe and large parts of North and South America, the spatial and temporal variability of water resources can cause major water management problems. This may be attributed to the general view that there is ample supply of water, resulting in a lack of suitable controls with which to manage water as a resource. For the hyper-arid countries, such as the members of the GCC, much greater attention has been paid to managing supply, as there is a clearer realization of its importance as a resource. Ultimately, therefore, mismanagement of available water supplies can lead to water crises in any country or region.

Mohammed Dawoud presents the UAE as an example of a nation that is designing policies to achieve integrated management and sustainable development of scarce water resources. He states that the UAE government is undertaking a variety of measures to achieve water security, including: developing public policy and strategic planning; reviewing legislative, legal and regulatory frameworks for the management of water resources; raising awareness and education through the development of programs tailored to individual water-consuming sectors; and developing and adopting modern technologies in order to rationalize water usage in all water-consuming sectors.

Seetharam Kallidaikurichi and Mingxuan Fan observe that a major challenge for many countries in the water sector is how to coordinate all of these elements—resource policies, legal and regulatory frameworks, and the institutions responsible for formulating and implementing these policies. The current and past practices of formulating policies in one sector without adequate consideration of – and coordination with – policies in other sectors will become increasingly costly, inefficient, and unsustainable. Herein lies a major future challenge for all countries, explain the authors: how to integrate appropriately all the concerned resource policies in the areas of water, energy, food, and environment, the legal and regulatory frameworks necessary to support these policies, and the institutions responsible for formulating and implementing these policies. Such integration has been very difficult to accomplish in the past and is likely to be even more difficult and complex in the future. Yet this will be an important and critical requirement that must now receive accelerated attention from governments, research institutions, and academia.

At the regional level, cooperation and integration would also be beneficial, argues Mohammed Tayie. He calls for the creation of a body similar to the Organization of the Arab Petroleum Exporting Countries (OAPEC) that would be concerned with the organization and management of water resources in the GCC countries. He states that such an organization could organize meetings and forums bringing together public officials responsible for Gulf water affairs, civil society organizations interested in water, and water users' associations, with the aim of creating a state of partnership to achieve good governance in the field. The author suggests that this would enhance regional cohesion by unifying the interests of the member states, bringing about greater political, economic and strategic integration of the Gulf countries.

Like water security, global food security also faces an uncertain future. Food supply is increasingly threatened by scarcity and degradation of natural resources – namely water and land – as well as by the growing competition between agricultural, domestic and municipal uses of water and energy.

Mohamed Ait Kadi remarks that feeding the world's growing population and allocating enough resources to food production have continued to be basic yet significant challenges.

In addition to the need for land and water, global agriculture will have to cope with the burden of climate change, whose likely impacts have been documented extensively. Most conclude that global food production potential is expected to contract severely, and that yields of major crops like wheat and maize may fall globally. Severe weather occurrences such as droughts and floods are likely to intensify and cause greater crop and livestock losses. The implications are that food prices will rise, as will their volatility.

Threats from interacting drivers of change will converge in the food system over the next four decades. Hence, careful assessment of the implications of these drivers is essential if major pressures are to be anticipated, and future risks managed.

As Abdu Gasem Al-Assiri notes, the Arabian Gulf region suffers from a substantial food gap, as all the countries of the region are net food importers. The increase in the region's population, rising income levels, and harsh weather conditions that prevent the increase of local food

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production, have resulted in a vast increase in the region's food imports, from a total value of US$ 6.5 billion in 1990 to US$ 28 billion in 2008. Over the past few decades, there have been major changes in the Gulf populations' food consumption patterns and behavior. He states that it is necessary to evaluate these trends, and to determine their social, economic, and health-related consequences.

According to Nadim Khouri, et al., this dependency is expected to continue to rise as a result of rapidly growing populations, improving living conditions, sustained economic/industrial development and depleting natural resources. To meet their food needs the Gulf countries must rely on international markets, which makes them vulnerable to the vagaries of global food production, trade policies and commodity prices. This is exemplified by the food crisis of 2007/2008, which led Arab Gulf countries to adopt strategies that include building up national strategic food reserves, scaling up subsidies, and acquiring land abroad for agricultural investments. Khouri et al. suggest that what is needed is perhaps a multi-pronged food security strategy that builds on these elements while integrating them in a GCC-wide approach.

International agro-investments have been a widely publicized reaction of the UAE and other Gulf countries to the global food crisis of 2008, but Eckart Woertz suggests that to improve food security other policy fields are more important, and the UAE has a considerable number of national levers at its disposal to influence them in its favor. International storage solutions and other forms of multilateral engagement, he writes, could make global food markets more reliable and predictable.

He also cites the high prevalence of obesity and diabetes caused by unhealthy diets in the Gulf region, which constitutes a different and possibly unexpected threat to food security; the UAE has an opportunity to address such issues with national policies. This is also true for policies of economic diversification and steps to address labor grievances. The former influences food import options in the long run, the latter safeguards the food accessibility of vulnerable segments of the population.

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KEYNOTE ADDRESSES

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Enhancing Water and Food Security in the Arabian Gulf

H.E. Dr. Rashid Ahmad bin Fahad[*]

It is my pleasure to welcome you to this conference being held under the patronage of His Highness General Sheikh Mohammed bin Zayed Al Nahyan, Crown Prince of Abu Dhabi, Deputy Supreme Commander of the UAE Armed Forces and President of the ECSSR.

This event is particularly timely, not only because it comes a few days after World Water Day, but more importantly because water and food security are strategic issues of top priority in the GCC that have direct impacts on the region's development.

Environmental and climatic conditions across the GCC countries are very similar, and except for certain areas in the Kingdom of Saudi Arabia and the Sultanate of Oman, the GCC represents an arid part of the world with scarce natural water resources, lack of rainfall, high evaporation rates and poor soil. These characteristics are clearly reflected in the lack of renewable water resources and the limited amount of arable land in the region.

According to an assessment of the GCC water sector conducted by the World Bank in 2005, total water demand in the region increased from around six billion cubic meters (bcm) in 1980 to around 27 bcm in 2000, while annual renewable water resources per capital declined rapidly from 678 cubic meters (m^3) in 1970 to 176 m^3 in 2000. Hence, one can only imagine the decline in per capita renewable water resources given the

* This presentation was delivered on behalf of H.E. Dr. Rashid Ahmad bin Fahad by H.E. Dr. Mariam H. Al-Shenasi, undersecretary at the UAE Ministry of Environment and Water.

pace of development in the GCC during the last decade, and under the added pressure of climate change.

The inability of groundwater to meet growing demand from various sectors has resulted in the adoption of desalination as a means to satisfy a significant proportion of the GCC region's water needs, alongside the use of treated wastewater for irrigation.

In light of projected increases in water demand, the GCC is planning to construct more desalination plants; it is expected that investment in this sector will total US $100 billion between 2011 and 2016.

Irrigation for agricultural purposes is the primary source of water consumption, accounting for around 80 percent of total water use in the region. Furthermore, the over-exploitation of groundwater resources to meet the requirements of this sector has not only hastened their depletion, but also reduced their quality.

Various studies and reports attribute the adverse impacts of the agricultural sector on water resources to its dependence on traditional irrigation techniques, as well as generous government subsidies that encourage farming practices which focus on low-value crops, thereby failing to exploit valuable agricultural opportunities. Indeed, the National Strategy for Water Resources in the UAE states that less than five percent of groundwater is used in the production of economically viable crops.

Excessive water consumption is not limited to the agricultural sector. Urban water demand has more than doubled, resulting in a rate of per capita water consumption in the GCC that is among the highest in the world. Although this growth is mainly attributed to large increases in population, we must not overlook the disturbing tendency across the GCC towards irresponsible and wasteful consumption practices—particularly in terms of domestic use.

The GCC states have come to appreciate the adverse impacts of excessive water consumption across all sectors, and the related consequences for water and food security, and have therefore reviewed their water and agricultural policies accordingly.

In the UAE, where the agricultural situation is similar to that of the rest of the GCC, the concerned authorities have adopted a series of measures to achieve and sustain water security and to enhance food security as part of a clear and comprehensive national strategy. These measures aim to amend institutional and legal frameworks in order to better conserve resources in accordance with the principles of integrated water resources management. They include the development of a national strategy to preserve water resources – which is currently being implemented – a comprehensive review of agricultural and water policies, and the formulation of a new approach to agricultural development aimed at achieving greater balance between water and food security, taking into account all economic, social and environmental considerations.

Given the projected growth in demand for desalinated water, which today accounts for about 40 percent of the UAE's water supply, particular attention has been paid to developing the desalination industry. The estimated capital investment required is expected to reach AED 51 billion by 2016. Plans have also been made to use nuclear or renewable energy to power desalination in order to reduce greenhouse gas emissions and mitigate the impacts of the desalination industry on marine ecosystems.

The UAE has also focused on increasing the use of treated wastewater, which constitutes about 10 percent of supply in the UAE, and has conducted studies on the possibility of expanding its usage beyond irrigation.

Other measures include discouraging irresponsible water consumption in various sectors, and especially in households. The UAE's policy in this regard is based on a mix of options including the adoption of a progressive water tariff system, the use of modern water-sparing technologies, and raising awareness of water conservation methods.

It is expected that these measures will be further enhanced and complemented in light of the UAE's "Green Economy for Sustainable Development" initiative, launched in January 2012.

As for enhancing food security, besides adopting more efficient agricultural development approaches, the UAE has paid significant attention to issues such as enhancing livestock production, preserving and developing fisheries, improving food safety and bio-security, developing the food industry and encouraging private sector participation in water and food security projects.

The pressures and challenges facing water and food security in the GCC – whether as a result of natural factors such as climate change or human factors such as excessive consumption and world food crises –

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mean that efforts to develop a comprehensive regional long-term strategy for water and food security must be expedited. This need was enunciated both in the Abu Dhabi Declaration on Food Security for the GCC, issued in November 2010, and in the Abu Dhabi Declaration on Water in the GCC issued by the 31st GCC Summit in Abu Dhabi the following month. In both declarations the GCC countries expressed concern regarding the aggravation of water and food insecurity, and an interest in developing regional strategies to ensure water and food security.

Despite the fact that limited water resources and farmland may render water and food security elusive, the GCC states have a wide range of options, capabilities and experiences that make it possible. I hope that this conference, which has brought together a select group of experts and researchers, will discuss with the outmost candor all the pressures and challenges facing water and food security in the GCC countries, as well as the options available to face them, and the economic, social and environmental impacts of each. I am confident that the deliberations of this conference and its recommendations will support and bolster our efforts towards developing successful strategies to guarantee the GCC countries' water and food security.

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Water, Food and Agricultural Challenges in the GCC

Abdu Gasem Al-Assiri

I would like to extend my thanks to the Emirates Center for Strategic Studies and Research for organizing this conference, and for raising such important topics relevant to the lives of citizens in all of the countries in the Arabian Gulf region.

The agricultural sector is undergoing significant development in the member states of the FAO Sub-regional Office for the Gulf Cooperation Council States and Yemen (SNG). Besides being an important economic activity, agriculture is a way of life which people depend upon to provide a living. The agricultural sector accounts for around three percent of total GDP in the GCC countries, and 19 percent of the population work in related economic activities in this sector. In general, agriculture plays a pivotal role in economic development and in achieving social stability and security.

By increasing production and added value, developing marketing and manufacturing, and providing employment opportunities, agriculture also helps in achieving food security and family and social stability, combating poverty and unemployment, curbing migration to urban areas, and preventing a number of social, economic and security problems.

Food security faces huge challenges, as the world's population is expected to rise from 7 to 9 billion by 2050. Furthermore, prices in emerging economies will force poorer sections of society to spend 50% of their income on food, and global demand for food will increase significantly. Satisfying this demand would require a 70 percent increase in overall food production, while production in the developing countries

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would need to almost double. Investments in the agricultural sector, however, are not increasing at the same rate. The share of agriculture in official development assistance declined from 19 percent in 1980 to three percent in 2006, and currently amounts to around five percent; furthermore, developing countries are allocating only about five percent of their national budgets to agriculture. Meanwhile, more than 100 million tons of grain are used in biofuel production, encouraged by generous financial support which amounts to around US$ 13 billion annually, provided by developed countries for biofuel-related agriculture. If we add to this the impacts of droughts, floods and hurricanes and speculation in the futures markets over agricultural products, we believe that the current food security situation portends an impending disaster, to which the famine that hit the Horn of Africa in 2011 is merely a prelude.

At the regional level, the Arabian Gulf faces many challenges to its food and water security, the most prominent of these is a result of the severe lack of water resources, arable land and pastures. Other challenges are climatic, environmental, economic, social, technical or institutional. The past few years have also seen numerous regional and global challenges, resulting in falling food security and a slowdown in the pace of development in the agricultural sector. The most notable of these are the global financial crisis and high food price volatility in the world market, in addition to the many problems affecting capital markets and imports, the expectation of severe climatic changes – which are beginning to negatively affect global food security – in addition to the obligations placed on those countries in the region that have joined the World Trade Organization (WTO).

The Arabian Gulf region suffers from a substantial food gap, as all the countries of the region are net food importers. The increase in the region's population, rising income levels, and harsh weather conditions that prevent the increase of local food production, have resulted in a vast increase in the region's food imports, from a total value of US$ 6.5 billion in 1990 to US$ 28 billion in 2008. Over the past few decades, there have been major changes in the Gulf populations' food consumption patterns and behavior. It is necessary to evaluate these trends, and to determine their social, economic, and health-related consequences.

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As for the situation regarding water resources in the region, it is widely accepted that this represents the most important and significant challenge not only for agricultural development, but also for economic and social development. Rain falls intermittently at an average of 50–100 mm annually in most GCC states, except in the highlands of Saudi Arabia, Oman and Yemen, where the average annual precipitation can exceed 250 mm. The GCC is one of the most water-stressed regions in the world, and average per capita renewable groundwater resources in the region stand at less than 100 cubic meters compared to the world average of more than 6,400 cubic meters per capita.

As a result of the excessive use of non-renewable groundwater over the past few decades, remaining water resources are irregular, only to be found at great depths, and very expensive to extract. Groundwater exploitation has also led to increased salinity of water resources, thanks to seawater incursion in coastal aquifers. In recent decades some water desalination projects have been completed, however, the costs are still high, rendering them economically unviable for use in agriculture.

This brief analysis provides an overview of the main food and water security challenges facing both the Gulf region and the world. The priorities of the SNG in this regard were set during a workshop held on October 27, 2011 in Abu Dhabi, during which the Office proposed a framework to address the key issues facing agricultural development and food and water security in the region. Areas of priority and action were identified, reflecting the needs of SNG's member states and the global strategy developed by the FAO. The SNG's framework of priorities is based on ensuring the sustainable management of natural resources, whilst also achieving food and water security in the region.

Food security – from a comprehensive and sustainable perspective which incorporates elements such as food availability, accessibility, stability, safety and healthiness, as well as ensuring that food meets the nutritional needs of citizens and is subject to internationally recognized criteria and standards – can be achieved through the coordinated implementation of strategies, policies, programs and projects with a long-term perspective to address the potential challenges facing food and water security. The SNG's programs and activities include providing technical support in several areas, particularly in the areas.

First, by enhancing the capacity of member states in area of food security in terms of improved productivity, providing safe and adequate food supplies, locating reserves of strategic commodities, stabilizing food supplies and prices, rationalizing consumption and improving the quality and safety of food.

Second, by enhancing the capacity of member states in the field of water security by analyzing the supply and demand for water, assessing the economic, social and environmental impacts of irrigated agriculture, assisting in establishing policies and programs designed to adopt and manage modern irrigation systems and water saving techniques, as well as applying mechanisms to recover the costs of water services to stimulate and enhance water supply.

The Food and Agriculture Organization of the United Nations, represented by the FAO Sub-regional Office for the Gulf Cooperation Council States and Yemen (SNG) is ready to provide all the technical support needed by the member states to achieve water and food security to support sustainable agricultural and rural development.

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PART I

WATER SECURITY IN A CHANGING WORLD

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1

Water Security: Supplies, Resources, and Uncertainty

Peter Rogers

This conference is concerned with water and food security in the Arabian Gulf countries. The connection between water and food has become a source of great global concern as the world's population grows and its wealth increases. It is of special concern in the Arabian Gulf region, where population growth has been extremely rapid and diets have become more associated with foods which are very water intense in their production, such as animal products.

The current water situation in the GCC countries and approaches to deal with the issues of sustainable supplies in the future were the focus of three insightful papers by Al-Zubari, Dawoud and Abdelrrahman, and Al-Rukaibi.[1] Since two of the authors are making presentations in this conference we can leave it to them to outline the current situation of water and food in this region and instead should focus on how to plan water resources to achieve better water and food security.

The Arabian Gulf region has very low rainfall, and many of its areas have large unpredictable rainfall variations from year to year, leading to major droughts and floods. It is the most water scarce region of the world. Also, it has had some of the most rapid rates of population and income growth worldwide. Water demands have been met primarily by investments to increase the supply available to cities and agriculture by pumping underground water, desalination, small surface dams to control runoff, and other applications of technology.

Unfortunately, the era of finding new water to develop larger supplies at a moderate cost is ending. No large rivers or natural lakes originate in

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the region itself, most of the possible water resources have already been developed, and are now producing for human use virtually all the water that can be drawn from them. Many ancient deep aquifers are being mined, meaning that the present population of the region is taking water that cannot be replaced for their descendents. Desalination is increasingly being used.[2] Reallocation of water among users and between countries is extremely difficult to arrange. Broadly, we can conclude that new and increased water supplies are going to be hard to find, and new water cannot be relied upon to make up large-scale insufficiencies, as it often has in the past. Two general responses are suggested by Dziuban;[3] first, the need to devote more balanced attention to both demand management and supply augmentation; and second, water development and water allocation must be more purposeful, conscious, and calculated.

In discussing water and food security it is important to distinguish between "water supplies" and "water resources." Water supplies refer to the physical quantities of water that are available for use, but water resources imply human use and management of those supplies. Neither water supplies nor water resources are fixed quantities; both can be influenced to be larger or smaller based upon technology, water management, and hydroclimate change. The physically available quantities of water can vary depending upon the technology chosen to develop the water as a resource; for example, reducing evaporative losses by conjunctive use of surface and ground water, and the reduction of coastal outflow by strategic groundwater extraction. Management of demand by regulation or pricing can also increase the available supply, as can demand management and exploiting trans-boundary sources of surface and groundwater. Finally, changes in climate can change precipitation and temperature, which in turn change stream run-off and evaporative losses. Al-Rukaibi discusses the implications of future climate change in Kuwait Bay and over Saudi Arabia,[4] while Hallegatte, et al. provide a general methodology for assessing changes in flood risk due to climate change which could be expanded to cover all water and food risks.[5]

Water resources are the amounts of water planned and used for human activities by technology, and according to political and economic regulation. Planned "water resources" do not have to be less than the available "water supply" because we now have the technical and economic means to desalinate unlimited amounts of saline and brackish water. For the first time in human existence we have become almost able to guarantee an extremely high level of food and water security for much of the globe's populations.

The Nutrition Transition

One cannot discuss food and food security without looking at the unprecedented shift in the composition of diets around the world, particularly the rapid changes occurring in many of the increasingly wealthy developing nations. Recent rapid economic growth in many countries, particularly in Asia, has at the same time also sown the seeds of potential food crises as millions of people have gone through the "nutrition transition," whereby with increasing affluence consumers are moving toward a diet relying less on carbohydrates for calories and more on ever increasing consumption of fats as a percentage of total calorie consumption, while at the same time consuming more calories in their diets. For example, China, Brazil, and Mexico are approaching the recent levels of calorie and fat consumption of the OECD countries.[6]

The "nutrition transition" is akin to the "demographic transition," whereby over the course of 50 years the population of the globe has changed from a high birthrate/high mortality to a low birth rate/low mortality rate regime. Almost all of the countries of the world have passed through this transition, leading to a much more benign population outcome than otherwise would have occurred. Slowed population growth has led to moderation on resource use and environmental degradation, and to a general improvement of well-being for new populations. Unfortunately, the "nutrition transition" is not likely to have such benign effects. Under this transition a high carbohydrate/low animal fat diet is being replaced with a high animal fat/low carbohydrate diet, leading to increased health effects (cardiovascular diseases, etc) and large increases in land, water, and energy consumption for the provision of animal products. This is exactly the opposite direction that we should be heading in a resource constrained world. While we do not have very good explanations of how and why the demographic transition took place – other than improvement in public health, increasing wealth, and educational development of the poor – neither do we have good explanations for the nutrition transition, other than similar generalizations of increasing wealth, emulating the wealthy, fatty food tasting better, and improvements in public health. However, we do know that once they have occurred these transitions are inexorable and very difficult to reverse. Even the vaunted French diet has seen fats rise in the daily calorie intake from less than 30 percent from fats in 1960 to more 40 percent in the year 2000.[7] Another effect of the nutrition transition is the increase in the total calories consumed in the average diet, with the developed world consuming more than 3,500 calories and the developing world consuming between 2,500 and 3,000 per capita per day. Not only are these countries switching to animal product calories, but also they will most likely be consuming 3,600 calories per day by 2050.[8]

All sorts of policy tools have been suggested to stop the nutrition transition to animal products, ranging from regulating food prices, taxes on animal products, subsidies on carbohydrates, to absolute bans on certain products and major public relations campaigns to enhance certain diets. It is unlikely that these will stop the inevitable nutrition transition. If, however, the developing countries were able to limit their total consumption to 3,000 calories per day, total estimated food demand for 2050 could be reduced by 30 percent.[9]

Another closely related subject is food wastage. The amount of food wasted in the chain from "field to fork" is exceptionally large in many settings, and even in average settings appears to be unacceptably large. On average globally in the early 2000s it took a harvest of 4,600 calories to provide a daily supply of 2,000 calories.[10] Many of the losses in this chain are unavoidable or extremely expensive to control; however, many sources of loss would respond well to improved transportation and marketing logistics. Transportation is often mainly a roads and bridges infrastructure concern of the governments, but it is also an area where commercial firms could greatly assist in reducing the losses by providing refrigerated trucking, storage and marketing facilities. As much as 50 percent of the losses could be avoided leading to a further 20–25 percent reduction in the 2050 food production target.

Urban Water and Food Demands

Another contributor to water and food insecurity follows directly from the above discussion of the "nutrition transition." Not only have diets changed, but rapid urbanization is occurring worldwide. This implies not only a shift in total food (and its concomitant water requirements), but also a movement of people to large population centers where they exert their demands for new water-intensive diets, require larger quantities of water for drinking and sanitation, and drive up electrical energy demand (itself an intensive source of water use). These issues are discussed in more depth in the context of the urban water–energy nexus in the Greater Mekong Sub-region elsewhere.[11] The paper does not directly address the water–food–energy nexus, but the underlying analysis shows that when food enters the equation the urban demand for water increases by an order of magnitude. However, since most of the populations are already urban in the Gulf region, these effects have already been observed and are embodied by the increased import of "virtual water" as food.

Water and Food Security

The concept of joining "water" and "food" security has recently come into widespread use, and there have been many seminars, conferences, and publications on this subject. In this section we examine the definitions of water security by itself, and later in conjunction with food security.

There are a large number of definitions of water security, most of which focus on physical quantities, such as Falkenmark's less than 1,000 cubic meters per capita per year,[12] or even Maplecroft's Water Security Index,[13] which has a broader basis. Ultimately, it is a weighted average of: access to improved drinking water and sanitation; the availability of renewable water and the reliance on external supplies; the relationship between available water and supply demand; and the water dependency of each country's economy. However, this definition does not make the distinction between internally available water and actual water resources available for use—it is still heavily weighted by the internally available water, not the actual amounts used. So in the 2010 index, Egypt, Kuwait, the UAE, Libya, and Saudi

Arabia were ranked as the most at risk countries worldwide, and categorized as being at "extreme risk." While each of these countries have very limited internally available renewable water, none of them – for a variety of different reasons – faces an extreme risk in terms of water security. Egypt has appropriated most of the flow of the Nile, which is an external source, and the other four countries are all wealthy oil-producing countries which for the foreseeable future will be able to "buy" their way out of water scarcity via desalination and imports of water intense-products such as food.

This leads us to attempt to find definitions that could be more useful for policy makers. The following definitions, which are not narrowly focused upon the magnitude of fixed "water supplies," attempt to move from general descriptive formulations to very specific applications.

Water Security

A good general definition of water security was given by the Global Water Partnership, and is paraphrased as follows: A water secure world integrates a concern for the intrinsic value of water together with its full range of uses for human survival and well-being. A water secure world harnesses water's productive power and minimizes its destructive force. It is a world where every person has enough safe, affordable water to lead a clean, healthy and productive life. It is a world where communities are protected from floods, droughts, landslides, erosion and water-borne diseases.[14]

This is a comprehensive statement about the consequences of water security, but does not define exactly what is meant in operational terms by water security itself. A more precise and more useful definition is given by Grey and Sadoff:

> … the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies.[15]

From these definitions we can deduce that water security relates operationally to the risks associated with not having given levels of water quantity and quality. So, as mentioned above, a direct way to assess water security would be to establish those levels and compute the risk associated with not achieving that level.

The discussion about water security is all about "risk." It relates operationally to the risks associated with not having desired levels of water quantity and quality. So, a direct way to assess water security would be to establish those levels and compute the risk associated with not achieving them. Unfortunately we know little about the magnitudes of these risks, even for the most obvious levels of water need in terms of domestic use; the consequences of not achieving desired water quantity and quality levels are not well understood. We understand even less about the consequences for groups of individuals. Even if we were able to determine these levels, there are many other water uses which conflict with them; for example, many societies assign acceptable statistical risk levels for floods (one in 100 years, or one in 10,000 years), but these levels may conflict directly with the acceptable risk levels for facing droughts or for other natural or man-made disasters. For example, the recent floods in Thailand—in this instance there was a major connection between the storage of water for dry season agriculture and releasing water to make storage available to reduce some of the flood peaks. We are no longer looking at independent events, but rather coupled events which have joint probability distributions. In this case the agricultural communities and the hydropower sellers and purchasers were much more secure due to the construction of storage reservoirs, but downstream urban dwellers were made much more water insecure by the operation of these upstream storages.

Rogers et al. show that trying to assess the multidimensional aspects of water security leads directly to an insolvable index problem.[16] The creation of a water security index requires us to be able to assess risk, and then integrate inter-personal and inter-group preferences for risk (which are in themselves intractable problems). However, as in many societal issues, some outcomes seem preferable to others. Hence the struggle to assess water security should focus on comparing and contrasting outcomes. For instance, for some communities the insecurity of facing a drought will have much larger economic consequences than a similar risk of flooding. Restricting the outcomes to single value measures such as economic losses, or at most dual measures – economic losses and loss of life – would make the analysis much easier to understand. The actual measurement of security could then be easily computed by the well-known formula: risk equals outcome times the probability of it occurring. Therefore, if the probability of floods hitting a country and causing US $5 billion in damages and 200 deaths is 0.1 in any given year, and the probability of droughts causing $25 billion and 50 deaths is 0.0001 in any year, this would give the country an annual water security level of $ 502.5 million in economic loss potential and 20.005 lives lost. If one were willing to use the statistical value of a life lost (a current US figure is around $3 million), then these two measurements could be collapsed into one simple water security metric of $562.5 million. This simple hypothetical model has many hidden – and not so hidden – assumptions that make it a less than analytically perfect tool. It is a fairly robust and easily understood approach to the irresolvable index number problem, but it does not easily resolve the multidimensional conflicting uses of water that will affect the uncertainty levels surrounding water and food supplies.

The latest UN World Water Development Report, entitled "Managing Water under Uncertainty and Risk,"[17] is devoted entirely to discussing how best to characterize risks associated with all aspects of water management:

> Risk perception and tolerance depend on a person's likelihood of harm, control over harm, extent of harm or hazard, voluntariness of exposure to possible harm, and trust in the sources of risk information.[18]
>
> … Uncertainty can result from variability of an underlying process or incomplete knowledge of that process. Decision-makers are often required to make decisions, sometimes having considerable consequences and involving considerable expenditures of money, without knowing with adequate certainty the extent of those possible consequences and expenditures.[19]

In an uncertain world decision makers look for best outcomes, but risk analysts can only offer the best strategy for action now. In the absence of providing best outcomes the analysts can offer plausible scenarios which decision makers can ponder, bringing their own perceptions and prejudices to help choose a path for the future. Donald Rumsfeld, the former US Secretary of Defense, is purported to have said that there are “known knowns, known unknowns, and unknown unknowns.” These can be roughly characterized for water uncertainty as “certainty, statistical uncertainty, and pure uncertainty.” For water the uncertainty may be attributed to several sources:

Hydrological uncertainty: this is the classical concern of hydrologists and engineers. Unfortunately most of the research on this subject conducted during the past 100 years has relied upon concepts of a stationary climate; that is, one that is variable, but for which the mean does not change over time. These can be considered “known unknowns”—in other words we know the distribution of the stochastic outcomes; even though we do not know the exact outcomes we can still posit limits on the potential outcomes with a certain degree of confidence. While we are not sure whether there are long-term trends or cycles in climate, recent events have led to conclude that climate stationarity is not a reasonable assumption. If we are to discard this assumption, however, we must also reject most of the analyses upon which engineering designs have been based in the past, and our confidence in outcomes must be discarded as meaningless.

Knowledge uncertainty: this is an area rife with known unknowns. In this case we assume that uncertainty can be reduced by investing in research in areas of concern such as climate modeling and geophysical exploration. The research will almost always serve to reduce uncertainty regarding outcomes.

Climate change: the known unknowns about climate change are being revealed by the massive research initiatives being spent globally to firm up our estimates of the reliability of the potential outcomes. The unknown unknowns still remain elusive; under what conditions would the great ocean conveyor belts of heat and salinity be disrupted? What about tipping points and irreversible outcomes?

Social and political uncertainty: human behavior is unpredictable; hence, this is the realm of “unknown unknowns.” Water resource literature contains few studies on the relative contribution of social and political uncertainty upon the variability of outcomes. One study by

James, et al.,[20] comes to mind, in which the authors analyzed the relative contributions of political, economic, environmental, and hydrological uncertainties. Using four-way analysis of variance they demonstrated that political decisions were much more likely to be responsible for variations in outcomes than any other source.

Given the pervasive nature of uncertainty, it is understandable that the following phenomenon is often observed:

> The results from quantitative and qualitative analyses, based on science and economic principles, are often considered less relevant than political factors, emotion, religious beliefs and just gut feelings based on intuition.[21]

Unfortunately, after several hundred pages of discussion elaborated with many case studies, the WWDR4 report was not able to provide a simple and coherent approach to dealing with uncertainty and risk. It seems that the subject is subject to considerable "uncertainty."

Food Security

As with water security, there are many diverse ways of defining food security. The World Food Summit of 1996 organized by the Food and Agriculture Organization,[22] defined food security as existing; "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life."

Commonly, the concept of food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences. In many countries, health problems related to dietary excess are an ever increasing threat; in fact, malnutrition and food-borne diarrhea are a double burden. There are at least three components that have to be considered:

- Food availability: sufficient quantities of food available on a consistent basis
- Food access: having sufficient resources to obtain appropriate foods for a nutritious diet.
- Food use: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

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The recent Commission on Sustainable Agriculture Climate[23] had several important observations on food security and water. Their focus was on increasing food production, reducing losses in the food chain, and reducing the demand for food by suitable adjustments of the composition of diets. If handled properly, meeting the global food demands of 2050 would be a fairly orderly process, although "… none of these three policy approaches alone are sufficient to achieve the goal and all three require substantial innovation in the food system."[24] In each of these three action areas there would be major opportunities for reducing the pressure on the world's water resources.

Hydrological Uncertainty and Climate Change

Of course, the world is not homogeneous with respect to climate, water resources, and levels of social and economic development. For example, in 2007 a comprehensive view of water development in the MENA region was produced by the World Bank,[25] which classed the countries of the region into three distinct types based upon their water situation:

Variability: this group of countries has adequate quantities of renewable fresh water (with variations in different parts of each country). Examples include Algeria, Djibouti, Lebanon, Morocco, Tunisia, and the West Bank. For these countries a major concern is the internal distribution of the resource.

Hyper-aridity: this group experiences low levels of renewable water resources and depends heavily on non-renewable groundwater and desalination of seawater or brackish water. Countries in this group include Bahrain, Gaza, Jordan, Kuwait, Libya, Oman, Qatar, Saudi Arabia, the UAE, and Yemen.

Transboundary water: this group depends on international water bodies, with as much as two thirds of its renewable water supply coming from outside the region. The major countries in this group are Egypt, Iraq, and Syria.

This categorization shows the heterogeneity of the countries within the MENA region and the futility of providing one set of policy recommendations for the region as a whole, as attempted by Rogers and Lydon.[26] Even within the six GCC countries – all within the hyper–

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aridity group – Al-Zubari points out the large heterogeneity of rainfall ranging from less than 70 mm per annum to more than 500 mm per annum (south-western Saudi Arabia and along the Gulf of Oman).[27] The societies in the GCC countries have individually developed elaborate technologies over many millennia to deal successfully with problems of water supply and development which today are struggling to counteract the forces of rapid economic and population growth. They are now trying to put these institutions and technologies into a modern nation-state context, in the face of – potentially major – climate change.

One advantage of hyper-aridity is that the water environment is much less forgiving than in the well-watered regions of the world. This means that individuals and decision-makers are much more likely to be risk averse. As indicated by the papers on water availability cited above, as time has progressed the GCC countries have become increasingly committed to choosing water supply technologies with ever-increasing levels of variability. The exception to this is desalination, which removes uncertainty of supply, but relies almost 100% on the supply of energy. Therefore, water supplies have become more secure – albeit at a higher cost – than in the past. This is a good strategy, provided energy supplies are themselves secure.

We know that precipitation in the region is variable. Kuwait, for example, has a mean precipitation of 110–190 millimeters per annum and a standard deviation of 40–70 mm.[28] This implies a distribution with a low mean and high variation, with long tails on its statistical distribution. We do not know how the statistical distribution of precipitation will change in the future; however, if there is an increase in variability – as currently seems to be occurring – the prospect of more extremes of rainfall is the worst case scenario for long-tailed distributions. This could lead to major shifts in the actual risk levels faced in terms of food production and available water supply. Of course, if this were to happen, the GCC countries could continue to plan around their almost risk-free investments in desalination.

Global Lessons for Water Resources Management

Water management decisions are always political in nature. The allocation of water rights to users involves political decisions between and among

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groups which will affect the globe long after we have departed. What makes water interesting is that those political decisions are heavily impacted by technical and economic choices. There is a continuum along which benefits accrue to different groups of individuals as the type of decision moves away from activities that can be easily privatized toward those with qualities that serve the public interest, such as flood control and sanitation. Rent-seeking behavior sees many groups attempt to label all water investments "public goods" which should be paid for by the whole of society while they reap the private benefits. This is often referred to as "privatizing the benefits and socializing the costs!"

As long ago as 1962, the political scientist Arthur Maass pointed out the failings of traditional water planning in the United States;

> In the past, water planners and engineers, in search of constraints to simplify the task of system design, have found it convenient to read inflexibility into governmental institutions and to treat them as immutable, if irrational, restrictions. On the contrary, there is and should be considerable flexibility in legal and administrative forms, which are quite adaptable in the face of demonstrated economic, technologic, social, or political need.[29]

In particular he stressed the need for leadership, accountability, and the public interest. To modern ears this sounds very much like the enabling environment promoted under integrated water resource management (IWRM). A later review of global water issues concluded that:

> There are three types of water problems to be faced. The first is self-inflicted and is caused by irrational waste of resources. The second consists of problems that can be described but for which there are no solutions that are currently economical. The final type is problems that are amenable to study and analysis and responsive to government policy and investment strategies.[30]

Little can be said about the first type of problem, other than that it should be avoided. The second, such as the consequences of global warming, have no local solutions and even the global solutions look to be uneconomical. This leaves the third type of problem, which is amenable to study and analysis and is responsive to government policy and investment strategies—it is these strategies and policies that we should seek to elucidate.

In 2006 the author's co-edited book, *Water Crisis: Myth or Reality*, claimed that because of mitigating factors including substitution for irrigation water, cheaper desalination, and new dry sanitation techniques, there would be no need for the world to suffer a "water crisis."[31] This does not mean that there would not be major problems with water management in the future in certain regions, but rather that we have all of the physical resources and required technologies in place, but may not yet have developed the social and political institutions to transform this "crisis" into a "problem."

The book proposed "Six Steps to Enhance Water and Food Security." We believe that these six steps can be followed anywhere in the world and will apply to the hyper-arid GCC countries. Obviously any way of improving the efficiency of water use will free up more water for enhancing food security. Four of the steps are based upon existing technology and two rely mainly on socio-economic and political actions by governments:

- Conserve irrigation water (technical changes): using water saving technologies such as center-pivot and drip irrigation can greatly reduce water use by as much as two thirds and double crop yields. In a given setting these technologies have the potential to expand the water resource base by significant amounts.

- Invest in water infrastructure (maintenance issues): in many settings water is lost due to non-beneficial evaporation and seepage as a result of poor maintenance of both irrigation systems and urban systems. As water becomes more scarce (and valuable), maintenance practices will improve.

- Exploit advanced desalination technology: Dawoud and Abderrahman document the rapid development and reduction in cost of desalination in the GCC.[32] This is certainly now cost-effective for municipal and industrial uses and may be approaching cost-effectiveness for irrigating horticultural products.

- Wastewater recycling (cuts water demand): taking advantage of new low cost desalination techniques enables urban areas to recycle their wastewater for potable and non-potable uses. This will relieve the pressure on new sources for urban areas, leaving more water for food and ecosystem use.

- Water pricing—toward full socio-economic costing: in most parts of the region water is underpriced,[33] with huge government subsidies remaining unchanged for almost 20 years.[34] This leads to overuse of water resources. Policies need to be set in place to gradually raise water tariffs to cover the full economic costs and ultimately the full environmental costs. This will require major social and political efforts, but will in the long-run result in substantial water savings. Also, increased charges for water will make newer technologies such as desalination more economically attractive, and will also enable utilities to implement maintenance and conservation technologies which are currently uneconomical.
- Ship virtual water—rationalize the food trade: one of the major means of conserving water and increasing water and food security is by exploiting the potential for using virtual water embedded in imported food and agricultural products. Another way is by direct importation of water. Dawoud and Abderrahman, and Al-Rifia,[35] review potential supply sources in Turkey, Egypt, Iran, India, and Pakistan, and conclude that they are much more expensive than *in situ* desalination. For conventional foodstuffs, however, nothing comes close to relying on the importation of virtual water.

Conclusions

Water and food security remain major concerns for many countries around the globe. The countries most at risk are those with large populations and meager water supplies, particularly if they are low-come countries with poor agricultural lands. The continent of Africa will see most of the more stressful manifestations of hunger and malnutrition, but the hyper-arid countries of the GCC will be well placed to take advantage of many of the six steps outlined above to avoid the crisis, because even if the water supply in the future is reduced and is more variable because of climate change, the GCC countries will have the economic clout to be able to move ahead and improve water and food provision for their populations, and to develop water resources which go way beyond the shrinking water supply base.

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We believe that the emphasis on food and water should go beyond the traditional focus of government investment in irrigation facilities and production enhancing activities including agricultural research, extension, and subsidies for chemical inputs. There is also a need to pursue nutritional management of their populations to ensure healthy, low-impact production and develop logistic approaches that reduce "field-to-fork" losses. These two neglected areas can help in achieving the goal of feeding the world by 2050, as is discussed in great detail by the Commission on Food Security and Climate Change.[36]

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2

Challenges Facing the Management of Water Resources

Seetharam Kallidaikurichi and Mingxuan Fan[*]

Water is the lifeline of our planet. Across various cultures, we share a common perspective with regard to water as a symbol of reconciliation, healing and regeneration. Water is not only essential for sustaining human life, but also important for public health, food and energy production, and hence the prosperity of our society. Despite this common perspective, however, there is no global consensus on standards for important indicators such as the minimum per capita requirement for water. Various organizations and researchers have advocated different standards, ranging from 20 liters per capita per day (lpcd) for *basic domestic health and hygiene needs* (according to the United Nations Children's Fund [UNICEF] and the World Health Organization [WHO]), to 4,651 lpcd of *drinking water for active and healthy human life* by the Water Assessment Program. As Chenoweth[1] rightly points out, existing estimates of human water requirements based on specific quantities of water for basic domestic functions are much lower than those based upon water quantities actually used by a modern society which utilizes its water resources relatively prudently, and are at least an order of magnitude lower than actual water requirements for satisfying domestic, industrial and agricultural needs.

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Chenoweth also estimated, using a self-proclaimed, more theoretical approach, that 135 lpcd is required for achieving high human development.[2] This estimate has become more relevant in the context of the recent announcement that the Millennium Development Goals' (MDG) target on water, "to halve, by 2015, the proportion of the population without sustainable access to safe drinking water," has been achieved three years ahead of the timeline. Now, therefore, is the time to not only focus on providing access to drinking water to the remaining population, but also to ensure that the quality and quantity of water accessed is sufficient to sustain high human development. Continuing with the estimation, Chenoweth concluded that according to the data from the Food and Agriculture Organization (FAO), all countries, except Kuwait and the United Arab Emirates, have the water required – more than 135 lpcd – to achieve high human development.[3] For Kuwait and the UAE, high human development has already been achieved due to the significant income received from petroleum exports, and the shortage of water compensated for through desalination. This conclusion reconfirmed that the current challenges in the water sector are not about shortage of resources, but rather about the policy, governance and management pertaining to water resources. Based on the findings of various research projects at the Institute of Water Policy, in this paper we present challenges to water policy, water governance and urban water management, and the best practices that can be employed to address these challenges.

Water Policy

A decade ago, Biswas critically reviewed the state of water polices in the developing world and pointed out that rational water policy formulation and implementation had received only lip service, and that practitioners in the water policy profession had failed to formulate, implement and update national or sub-national water policies on a regular basis in most of the countries of the world.[4] He also predicted that water policy issues were likely to continue to receive inadequate attention over the near to medium term. A decade later, Bhullar, from the Institute of Water Policy (IWP), conducted a desk review on the national water policies of 136 developing members of the United Nations (not including island states).[5] Based on secondary sources, the review identified countries with designated national

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water policies—that is, countries with a national water policy (NWP), a national water resources policy (NWRP), a national integrated water resources management (IWRM) policy, or a variant thereof. It also listed the countries with documents containing water plans, programs, strategies, or laws instead of a designated national water policy. Table 2.1 summarizes the status of national water policy across five geographical regions.

Table 2.1

National Water Policies in 136 Developing Countries

Region	Countries [information obtained]	Countries with designated NWP	Countries with NWP in other forms*	Countries with NWP under preparation
Africa	49[40]	26	11	2
Asia and Oceania	36[33]	17	12	3
Caribbean	11[11]	5	6	0
Latin America	21[19]	15	4	0
Middle East and North Africa	19[19]	6	13	0

Notes: *This category includes countries with water laws / plans / programs / strategies, countries that included their water policies in other documents as well as countries that have formulated draft NWPs but have not approved or adopted them.

Source: Lovleen Bhullar, "National Water Policy: A Brief Review," in Kallidaikurichi E. Seetharam and Mingxuan Fan (eds.), IWP Staff Papers 2011 (Singapore: National University of Singapore Press, 2011), pp. 3–20.

Of the regions covered, in the countries that provided information, Africa had one country with no NWP and nine with no information available, meaning over twenty percent of NWP data was unavailable for the continent; in Asia and Oceania, there was one country with no NWP and three with no information; in Latin America, two countries had no information. Only in the Caribbean and the Middle East and North Africa (MENA) were all countries accounted for, each having an existing NWP in one form or another.

Although the paper did not examine in detail the actual implementation and the impact of these national water policies, it provided evidence that more and more countries are concerned about and have formulated policies,

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plans or laws for water resource use and management as compared to a decade ago. However, more intensive studies are required before we can draw any conclusions on the progress of NWP implementation, as we have yet to discern if these NWPs are relevant and can keep pace with the fast-evolving water sector due to climate change, technology advancement, and economic development. In low lying countries alone, climate change is certain to cause significant changes in water use and management. Since the quantitative short and long term effects of climate change are not reliably known as yet, it seems realistic to expect that new NWPs will have to be drafted to deal with the changes in water management as water issues become more apparent. Additionally, it is almost certain that climate change will have an effect in high-lying areas as well, not to mention the effects on developing and developed countries.

While it is crucial for countries to work towards improving the relevance of their national water policies, managing inter-sector linkages and prioritizing water in their national development agendas, it is also critical to realize the risk involved in the policy changes, as only those insights derived from a solid understanding of the circumstances on the ground can lead to desirable policy changes. This, in turn, relies on good quality data and monitoring tools. The Institute of Water Policy has always been active in campaigning for standardized and regular data collection in water and related sectors. Nevertheless, we acknowledge that it requires long term efforts to bring about change, and improved data would only be able to provide policy insights when collected over a period of time.

To assist policy making based on the limited data available for the drinking water sector, Kallidaikurichi Seetharam and Bhanoji Rao at the Institute of Water Policy developed and applied the Index of Drinking Water Adequacy (IDWA).[6] The IDWA was originally proposed and constructed for 28 Asian economies in the *Asian Water Development Outlook* (AWDO) 2007 of the Asian Development Bank (ADB), inspired by the success of Human Development Index (HDI) and the lack of appropriate indicators for MDG monitoring, and building on the work of the Water Poverty Index.[7] The IDWA is constructed by the averaging of five components, namely: water resources availability; access to improved drinking water sources; capacity to buy water; water quality; and water usage. Each component consists of only one essential indicator. The details on indicators and the calculations for components of the index are shown in Figure 2.1.

Figure 2.1

IDWA Indicators and Estimates

***Resources*:** Estimates of renewable internal fresh water resources per capita, Resource Indicator for country j = $[(\log R_j - \log R_{min}) / (\log R_{max} - \log R_{min})]$ x100.

***Access*:** Instead of a percentage of the population with access to sustainable "improved" water sources, the percentage of the population with a "house connection" is used in this index. Access Indicators for country j = the percentage of the population with a house connection x100.

***Capacity to Buy Water*:** Per capita GDP in US dollars (PPP) is used as a measure of a nation's capacity to produce, purchase and supply adequate amounts of drinking water. The capacity indicator for country j = $[(\log C_j - \log C_{min}) / (\log C_{max} - \log C_{min})]$ x 100.

***Use*:** This component calculates the per capita water consumption by the domestic sector. The norms for minimum and maximum consumption levels are retained as 70 lpcd (as per the Indian government's standard for minimum water need) and 167 lpcd (as the Singapore level in 1995, which guarantees 24/7 water supply of directly drinkable tap water), and the use indicator for country j is calculated as: $[(U_j - 70)/(167-70)]$ x 100.

***Quality*:** WHO data on diarrheal deaths per 100,000 people for the year 2000 is used as an indirect measure of drinking water quality. The quality indicator based on the diarrheal death rate for country j = $(Q_{max} - Q_j) / (Q_{max} - Q_{min})$ x 100.

Source: Kallidaikurichi E. Seetharam and Bhanoji Rao, *Index of Drinking Water Adequacy: International and Intra-national Explorations* (Singapore: National University Press, 2010).

In 2010, the index was further modified and applied at the global level, and to the various states in India and provinces in China, compiled in the monograph "Index of Drinking Water Adequacy: International and Intra-national Comparisons."[8] The IDWA offers a number of advantages, in that it is more comprehensive than the single access indicator used for MDG monitoring, and yet much more straightforward compared to other indices of a similar kind, such as the Water Poverty Index.

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Although not its primary purpose, the index can be used to illustrate a country's relative standing in terms of drinking water adequacy. Table 2.2 presents the IDWA and ranking for selected countries. The index helps in visualizing the broad areas of weakness in the water sector of each country; for example, the lack of resources in Singapore and Saudi Arabia, and the low quantity of water used for domestic purposes in Yemen, which requires the government's attention. In many cases, the measures taken to address the pressing issues under the stress and urgency of improving the situation have turned out to be the best practices in its area – for example, Singapore's water reuse and rain water collection to improve the resource availability – these will be discussed later in the paper.

Table 2.2

IDWA for Selected Countries

	Resource	Access	Capacity	Use	Quality	IDWA	Ranking
Japan	49.2	97.0	90.0	86.8	99.7	84.5	14
Singapore	17.4	100.0	100.0	100.0	99.9	83.5	18
Iran	43.0	82.3	68.0	74.8	96.6	72.9	56
Saudi Arabia	13.7	77.0	83.2	75.9	98.1	69.6	65
China	44.6	69.1	60.8	48.8	97.7	64.2	74
India	38.2	30.9	45.1	64.1	88.2	53.3	93
Yemen	20.4	26.2	40.2	0.0	73.3	32.0	125

Source: Seetharam and Rao, op. cit.

At the state level, the IDWA could help with more concrete policy-making. Fan constructed IDWA data for the provinces of China and argued that IDWA could help the national government perceive water challenges from a regional perspective.[9] The example given concerned the measures needed for addressing Beijing's water shortage. The water shortage in Beijing (the municipality has a resource index of 33) has long been a concern of the Chinese government. Over the years, the city and its surrounding areas have been receiving water transferred from the neighboring province of Hebei, which also suffers from a severe water shortage (the province has a resource index of 39). Such an arrangement obviously has its political appeal but should not be considered as a viable option in the long run owing to its potential damage to the people, economy and environment in Hebei. With the IDWA as a policy supporting instrument, the disadvantages of this arrangement are more clearly illustrated. Longer term solutions would have to be based on a serious discourse on inter-provincial differences and coordinated policies and programs. The IDWA and its variants, based on further modifications and simplifications, could serve to alert central and provincial governments on the gaps to be filled and differences to be bridged by coordinated efforts for all to be well served with an appropriate quantity and quality of water.

The IDWA is only one example of how high quality data could be used to assess, monitor and benchmark performances in the water sector, hence assisting in better policy making. The Institute of Water Policy stresses that the challenges for the water sector are not only to have relevant policies and plans, but also to have adequate monitoring systems to support policy making, without which it would be impossible to formulate the right policy.

Water Governance

The Organization for Economic Cooperation and Development's (OECD) recent study on water governance reconfirmed that the key obstacles to improving water management are institutional fragmentation and poorly managed multi-level governance.[10] Improving water governance across all levels of government is considered a prerequisite for sustainable water policy and crucial to achieving water security.

As defined by the OECD,[11] water governance formally refers to a set of administrative systems, with a core focus on formal institutions (e.g., laws and official policies) and informal institutions (power relations and practices), as well as organizational structures and their efficiency. It considers institutional and policy frameworks that foster transparency, accountability, and co-ordination as part of good water governance. The study identified the main multi-level governance challenges in the water sector and organized those around seven gaps, namely, the administrative gap, the information gap, the policy gap, the capacity gap, the funding gap, the objective gap and the accountability gap. Based on a single proxy indicator for each gap, the study concluded that given the mutual dependence that arises from decentralized contexts and the network-like dynamic of multi-level governance relations, most of the OECD countries studied face almost all the above challenges simultaneously. Table 2.3 presents the gaps, proxies and results based on the study of 17 OECD member countries.

Table 2.3
Multi-level Water Governance Gaps in OECD

Gap	Proxy	Countries*
Administrative Gap	A mismatch between hydrological and administrative boundaries	9
Information Gap	The existence of asymmetries of information between central and sub-national government organizations	9
Policy Gap	The existence of overlapping roles, or the unclear allocation of roles and responsibilities	9
Capacity Gap	The lack of technical capacity, staff, time, knowledge and infrastructure	11
Funding Gap	The instability or insufficiency of revenues available to the sub-national government to effectively implement water policies	11
Objective Gap	The existence of intensive competition between different ministries	4
Accountability Gap	The lack of citizen concern about water policy and low citizen involvement in the water users' association	9

Notes: *This column counts the number of countries that considered the gap as important or very important to their country.

Source: Organization for Economic Co-operation and Development (OECD), *Water Governance in OECD Countries: a Multi-Level Approach* (Paris, France: OECD Publishing, 2011).

The capacity and funding gaps are the two most important, followed by the administrative, information, policy, and accountability gaps. The objective gap is seen as the least important.

Acknowledged by the OECD study, the Asian Water Governance Index (AWGI) is another tool used to understand governance practices in

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water sector. The AWGI was developed by Araral and Yu at the Institute of Water Policy, using the institutional decomposition method.[12] The index covers the three dimensions of institutions, namely water law (using six indicators), water policy (eight indicators) and water administration (six indicators). The three dimensions focus on different aspects of the water governance problem between countries. These indicators are shown in Table 2.4.

Table 2.4
Asia Water Governance Index

AWGI Dimension	AWGI Component
Water Law	Legal Distinction of Different Water Sources
	Format of Surface Water Property Rights
	Legal Accountability of Water Sector Officials
	Decentralization Tendency within Water Law
	Legal Scope for Private and User Participation
	Legal Framework for Integrated Treatment of Water Sources
Water Policy	Project Selection Criteria
	Linkages with Other Policies
	Pricing Policy
	Private Sector Participation
	User Participation
	Linkage Between Water Law and Water Policy
	Attention to Poverty and Water
	Finance for water Investment
Water Administration	Organizational Basis
	Balanced Functional Specialization
	Existence of Independent Water Pricing Body or Apex Body
	Accountability and Regulatory Mechanisms
	Validity of Water Data for Planning
	Science and Technology Application

Source: Eduardo Araral and David Yu, "Asia Water Governance Index," Institute of Water Policy, Lee Kuan Yew School of Public Policy, University of Singapore, undated (http://www.spp.nus.edu.sg/docs/AWGI%20brochure-IWP-LKYSPP%289-10%29.pdf).

Although the AWGI and OECD studies took on slightly different approaches, such as the number and grouping of indicators and the presentation of survey results in identifying water governance challenges, the main focus of each is similar. Contrary to the OECD's

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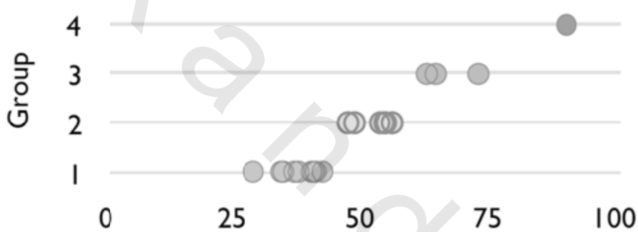
understanding, the index did not aim to rank countries, but was instead used by countries to identify the challenges in their own water governance and to trigger a cross-country knowledge exchange based on comparative studies and advantages. Although the index is constructed by weighing and aggregating 20 institutional components and the resulting measurement is on a scale of 0 to 100 (with 100 being "Leading Governance," 0 being "Lagging Governance"), the actual rankings of countries are not released. Rather, they are arranged into four broad categories. Figure 2.2 presents the preliminary result based on 102 survey responses from 20 countries/states in Asia-Pacific region.

Figure 2.2
Asia Water Governance Index: Overall



Group 4	Singapore
Group 3	Australia, Japan, Taiwan
Group 2	New Zealand, Korea, China, Thailand, Vietnam, Philippines, Indonesia
Group 1	India, Bangladesh, Pakistan, Sri Lanka, Nepal, Uzbekistan, Mongolia, Laos, Cambodia

Source: Eduardo Araral and David Yu, "Asia Water Governance Index," Institute of Water Policy, Lee Kuan Yew School of Public Policy, University of Singapore, undated (http://www.spp.nus.edu.sg/docs/AWGI%20brochure-IWP-LKYSPP%289-10%29.pdf).

The OECD member countries in the region, namely Australia, Japan, New Zealand and Korea, performed relatively better than other countries in terms of overall water governance. However, the overall index provides only a broad view of how countries perform in governing their water sector, and it is necessary to examine in detail which areas of governance

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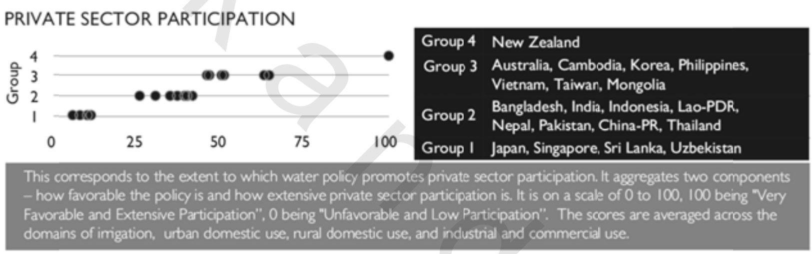
are especially lagging and how each of the indicators is related to one other in an holistic approach. It should also be noted that for certain indicators there is no consensus on whether a higher score is indeed better, although in constructing the index, higher individual scores do contribute to better overall water governance. For example, from the survey results of the AWGI, we can see that both Singapore and Japan, with overall better water governance, do not promote private sector participation; on the other hand, Australia, which also outperformed most of the countries in overall water governance, has a higher level (or more) of favorable private sector participation. This leads to a debate on whether private sector participation is necessary for better water governance.

Figure 2.3
Private Sector Participation



Source: Ibid.

Overall, it is evident that neither the public nor the private sector is superior in rapidly improving water supply performance; both systems have achieved successes and failures. Historically, water sector infrastructure has mainly been delivered by the public sector through traditional procurement methods, such as design–bid–build and design-and-build, using public financing to award contracts to private sector contractors.[13] For a variety of reasons, including a lack of financing, technology and management skills, and the need for mitigating risks, governments in both developed and developing countries increasingly rely on the use of private finance initiatives (PFIs) and public–private partnerships (PPPs) for developing water infrastructure facilities. Worldwide, as of 2006, water services were operated by the private sector in 11 percent of the cities with a population of more than one million, ranging from none in South Asia, to 7.2 percent in East Asia, 9.5 percent in the MENA, 13 percent in high income countries, and 17 percent in Latin America.[14] However, not all PPPs have been successful in this area, and for various reasons – such as severe economic crises – there has even been a reversion to public ownership in certain regions—especially Latin America.

A team at the Institute of Water Policy is carrying out a research project to collect sufficient data and information to figure out which type of architecture is seen to be most efficient under various different circumstances. Thus far, the project findings show that for PPPs to work in developing countries, the public sector should first understand the commercial viability of engaging private sector entities, as no private investor invests in a project that is unlikely to return profits. The two key issues, therefore, are whether members of the public could afford water provided by private operators and, if not, whether the rates could be subsidized using public funds.[15]

In some countries – particularly developing countries – citizens still expect water to be delivered free as a basic right—under which neither publicly nor privately operated water utilities could function owing to a lack of revenue. Hence, a simple discussion on whether private sector involvement would improve water sector performance is not sufficient. It is necessary to engage government, the corporate sector and society in a three-way collaborative effort towards defining and driving service delivery. Padawangi presents cases of private water companies, as a result of lack of investment, seeking the support of public financing institutions (the Global Partnership for Output Based Aid in particular) and the involvement of informal leaders and representatives among the urban poor, to expand the water services to poor communities in Jakarta and Manila.[16]

Although these cases show significant improvement in service provision to the urban poor, they raise questions as to whether the provision of services would give the urban poor incentives to voice challenges to a system that still works against them. Nevertheless, with the community distinctly involved, and the poor empowered, the government–corporate–society partnership could result in greater long-term benefits.

Urban Water Management

Even with a relevant water policy and appropriate governance structure in place, dysfunctional water utilities could still undermine the efforts that countries implement to address water challenges, which are very different in urban and rural areas. In general, urban water challenges can be categorized into five main areas, corresponding with each of the IDWA components mentioned earlier:

- *Resource availability*: unlike many parts of the world, physical water scarcity is not the main issue for most Asian countries—rather, it is mismanagement of water resources, inefficient water use and deteriorating water quality, which cause stress on water resources.
- *Access to water*: to give equal access to water, it is believed that a piped water connection into each household is the optimal solution;[17] however, the access rate in terms of house connections is still low in most developing countries.
- *Capacity*: the ability to pay for pipe installation and water tariffs is still low in much of Asia.
- *Quality*: in general, water quality is deteriorating for many reasons outside the water sector.
- *Use*: water for domestic use is not sufficient in some countries as a result of loss in the process of water distribution, which can be very inefficient.

At times, those countries facing the severest challenges have improvised an effective solution to address the above-mentioned challenges; sometimes one solution can tackle more than one aspect of a challenge. In a research project on urban water management in eight Asian cities – Bangkok, Colombo, Kula Lumpur, Manila, Phnom Penh, Singapore, Shenzheng and Jamshedpur – implemented with the support of the Asian Development Bank, we analyzed the performance of water management in tackling the above-mentioned challenges, identifying the factors that contributed to their successful performance over a ten-year period. The next section provides examples of how these challenges have been addressed in selected cities.

Breaking the Constraint of Physical Water Scarcity

Singapore is one of the few Asian countries that faces physical water scarcity. As a small city state with no natural aquifers or abundance of land, about 40 percent of Singapore's water supply was imported from the neighboring state of Johor, Malaysia, under the terms of treaties signed before Singapore became an independent country.[18] Since independence in 1965, the long-term water security of the country has been the main concern of its leaders, and achieving self-sufficiency in water has long been a priority in the country's political agenda. Over the last 40 years, through strategic planning and investment in research and technology, the Public Utility Board (PUB), the national water agency of Singapore, has built a robust and diversified supply of water known as the "Four National Taps." The water supply is comprises:

- *Local catchment water*: rainwater is collected through a comprehensive network of drains, canals, rivers and storm water collection ponds before it is channeled to Singapore's seventeen reservoirs. This makes Singapore one of the few countries in the world to harvest urban storm water on a large scale for its water supply, with two thirds of the country's land used as catchment areas.[19]
- *Imported water*: one of the two water agreements with Malaysia ended in 2011, which brought the country one step closer to self-reliance in terms of water; the second treaty will expire in 2061.
- *Highly-purified reclaimed water, known as NEWater*: NEWater is high-grade reclaimed water produced from treated used water that is purified using advanced membrane technologies, making the water ultra-clean and safe to drink. NEWater has passed more than 65,000 scientific tests and surpasses World Health Organization requirements for water quality. Although mostly supplied to industries, PUB also blends a small percentage of NEWater with reservoir water, which is later treated for domestic use. Since 2003, four NEWater plants have been installed and at present, their production can meet one-thirds of Singapore's water demand.[20]

- *Desalinated water*: in 2005 the first desalination plant was installed in Singapore under the twenty-year build–own–operate model, with a capacity to meet 10 percent of the water demand in Singapore.[21] By 2013, a second desalination plant will be built.[22]

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Increasing Water Coverage to the Urban Poor

Even though Asian cities have a higher rate of water access compared to their rural counterparts, improving water coverage and reaching out to the urban poor are still of critical importance. Indeed, there should be a continuous effort to provide coverage to the urban poor as the fast rate of growth in urban populations could offset the improvement in the overall urban water coverage rate. By finding a way to help low-income communities pay for the high entry cost of household metering, installation, and piping, the problems of a low water coverage rate and residents' low ability to pay are addressed simultaneously. The inclusion of the urban poor into the water supply network also helps the poor reduce their expenditures, because many low-income communities are forced to pay private vendors for water, at prices much higher than utility tariff rates.[23]

An example of a flexible approach can be found in Phnom Penh, Cambodia. With the help of the World Bank's International Development Association and the city of Paris, the Phnom Penh Water Supply Authority (PPWSA) launched a new program targeting the urban poor in 2001, after a number of failed attempts. The program provided tiered subsidies of 30, 50, 70, and 100 percent of the connection fee to poor households, depending on their need. In addition, those households that consume a maximum of seven cubic meters (m^3) of water per month only had to pay 60 percent of the real cost. These measures have led the PPWSA to include about 30 percent of the slum population into its network, proving the efficacy of the subsidy model.[24]

Another innovative example is offered by the Maynilad Water Services in Manila, Philippines. Unlike the main water board in Manila – Manila Water – Maynilad Water Services did not pursue an external funding program to extend the water connection to the poor. Instead, it chose a method of community "self-help" for water, called Bayanihan Bayan Tubig, meaning Communal City Water. The program was launched in 2009 to reduce the cost of obtaining a water connection. Under this scheme, beneficiaries provided physical labor under the supervision of Maynilad engineers to install the pipes that will bring water to their community, hence bringing down the set-up cost.[25] At the same time, a 20 percent discount was applied to the monthly charges for the low-income and informal communities. The success of this method lies in the combination of communal planning, local use of labor, and government subsidies to provide a necessary service to the urban poor.

Monitoring and Reporting Water Quality

The quality of water supplied through a water network is to a certain extent the most critical aspect that determines the success of a water utility as it directly affects the health of the end users.

In the case of the Bangkok Metropolitan Waterworks Authority (MWA), although the piped water that has been supplied has been certified safe for drinking by the Ministry of Public Health and meets the WHO standard, the perception of tap water quality in Bangkok is still very low,[26] and most residents buy bottled water or install water purification units at home rather than drinking tap water directly. In this case, it is the public's *perception of the quality* of water, rather than the availability or actual quality of the water, that is causing a shortfall in use.

To ensure a standard quality of water, the MWA implemented stringent water quality monitoring measures from production to distribution, as well as continuous rehabilitation of the distribution system. The water quality is monitored and reported at three stages:

- Raw water sources.
- Produced water.
- Water in the distribution system and taps.

Around fifty water quality parameters are monitored and reported at these three stages, adhering to a frequency and number of samples in accordance with the WHO standards.

The frequency of quality monitoring is shown in Table 2.5. Analysis includes checking for various physical, chemical and microbiological agents, heavy metals, carcinogenic compounds, and other parameters. Moreover, the MWA monitors in real-time two critical water quality parameters – residual chlorine and turbidity – at twenty locations in the system, the results of which can even be viewed online to assuage public concerns.[27]

Table 2.5

Frequency of Water Quality Monitoring

Stage	Checking Frequency
Raw water sources	Monthly
Production/treatment plants	From every four hours to monthly (depending on the parameter being checked)
Distribution pumping stations	Daily, with one thousand, two hundred (1,200) total samples per year; one hundred samples are collected per month
Consumers' premises	Fifty random samples from certified areas and fifty random samples from other areas
Real-time monitoring	Sampling every ten seconds for two parameters at twenty different locations within the distribution system

Source: M.S. Babel, A.A. Rivas, and Kallidaikurichi E. Seetharam, "Municipal Water Supply Management in Bangkok: Achievements and Lessons," *International Journal of Water Resources Development*, vol. 26, no. 2, 2010, pp. 193–217.

Reducing Non-revenue Water

In order to ensure the availability of water to households, a number of measures are required, one of which is the reduction in non-revenue water (NRW) to close the gap between production and consumption. The PPWSA is one of the best-performing utilities in this area, with an NRW of 6.15 percent in 2009, reduced from 72 percent in 1993.[28] As revealed in an interview by Mr. Ek Sonn Chan, the General Director of the PPSWA, various measures have been taken to tackle commercial and physical losses.[29] First, all connections are metered and illegal connections are immediately stopped. Incentives were provided to people to provide

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information on illegal connections, while heavy penalties were also imposed simultaneously, especially in cases where the staff of the PPSWA were involved. Second, to reduce the physical loss of water in the system, pipes were renewed, leak repair teams were established with a commitment to respond to reported leakages within two hours, and a leakage monitoring system was installed. In the fight against NRW, the PPSWA considers their own staff to be its best resource, and has invested heavily in their capacity-building and provided motivational incentives. A public awareness campaign also helped to make the public an active partner in reducing NRW.

Urban Water Management Best Practices: Barriers and Enablers

In the previous section, selected best practices were presented which addressed various urban water challenges. However, these best practices are not stand-alone factors in achieving successful urban water management. In each city, there are many other aspects that have contributed to this improvement in water management.

For example, throughout the discourse on Singapore's expansion of water resources, political tensions with Malaysia have played a critical role. The leadership of the country placed water security high on its political agenda, and built an autonomous and well-functioning water utility. The country's economic success, clean political environment and efficient government enabled the development of its research and technological capacity, which allowed the implementation of expensive solutions and integrative planning in its water sector.

A similar story of strong leadership can be found in the success of Phnom Penh; however, the leadership comes from within the water supply authority, which has limited power to influence the country's overall political, social and economical environment. Nevertheless, strong political and public support and a reform agenda from within to gain autonomy, financial sustainability and operational capability are the important factors that have led to success in Phnom Penh.

The Institute of Water Policy and the Asian Development Bank have built on the case studies in eight Asian cities and developed the SUCCESS

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model (as shown in Figure 2.4) as a framework for water utilities management.

Figure 2.4

Good Practices: The Success Framework

Notes: UFW = uncounted-for-water.

Source: Asian Development Bank and Institute of Water Policy, *Every Drop Counts: Learning from good practices in eight Asian cities* (Manila, Philippines: Asian Development Bank, 2010).

Each component contributes to the whole:

- *Staff*: increasing productivity.
- *UFW*: reducing uncounted-for-water.
- *Collaborative Vision*: ensuring that government, the corporate sector, and society have the same vision and mutual support.
- *Corporatize*: ensuring that accountability exists, as it would in a private company.

- *Empowering*: guaranteeing the inclusion of the urban poor in any planning and development efforts.
- *Sustainability*: outcomes should be financially and ecologically sustainable in the long term.
- *Sanitation*: general sanitation must be an essential part of the water management process.

As stated earlier, the global water crisis is essentially a crisis of governance, or lack thereof. Inadequate leadership and governance is the fundamental reason that struggles exist in the urban water sector.[30] Hence, the implementation of all best practices ultimately depends upon the political will and leadership available.

Strong leadership and a commitment at the highest political levels are often explained as the critical ingredients for successful utility reform. The vision and leadership provided by Lee Kuan Yew, the first Prime Minister in Singapore, and Ek Sonn Chan, the Director General of the PPWSA in Phnom Penh are often cited as key actors in mobilizing wide-ranging commitment and maintaining a steadfast focus on improving the performance of water utilities in those two cities.[31] In both cases, this vision was backed by decisive efforts among the senior leadership to build a motivated and capable workforce that was fully empowered to translate the vision into practice at the operational level.

Both leaders shared a similar starting point, characterized by the tremendous pressure they were facing. In other words, the lack of political commitment in other cities could be partially due to the lack of knowledge about the water sector or the lack of information on the urgency of addressing challenges in the water sector. For example, charging for water is widely recognized as an essential measure to sustain good water services and is often not implemented correctly owing to a lack of political will—which is often caused by the misconception that the poor are not willing to pay for and will not be able to pay for piped water. However, as numerous cases have shown, the urban poor will often actually pay more to water vendors in order to secure clean water. This is certainly the case in Mumbai, which has chronic water shortages, and where the urban poor routinely have to fight for access to clean water and are often charged (and over-charged) for water provided by private vendors. In other cases, utility managers often see the problem for improving services as a result of a lack of investment. This is another misconception, as even without the initial funding to improve infrastructure, utilities could start to look at improving efficiency and savings from within, and looking at measures that are less expensive. The initiative to make small improvements in service quality could have an effect on building trust between customers and suppliers, which could eventually lead to an increasing willingness to pay and set the utilities on the right track of reform.

Different political, economic and intuitional environments often cast doubt on the feasibility of replicating best practices learned from elsewhere. This is a valid point to a certain extent; however, there has never been a one-size-fits-all solution to solve a problem of this magnitude, and local adjustments must be made to global knowledge in order to produce suitable measures for reform, which can be applied to any city.

At the top, however, insightful leaders and a capable staff all need to be equipped with the right understanding of water challenges and best practices from all over the world; only then can they use their expertise on local circumstances to tailor solutions for their own cities.

Conclusion

Water is becoming an increasingly scarce resource for various reasons, ranging from physical shortages or pollution of fresh water, lack of infrastructure, and fast population and economic growth, to inefficient water use, and competition for water among different sectors. Climate change has added to the uncertainty of water availability. However, it has also been widely acknowledged that most countries have enough water to maintain high human development if they manage their water appropriately; the world water crisis is therefore essentially a failure of water policy and governance.

A major challenge for many countries in the water sector is how to coordinate all the concerned resource policies, legal and regulatory frameworks, and institutions responsible for formulating and implementing these policies.[32] The current and past practices of formulating policies in one sector without adequate consideration of and coordination with the policies in other sectors will become increasingly costly, inefficient, and unsustainable; herein lies a major future challenge for all countries: how to integrate appropriately all the concerned resource policies in the areas of water, energy, food, and environment, the legal and regulatory frameworks necessary to

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support these policies, and the institutions responsible for formulating and implementing these policies. Such integration has been very difficult to accomplish in the past and is likely to be even more difficult and complex in the future. Yet this will be an important and critical requirement that requires accelerated attention from governments, research institutions, and academia.

In this paper, we discussed the current status of water policy around the world and emphasized the importance of completing the policy circle through better monitoring and evaluation schemes. Based on the OECD studies and the Asian Water Governance Index, we identified the gaps in water governance in selected countries and reviewed the dynamic relations among public institutions, private companies and communities in providing water services in urban areas. Moreover, we examined the solutions used to address urban water challenges and provided a SUCCESS framework for urban water utilities management. Through these discussions, we hope best practices in the water sector can be adopted widely.

However, the debate on water policy and governance does not end here. There are many areas which are crucial to successfully addressing water challenges that are not covered in this paper. For example, the relations between water and sanitation and the water–food–energy nexus. We have no substitute for water and no technology to grow food without water; however, this doesn't mean that we should stop seeking technology advancement to address water challenges. Consider the state of telecommunications just 15 years ago, and then compare it with today's situation—mobile phones have connected hundreds of millions of people, who did not have teleconnectivity for decades. Use of mobile phones often even replaced that of existing landlines. In short, we need new solutions to replace traditional technologies.

Finally, we wish to raise a special issue relating to water policy: ethics.[33] As the foundation for improving global water management, we should discourage wasteful practices when it comes to our water and food consumption; ultimately, water governance is first and foremost about governing our own behavior.

Part II

Water Security in the Arabian Gulf Region

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3

The Geopolitics of Water Scarcity

Hussein A. Amery

The severe scarcity of freshwater in the Arabian Peninsula has forced the GCC countries to turn to the sea for a solution, rather than to other countries, near or far. They have chosen to desalinate seawater and ground water in order to ensure their supply, largely as a result of their geo-climatic and geopolitical settings. The hydrological reasons are self-evident, but the geopolitical considerations are the focus of this chapter. It will investigate the geopolitics of water scarcity in the Middle East, with a particular focus on what it means for the Gulf states. It will also discuss the political and security risks of reliance on desalination plants and on water imports.

Conceptually, the approach is one of geopolitics and security. Geopolitics is concerned with developing a spatial or geocentric understanding of the whole by studying specific components and mechanisms such as relative location and asymmetric endowments of countries, which in turn affect relative power and relations among states. For Klare,[1] geopolitics is about competition between current and aspiring great powers "for control over territory, resources, and important geographical positions, such as ports and harbors, canals, river systems, oases, and other sources of wealth and influence." Geopolitics can be illustrated in numerous ways, including as a strategic map showing the "flows of vital resources linking regions and exposing their vulnerability and interdependence."[2]

The Arab world is located in a generally arid region, and conditions have been getting worse for the people there. The renewable water resources available in 1950 were over 4,000 m^3 per capita per year, declining to 1,312 m^3 in 1995, and 1,233 m^3 in 1998, and are projected to

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reach 547 m^3 per capita by 2050.[3] For example, Yemen, one of the most water deficient countries in the world, has an annual per capita water availability of only 125 m^3, compared to the global average of 2,500 m^3.[4] The freshwater that is available for the people of Yemen, or for the GCC countries (Table 3.1), is significantly lower than the global average, underscoring the severity of the situation in this region. Hydrologists classify a country as experiencing "water stress" when its annual renewable water supplies are lower than 1,700 m^3 per person, slipping into "water scarcity" when it reaches 1,000 m^3 per person, and "absolute scarcity" at below 500 m^3 per person.[5] All the Gulf states fall into the latter category.

The hydrological effects of climate change are also exacerbating current conditions. A study commissioned by the World Bank reviewed the results of nine global climate change models and reported that the gross recharge between 2010 and 2050 is expected to drop sharply in "almost all" the MENA countries. In relative terms, Oman, the UAE, and Saudi Arabia are expected to experience the largest declines in the period. The models revealed the largest decreases in internal and external renewable water resources are observed in Jordan (-138 percent), Oman (-46 percent), and Saudi Arabia (-36 percent).[6]

Table 3.1
Renewable Freshwater Resources per Capita, and Percentage of Arable Land in the GCC Countries

	Renewable fresh water resources (m^3 /capita)[(1)]*	Arable land (% of agricultural land)[(2)]
Bahrain	-12	17
Kuwait	07	8
Oman	354	3
Qatar	52	20
Saudi Arabia	95	2
United Arab Emirates	33	11

Notes: *Renewable fresh water resources per capita = (internal flow + inflow of surface and groundwaters) / total population.

Sources: (1) United Nations Statistics Division, "Environmental Indicators: Inland Water Resources," March 2011; (2) United Nations Statistics Division, "Environment Statistics Country Snapshot," 2011 (http://unstats.un.org/unsd/ environment/waterresources.htm).

A new UN report[7] states that the population of the Arab region increased by about 43 percent between 1991 and 2011, and its population of 359 million (2010) is projected to rise to 461 million by 2025.

Variable degrees of water insecurity are prevalent in most arid or semi-arid countries of the world. This insecurity is amplified in the Arab Gulf states because of the accelerated pace of economic development, which has attracted a large number of guest workers, accelerating their rate of natural population growth. From the 1980s to the mid-2000s, natural population growth rates in the GCC countries have been 2.5–3.2 percent per year, which translates into a population doubling time of around 27 years. This high growth rate has been accelerated significantly by the massive number of guest workers that have come to the region since the 1970s. For example, Saudi Arabia's per capita water consumption in 2008 was increasing by about seven percent per year,[8] while population growth was only 2.6 percent per year.[9] Therefore, population growth is not the only force that has been driving the expansion in water consumption, it is also a result of improving quality of life. As the people become better educated, they will develop greater awareness about the importance of hygiene. Similarly, higher incomes often result in greater consumption of protein. Both behaviors yield sizable increases in the demand for more freshwater.

In this respect, it is worth noting that since the early 1900s, water use around the world has been growing at more than twice the rate of population increase.[10] This helps explain the stark empirical results of Maplecroft, a risk analysis firm, which used the following indicators to develop a Water Security Risk Index: countries water stress; population rates; reliance on external water supplies; sustainability of water use; intensity of water use in the economy; government effectiveness; and virtual water use. It found that 14 of the 18 countries that are in the 'extreme risk' category are located in the MENA region: Mauritania (1); Kuwait (2); Jordan (3); Egypt (4); Israel (5); Iraq (7); Oman (8); the United Arab Emirates (9); Syria (10); Saudi Arabia (11); Libya (14); Djibouti (16); Tunisia (17); and Algeria (18). In addition to these, Iran and Qatar were found to be in the "high risk" group.[11] All the Gulf states, therefore, are experiencing severe or high levels of risk, except for Bahrain.

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Water insecurity along with socio-cultural dynamics exacerbate some national security concerns such as existing border disputes, ethnic or sectarian cleavages in society, economic frustrations due to loss of income (e.g., climate change causing agricultural losses), and other divisive challenges. Climate change is making it harder and harder to predict weather patterns. Furthermore, weather events are becoming more intense so, for example, while some regions are experiencing lower precipitation, what rain they receive tends to be very temporally concentrated. This makes it harder for governments and farmers to plan for and adequately manage their meager (hence precious) water resources.

Similarly, just as desalination facilities are becoming ever larger, so is the range of potential threats they face, including earthquakes, cyclones, human error, pirates, trans-national terrorists, and groups of frustrated residents. These threats are real, even though the likelihood of their occurrence varies from very high to rare, depending on location of plants and related facilities, socio-political harmony in the country and the competency of its security services. Although desalination plants have not been the target of terrorist attacks or subject to catastrophic damage from natural hazards, Gulf countries need to plan for the eventuality of extended failure of water supply to a large segment of the population. In a speech titled "The Geopolitics of Climate Change," Chris Huhne, Britain's Energy and Climate Change Secretary, said:

> We cannot be 100% sure that our enemies will attack our country; but we do not hesitate to prepare for the eventuality. The same principle applies to climate change, which a report published by the Ministry of Defence has identified as one of the four critical issues that will affect everyone on the planet over the next 30 years.[12]

This type of reasoning applies to direct and indirect threats to water security, and measures should be taken to prevent both creeping threats and sudden disruption of potable water supplies.

In short, fresh water, already a scarce resource, is becoming harder to find due to population pressure, mismanagement, and climate change. Desalinated water is critical to the well being of the people of the Gulf and to the modern economies they have come to depend on. Enduring disruptions to water supply could have serious ramifications for the social

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and political stability of the affected country. Therefore, a better understanding of threats to water supplies would gauge the social resilience of affected countries, provide useful information to the business sector, and provide respective government agencies with an early warning, while considering preventative or mitigating measures that would ensure water security for all.

The Geopolitics of Water Security

Owing to its arid landscape, absence of perennial rivers, and deficiency of renewable aquifer water, the GCC states have pegged their water security on desalination technology. Desalination plants offer a technological solution to water shortages affecting arid countries that can afford their associated capital, maintenance and operational costs. This technological dependency introduces known and unknown threats to freshwater supply. The notion of "security" has been extended and now encompasses numerous non-military threats such as cyber-attacks, climate change, and degradation of the natural environment. Tindall and Campbell define water security as:

> … the protection of adequate water supplies for food, fiber, industrial, and residential needs for expanding populations, which requires maximizing water-use efficiency, developing new supplies, and protecting water reserves in event of scarcity due to natural, [manmade], or technological hazards.[13]

Grey and Saoff view water security as:

> [The] availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies.[14]

These conceptualizations of water security are centered on people and ecosystems, with some being more explicitly eco-centric. However, given the semi- to hyper-arid landscape, the absence of perennial rivers in the Arabian Peninsula, the rapid depletion of most aquifers, and the fact that the GCC states have pinned their hopes on desalination technology, have all made water security in this region more people- and technology-dependent than in most other parts of the world. Between 1980 and 2005, for example, the water level in the Al-Ahsa aquifer in Saudi Arabia's Eastern Province dropped 150 meters.[15] The high speed of ground water depletion, a shortage of data about the volume of usable water in aquifers, and the agricultural sector's almost complete reliance on aquifer water all point to an unsustainable management of natural waters, and to an agricultural sector that will have to be reformed, modernized, and likely abridged.

In conclusion, the meaning and implications of water security vary in time and space, whereby a nomadic Bedouin's understanding of it is different to that of a dental hygienist, and its impact on the livelihood of a traditional peasant farming marginal lands is more severe than on an urban professional. In the absence of economic means and good governance, water insecurity will endure. This variable understanding of water security necessitates tailoring solutions suitable to the affected area. The policy measures that had been taken by the GCC countries to ensure water security for their citizens are understandable from historical and geopolitical perspectives because when these countries started their major push towards desalination technology, they were quite young, small and unsure of their future. These policies continue to evolve as the Gulf countries mature and learn from their own experiences.

Desalination is Destiny

A UN report states that about 66 per cent of the Arab states' surface waters arise from outside the Arab region, a situation that has at times "led to conflict with upstream countries. Local-level water conflicts can also exist between administrative districts, communities and tribes."[16] Such conflicts are evident in Yemen, and are an emerging issue in Iraq. The symptoms are a weak(ened) central government, peripheral areas that are difficult to govern, and an autonomous Kurdish region which is increasingly assertive. The major Arab countries most affected by trans-boundary water challenges are Syria, Iraq, Sudan, and Egypt. The latter is the most vulnerable because the Nile is its only source of fresh water. This total dependence on one water source carries significant risks for Egypt. What would happen to its water security if climate change were to cause a drop in precipitation levels received in eastern and central Africa or if precipitation patterns were to shift southwards, away from the springs of the Nile? Water consumption, especially for farming, is very wasteful and hence a lot of water can be "found" through greater efficiency. Yet, the people of Egypt are youthful, many are poor, and some are impoverished. In other words, as quality of life improves, Egypt's per capita water consumption is likely to grow, which makes the country's water security even more tenuous. The same applies to upstream states like Ethiopia, which has been actively developing its water resources.

The Gulf states' reliance on nationally-produced water offers them a significant degree of control and security, something not enjoyed by some of the largest Arab countries who share a watercourse with other states. Cooley et al. state that desalination facilities are an important water source in the arid parts of world, such as the Arabian Gulf, "where the natural availability of fresh water is insufficient to meet demand and where traditional water-supply options or transfers from elsewhere are implausible or uneconomical."[17] The authors state that desalination needs to be the very last option that water-deficient countries should explore; in other words, the natural conditions in a state dictate the resource acquisition choices available to its residents which, in some ways, is an extension of the idea of environmental determinism. This notion, which was developed in the early decades of the twentieth century, posits that the physical environment, rather than social conditions, has a deterministic influence on the cultural practices of a given region. For example, natives of mountainous terrain will likely be conservative, and freedom-seeking, while those living in coastal areas tend to be fishermen, traders, and socially tolerant of other cultures. In the Gulf states, the meager water resources initially dictated nomadic lifestyles and oasis-based communities, then water from small wells supplemented the resources of small but emerging urban centers, and then in the early decades of the twentieth century, water was brought in from further and further away including from what is today southern Iraq. This may explain why the founding fathers of the Gulf states found it so natural to choose desalination, an option that amounts to a state-centric, independent, and sovereign solution to the pervasive scarcity. They did not need highly-paid consultants to realize that importing fresh water from other countries carries, arguably, significant political risks. Furthermore, oil endowments made it feasible for the Gulf states to follow this capital-intensive path.

The Gulf states realized that water and food security are central pillars of human security, they made them national priorities. Since the 1980s, there has been rapid cumulative improvements in the quality of life of residents and this has produced an evolution in people's diets and other social habits; hence per capita water consumption has been on the increase. People have been consuming a lot more protein, for example, from beef—which requires the equivalent of 15,000 liters of water to produce one kilogram, while the same amount of wheat requires around 1,500 liters. Furthermore, wealthier residents of the Gulf states are embracing non-native water-intensive amenities such as having green lawns and swimming pools in their residences.

The idea of separating salt from seawater to make it potable is an ancient one. References to desalination go back to the Bible and Aristotle. Around 2,400 years ago, Aristotle reported on a scientific experiment that he had carried out. He wrote that:

> Salt water when it turns into vapour becomes sweet, and the vapour does not form salt water when it condenses again. This I know by experiment. The same thing is true in every case of the kind: wine and all fluids that evaporate and condense back into a liquid state become water. They all are water modified by a certain admixture, the nature of which determines their flavor.[18]

Julius Caesar's legions drank fresh water condensed from sea water during his siege of Alexandria in 48-47 BCE.[19]

In around 1500 BC, the Bible (Exodus 22–25) reports that Moses brought the sons of Israel from the Red Sea to the desert, where they walked for days but could not find potable water. When they arrived at Merra, they could not drink the water because it was bitter:

> '[Moses] gave to the place the name Bitterness. And the people murmured against Moses. Saying: What shall we drink? and Moses cried onto the Lord. And the Lord showed him a wood and he put it into the water and the water became sweet.' It is conceivable that the 'wood' mentioned above had ion-exchange properties[20]

Solar energy has for centuries been used to distill water. Malik et al.[21] and Delyannis[22] report that an Arab alchemist in the 15th century had used polished Damascus concave mirrors for solar distillation. During his voyage to the south seas in 1662, Sir Richard Hawkins used ship-based distillation to supply his men with fresh water, then in 1852 the government of Great Britain issued a patent for a distillation device. The island of Curaçao, the first territory to make a major commitment to desalination, began operating its first plant in 1928, while Saudi Arabia had its first seawater desalination plant by 1938.[23]

In 2011, the total worldwide inventory of contracted desalination capacity is 77.4 million m^3/d of water produced by almost 16,000 desalination facilities around the world.[24] Of these plants, 52 percent are located in the Middle East, concentrated primarily in Saudi Arabia, where 30 desalination plants supplement the country's dwindling aquifer supplies. North America has 16 percent of the world's desalination plants, Asia 12 percent, Europe 13 percent, Africa four percent, Central America three percent, and Australia 0.3 percent. All these regions and continents are expected to invest more heavily in desalination; so much so that the desalination market is forecasted to grow by 12 percent per year between 2009 and 2015, and to grow at a faster rate after that period. The forecasts call for 20 percent or more growth in China, India, Australia and the United States.[25] The data for 2011 shows a significant increase from 2009, when the world produced 59.9 mcm/d of water from around 14,700 plants.[26] The need to augment domestic supplies from non-traditional sources like desalination is, therefore, a worldwide issue that happens to afflict the Middle East, and particularly the Gulf states, disproportionately. For example, Saudi Arabia is set to double its annual volume of desalinated water from 1.05 to 2.07 bcm in the period 2010–2015, and will operate the world's largest solar power desalination plant, set to produce 10 mcm per year. Desalination plants provide around 50 percent of the Kingdom's drinking water, while ground water provides around 40 percent.[27]

While there have not been any major reported failures of desalination plants in the Gulf states, there have been numerous incidents where critical infrastructure has been targeted by criminals or terrorists. Vulnerability of infrastructure becomes a concern when the delivery network is extensive, the dependency is high, and the security climate is prone to domestic or regional turbulence.

This inward-looking technology-centric security offers clear advantages but also raises questions about, for example, its long term

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financial and ecological sustainability, as well as its vulnerability. Richard Perrow[28] writes that "Even highly reliable systems are subject to everyday failures, and even if we avoid these, there is always the possibility of normal accidents—rare but inevitable in interactively complex, tightly coupled systems."[29] While the author was referring here to technological systems like those in Japan's Fukushima Daiichi Nuclear Power Station that was damaged in the 2011 tsunami, his comments should inform approaches to the security of huge and complex desalination systems. Perrow adds that, "It is much more common for systems with catastrophic potential to fail because of poor regulation, ignored warnings, production pressures, cost cutting, poor training, and so on."[30] Human error is a known cause of accidents. Many desalination plants are designed in a modular fashion, hence a catastrophic system failure may be less likely, but the probability is not zero, and therefore it cannot be ignored.

To minimize the adverse effects of water supply interruptions, the security of water-related infrastructure becomes a central element in emergency planning. This needs to be integrated at the community, provincial, and national levels because water-related infrastructure includes electrical power generation plants, pumps, and pipelines, to name a few. Also, there is a constant need to maintain, upgrade, and sometimes replace portions of the infrastructure. This requires investment at all levels, from updating the skills of resident scientists and technicians to purchasing modern technology. In times of economic challenges and budget cuts, water services may go underfunded, introducing system vulnerabilities that could lead to governments and societies paying a heavy price in terms of economic decline and social instability. In this context, vulnerability is about nation states' ability to grapple with and adjust to exogenous stresses that are either sudden or gradual. This is influenced by institutional dynamism, economic strength and diversity. In short, water emergency planning amounts to a "stress test" of how the entire system would react in case potable water suddenly become unavailable.

Researchers in the areas of hydropolitics and climate change differ in their definition of terms such as "resilience," "adaptiveness," and "adaptation capacity," and continue to debate these ideas (for an overview, refer to Gallopin[31]). A resilient system – one that can bounce back after an

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incident – is an indicator of the degree of water security in an area or country. A task force within the US Department of Homeland Security (DHS) reports that resilience is the "ability to resist, absorb, recover from or successfully adapt to adversity or a change in conditions." In the context of critical infrastructure protection, the DHS defines resilience as the "ability of systems, infrastructures, government, business and citizenry to resist, absorb, recover from, or adapt to an adverse occurrence that may cause harm, destruction, or loss of national significance." It also adds a precautionary, preemptive dimension to this conceptualization because resilience is also about the "capacity of an organization to recognize threats and hazards and make adjustments that will improve future protection efforts and risk reduction measures," as quoted by Sullivan.[32] This comprehensive framework would help states reduce the vulnerability of their infrastructures to catastrophic collapse. To be sure, however, this is a tall order for young states such as those in the Gulf.

A state is considered resource-vulnerable when it is susceptible to external political pressures or natural shocks. On the other hand, a state is resource-secure when it is able to adapt and successfully resist internal or external pressures or shocks. Normally, the development of a resilient system requires an advanced economy, and well-established, independent and streamlined institutions.

A recent illustration of water resource vulnerability and interdependence occurred in Australia. A power outage caused an electrical surge and blew over 100 fuses which irreparably damaged three motor drive starters forcing authorities to halt operations of a water pumping station. The fuses had to be flown in from Sydney. The station distributes water treated at the Bray Park Water Treatment plant to 75,000 residents in Tweed Heads, Banora Point, Tweed Coast, Mirwillumbah and neighboring smaller areas. A local water and sewerage operations engineer said the "failure of fuses powering the pumps was 'unheard of'," and suspects that the initial problem had occurred in a distant location, where "touched power lines … took out transformers." He also said that when the plant was built, it was one of the most advanced in Australia hence, "It was built for the future."[33] Reflecting on the high level surge protection placed on the facility, a local water manager said it was "just unlucky that all three (fuses) went at once." He then added: "We had hoped the fuse replacement was all that was

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necessary to fix the pump station, however once the drives were energised, further significant damage was discovered."[34]

Techno-optimists become heavily invested in the immense human benefits that technological advancements provide, which makes it difficult for them to accept the vulnerability of this dependence. Learning about these "normal" and induced accidents and failures will help water planners and decision makers introduce more informed policies that are responsive to the needs of the community and the country as a whole.

Sabotage of Critical Infrastructure

Attacks on critical infrastructure have been going on for as long as human societies have been around. It used to take local, primitive forms, such as throwing dead animals into the enemy's water wells. In recent decades, these attacks have grown in their scale, methods, and lethality. Iraqi forces occupying Kuwait in 1990–91 deliberately released three to four million barrels of oil, set over 700 of Kuwait's 800 oil wells on fire, and damaged other wells causing them to flow unchecked. Daehler and Majumdar argue that one motive for causing the oil slick was Iraq's interest in, "depriving civilians and soldiers there (mostly in Saudi Arabia) of drinking water and also possibly of generation of electricity."[35] The lasting damage was extensive, resulting in major ecological devastation. Given the shallow nature of the Gulf, the massive size of the slick, and the threat it posed to the desalination plants supplying Riyadh, Saudi authorities shut down many of the plants as a precautionary measure.

Like other GCC countries, Kuwait's power generation and water desalination systems are fueled by – and therefore dependent on – oil and gas supplies. What saved the people was their country's post-war ability to produce, "about 200,000 barrels per day, or just enough to keep people alive and maintain essential services" in terms of power and fresh water supplies.[36] With this experience in mind, a Colonel in the Kuwaiti military writes that his country, "will have to draw its water from easily targetable desalination plants."[37]

Saudi Arabia is also facing potential threats to its water infrastructure. Comparable to the deadly but un-successful 2004 attack on a major petroleum shipping terminal in Yanbu, Saudi Arabia, there was an attempted attack on Abqaiq oil facility in the Winter of 2006; one that was

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foiled by Saudi security forces. Al-Rodhan states that Abqaiq's importance is due to the fact that, "nearly two thirds of Saudi Arabia's crude oil is exported" through this port, and it "mostly produces Arab Extra Light crude, which requires little refining compared to other heavier crudes," and is the location of "the most important processing facility in Saudi and the world."[38]

These attacks raised doubts about energy security, but no "public" attention was given to the possibility of copycat attacks on the desalination infrastructure in the Kingdom or anywhere else in the GCC states. Targeting national infrastructure should not surprise the experts, however, because Al-Qaeda has been preparing its foot soldiers for exactly that type of battle. Ahmed Ressam, a member of Al-Qaeda, stated that the 1998 training that he and others like him had received in the organization's camps in Afghanistan included how to blow up "airports, railroads, large corporations" and how to wage urban warfare.[39]

The issue of terrorism and piracy in the Gulf is of growing concern to American and Arab governments in the area. US warships, in collaboration with the naval forces of Arab Gulf states, seek to obstruct the movement of terrorists, weapons of mass destruction (WMD)-related technology, and narcotics in the Gulf and the adjacent Arabian Sea. These forces also seek to contain piracy in the Arabian Sea. For the Americans, this is driven by national and strategic interests. For the Gulf states, their concern is the extreme vulnerability of critical high-capacity, long-lead-time replacement infrastructures such as energy installations and desalination plants.

After stopping in the United Arab Emirates, *M Star*, a 160,000-ton Japanese oil tanker, was struck by pirates in the Strait of Hormuz in July 2010. The ship's owner, Mitsui O.S.K. Lines, said the incident was probably a terrorist attack, according to a report for the US Congress. It also stated that "The explosion is widely suspected to have been a terrorist attack, and a faction linked to Al-Qaeda (Abdullah Azzam Brigades) claimed responsibility."[40]

It is worth noting that in 2000, Al-Qaeda used a speed boat to deliver a deadly attack on the United States Navy destroyer USS *Cole* while in port at Aden, Yemen. This method of warfare can be adapted and used by national and sub-national actors. Iran has been increasing its abilities to wage warfare suitable for "asymmetrical" battle. For this, it relies heavily on the irregular forces of the Iranian Revolutionary Guards Corps (IRGC), which includes a naval branch that is capable of attacking Gulf shipping, and numerous other vulnerable soft targets. Connell argues that "In 2010, Iran had the largest inventory of ballistic missiles in the Middle East," which "are probably intended for strategic targets such as cities, oil production and export facilities, ports and water desalinization plants."[41]

Wilner states that:

> The development of lightly armed, low-tech, cost-effective weapons systems such as armed speed boats and seaplanes … could very well be used to strike at US economic interests in the Arabian Gulf …[42]

They could also strike critical infrastructure along the shoreline of the Gulf. Since 2007, Iran has been increasing, modernizing and upgrading its high-speed crafts with core missile and torpedo capabilities; some are assumed to be radar-evading.[43] Therefore, Wilner's observation is incomplete because speed boats laden with explosives can be used on the high-seas like car bombs in urban settings, and can be more accurate and "effective" against their target than many missile systems. Furthermore, desalination infrastructure would face greater risk of becoming a target because Iran has territorial disputes with the UAE, Sunni–Shia distrust is at an all time high, and Arab–Iranian tensions have also been on the rise in recent years.

It should be noted that the United States and its Arab allies in the Gulf are capable of retaliating in the event of any aggression by Iran, and that its own infrastructure is also quite vulnerable to attacks. While this is a real strategic vulnerability for the Iranians, the focus of this chapter is on the Arab countries of the Gulf.

It is widely understood that Iran would retaliate if it were attacked by American or Israeli forces. The likely targets would be the Arab Gulf states and perhaps Israel. Colonel Salem Al Jaberi of the UAE Army argues that Al-Qaeda is likely to activate its so-called "sleeper-cells" to avenge Gulf states' support of American policies in the region.[44] He argues that they will likely target strategic installations that go beyond oil and gas infrastructure (pipelines, refineries, loading facilities) to include other offshore facilities like desalination plants.

There are frequent assertions that Iran has funded, trained, and armed Shia groups in Bahrain and Saudi Arabia, and liberation movements be they Shia or non-Shia.[45] In the spring of 2011, anti-government protesters in Bahrain took to the streets and occupied a public square. Because they were overwhelmingly Shia, the government viewed them as having a sectarian, geopolitical agenda; hence the security forces suppressed them with force which stoked Sunni–Shiite tensions. At one point, when the protesters blockaded the financial district in the capital city, Manama, the government became concerned about the impact the political crises might have on the economic outlook of the country. This was compounded by the fact that at one point, local "security forces were overwhelmed" by the protesters.[46] On March 14, 2011, and upon the request of the government of Bahrain, the Gulf Cooperation Council (GCC) dispatched the Peninsula Shield force that helped security forces in Bahrain quell the protest movement. This included 1,200 Saudis, some equipped with tanks and armored vehicles, and 600 UAE policemen. Their task was to protect key locations and infrastructure. Their land forces were bolstered by Kuwaiti naval forces who helped secure Bahrain's maritime borders. The protesters accused members of the Peninsula Shield force of taking part in suppressing them, a charge denied by Bahrain and Saudi Arabia.

In the fall of 2011, Bahrain announced that Qatar had arrested five Bahraini nationals who were reportedly planning to blow up the King Fahd bridge, the main causeway linking Bahrain to Saudi Arabia, in addition to the Bahrain Interior Ministry and the Saudi embassy in Bahrain's capital, Manama. According to a statement by the Bahrain Interior Ministry (November 2011), the apprehended men were, "encouraged by others to head to Iran through Qatar and Syria, in order to establish an organization in Bahrain that would carry out terror attacks on vital infrastructure and target personalities."[47]

Subnational and national actors appear to be considering attacks on critical infrastructure in the Gulf states, be it used for water, energy transportation or other purposes. Authorities are taking measures to prevent such threats and to ensure the safety of the people and the infrastructure on which they are so vitally dependent. However, the laws of probabilities work in favor of those who are set on a destructive path.

Geopolitics of Water Imports

Because oil is shipped across international borders, it is tempting for countries to consider extensive trade in fresh water over long distances, which is precisely what the Gulf states have done. In 1986, they turned down a dual pipeline project that would have moved water from the Ceyhan and Seyhan rivers in eastern Turkey to the Gulf states at an estimated cost of around $22 billion.[48] The pipelines, some 6,500 kilometers long, would provide six million cubic meters (mcm) of water per day or 2.2 bcm annually. The project was to be paid for by its primary beneficiaries in the Gulf states, hence the oil-for-water formulation. The project, proposed by Turkey's Prime Minister Turgut Ozal, was dubbed the "Peace Water Pipeline,"—"peace" because water scarcity was seen as a source of instability. Turkey re-floated different versions of the idea in 1993 as its contribution to a peaceful settlement of the Arab–Israeli conflict.[49]

In addition to this mega, multi-state proposal, some Gulf states have explored the possibility of bilateral water imports. Qatar receives 75 mm of rainfall per year, has an expanding farming sector (cultivated area grew from 2,256 ha in 1980 to 8,312 ha in 1994), and is "almost entirely dependent on irrigation from pumped groundwater." Because groundwater levels are falling by 0.5–1.1 m per year, the aquifers are experiencing intrusion of sea water and "saline water from deeper aquifers."[50] Furthermore, based on current rates of extraction (188 mcm in 1994) and recharge (50 mcm per year), Qatar's aquifer will be depleted by 2030. Given this grim hydrological reality, Qatar carried out a feasibility study for importing water from Iran for the purpose of recharging its dwindling groundwater reserves, and for irrigation. The pipeline was expected to carry 5 m^3 per second (or 160 mcm per year) of water from Iran's Karun River.[51]

Similarly, a recent paper by Amery assessed the security implications of a proposed 30-year project in which Iran would export 300 mcm of water per year to Kuwait. It found the potential hydropolitical costs to be unacceptably high for Kuwait.[52] Here, Iran tried to leverage its freshwater resources to serve its geopolitical and foreign policy goals in the Middle East. Kuwait feared that the proposed linkage would have aggravated its vulnerability and dependence on a neighbor with whom it had a rocky relationship since 1980. This raises a question of the conditions under which water imports can be realized without jeopardizing the national security of a country. None of these proposals was successful. The countries involved either turned silent on why they did not follow through with the projects and/or provided curt, unconvincing answers. For example, the Gulf states claimed that the cost of water desalination was lower than imports from Turkey, this at a time (mid-1980s) when the cost of desalination was significantly higher (around \$3–4 per m^3) than in 2011 (\$0.6–1.0).

Baldwin (1980 as quoted by Kroll[53]) finds that interdependence which affects vulnerability should be understood as mutual dependence, a relationship that manifests itself in power projection. He concludes that while dependent states lack power, interdependent ones have power. National economic power that emerges out of dependence can be used as political leverage.[54] In the case of exports of critical natural resources, leverage can create a political and economic linkage between the trading countries, and produce a diversification of security for the exporting state. If Iran, for instance, were to export water to a Gulf state like Qatar or Kuwait, their own national security would then be linked to that of Iran. In other words, this trade would create a dependency for the importing state and generate leverage for the exporting one. In their formulation of resource dependence theory, Davis and Cobb argue that trade relations between countries should be guided by policies that are least-constraining, and which "minimize uncertainty and dependence" and maximize the importer's autonomy.[55] This is the type of relationship Kuwait was seeking, because its water imports would have been small compared to its national water consumption. In other words, Kuwait was planning to avoid the "most-constraining" policies because it did not want Iran to be the primary supplier of this critical resource.

The relationship between trade and conflict is the subject of much debate among academics. An empirically-based study suggests that the type of trade affects the quality of relations countries are likely to have. It finds that trade involving manufactured products (both low-tech and advanced) has more of a pacifying effect than trade in primary (non-manufactured) goods and food products.[56] These findings imply that trade in water or virtual water (food products) is not likely to have a noticeable or pacifying effect on relations between states. Water imports that use a permanent physical infrastructure like a pipeline (as opposed to trucks or ships) tend to simulate upstream–downstream hydro-political dynamics, which makes the downstream state vulnerable to the up-stream one, especially if the exporting state is the stronger actor. Such an arrangement is harder for importers to break if the volume received is significant relative to the total consumption. By the same token, a state that is dependent on desalination is not vulnerable to external political pressure and blackmail.

Pollution, drought, upstream dams and other withdrawals have significantly reduced water flow in the Tigris and Euphrates rivers and increased salinity levels—to the point that in 2009 their water became un-potable when it reached the southern city of Basra on the Shatt-al-Arab. In some cases, it was not fit even for animal consumption. The governor of the Province of Basra, Shaltah Aboud, described salinity as "enemy number one" because it makes water unfit for drinking or irrigation.[57] To alleviate the pressure, the province mobilized a fleet of 70 water tankers to import water from Iran to Basra. Because the trucked amounts were insufficient to meet demand, the governor had asked the central government to build a pipeline from Iran.[58] There is no indication that this request was met.

John Mearsheimer argues that countries that "depend on others for critical economic supplies will fear cutoff or blackmail in time of crisis or war."[59] This would increase when the sending state is more powerful than the receiving one, which allows the former to pressure or blackmail the latter with a minimum cost to itself. States that aspire to greater regional roles and international respect, such as Turkey, would think hard before using a critical resource like water as a political tool to pressure opponents. In some instances, however, water-rich but politically weak states can curry favor with thirsty but stronger countries by offering to sell them water resources. Some dub Lebanon as a "water tower" because few of its mountain tops are covered with snow year-round and it receives a significant amount of precipitation compared with other countries in the region. Mountains are thought of as water towers because the snow melt feeds the watershed below, and sustains springs and rivers in the region. Precipitation in the highlands of Lebanon "averages 1,500 mm/year, and the mountain peaks along the western ranges receive about 2,000 mm," dropping to as low as 250 mm near Hirmil and rising to around 800 mm along the coast.[60] In 2010, the Speaker of the Parliament in Lebanon, Nabih Birri, offered to export Lebanese water to the Gulf states. He said that it would earn Lebanon money and lessen its debt burden, and went on to describe water as Lebanon's oil.[61] While he was explicit about the economic benefits, Birri remained silent on a major implicit political ramification: bringing Lebanon closer to the political orbit of the Gulf states. Such a move would likely not sit well with his more radical Shia compatriots who support Hezbollah. Their world view is more traditional, religious, and is more aligned with Iran than with the Arab Gulf states. On the other hand, the world view of Birri's primary constituency and members of his political party, Amal, tend to be urban, more secular and liberal Shia than their counterparts in Hezbollah. It is perhaps significant that Birri appears to have dropped the proposal. From the perspective of the Gulf states, water imports from Lebanon could enhance water security by diversifying sources of supply; this time from a friendly, weaker Arab state. It could have an added political benefit as well. Historically, Lebanon was very nervous about being perceived as water-rich. This apprehension stemmed from concerns that it would come under pressure to export water to Israel, something Lebanon would not be able to carry out because of its divided religious communities, and geopolitical location between Syria (which has some allies among the Lebanese) and Israel, which continues to occupy a small part of Lebanese territory.

The ideas and proposals discussed to import water, whether from Iran, Lebanon or Turkey, have geopolitical and security ramifications for both potential water importers and for exporters. In addition to the economic and engineering considerations that must be worked out regarding water imports, this type of trade can pull countries closer together or push them apart, and therefore affect the national security of the respective states. This security influence varies according to the volume of water imported, the number of political boundaries that will be traversed in the (physical) trade, harmony in political and economic relations between trading states, and by the power relations between them.

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Conclusions

Fresh water is a scarce resource in the Arab world, a condition that is exacerbated in the Gulf states. Since the 1970s, these states have experienced very high natural and net population growth rates, significant improvements in their quality life, and over exploitation of their aquifers. These conditions have led to rapid increases in levels of water consumption and motivated the Gulf countries to consider options that would help them augment their supplies. They considered water imports as they were building ever larger desalination plants. This technology is generally very reliable and has been critical to the Gulf state's success in improving water security for their people. However, as this chapter has shown, desalination technology, like any other, is susceptible to natural hazards, system failures ("normal accidents" affecting the plant or its related infrastructure), and terrorist threats. It has also analyzed the geopolitical ramifications of water imports, and argued that, for the Gulf states, the geopolitical and security costs of such a measure far outweighs the benefits.

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4

Water Security in the GCC Countries

Waleed K. Zubari

"Water security," as a term, emerged in the Arab world roughly four decades ago, when there was much talk regarding river water resource sharing, and the dependence of some downstream countries – such as Syria, Iraq and Egypt – on water from these rivers to meet their development plans.

Water security often occupied the headlines, creating a polarized atmosphere leading to political tension in the region; indeed, water began to be used as a political bargaining chip, and as a potential motivation for armed conflict.[1] A deterioration of water quantity and quality was experienced in the downstream Arab countries, owing to growing demand along the length of these water sources as a direct result of social, agricultural, economic, and industrial development. The water crisis in the downstream countries continues to grow, with expanding demand greatly outweighing supply.

Generally, the concept of water security is encompasses two different areas: the first is purely political, and is linked to concerns arising from the fact that a large proportion (over 60 percent) of Arab water (including form the Nile, Tigris and Euphrates, and Senegal rivers) comes from neighboring countries, rendering the Arab countries that rely on this water (e.g., Egypt, Sudan, Iraq, Syria, and Mauritania) vulnerable to the upstream countries; One example being the occupation of the Zionist entity, depriving the Palestinians, Syrians and Lebanese of their legitimate right to use their water.

The second area is purely related to the water security of the population, which is an issue that has emerged in the GCC countries in particular—

particularly after the liberation of Kuwait in 1990/1991. The water security of a population refers to the strategic reserves upon which a state can depend in the event that desalination plants are not operational (for example, as a result of the pollution of Gulf waters resulting from an oil spill or for any number of technical reasons, or even acts of sabotage, terrorism, or a military strike against desalination plants or oil tankers). This reserve can be measured in terms of the hours or days for which it is possible to continue providing people with water for drinking and hygiene.[2] For this purpose, a variety of measures have been put forward, ranging from developing underground strategic reserves (such as that proposed in Abu Dhabi), to protecting facilities and installations from sabotage.[3]

Contrary to the term "food security," which has been clearly defined,[4] no clear and precise definition of "water security" exists. Water has many uses, and the concept of water security may not carry the same meaning for each use. Consequently, water security in any country, or group of countries, can relate to a number of factors or elements. If all of these, or reasonable number of them, have been satisfied, it can be said that water security has been achieved.

Over the past twenty years, the concept of water security has evolved. Some definitions are comprehensive, while others focus on one or two specific elements of water security relevant to a particular industry or sector. The latter examples range from the provision of clean water for health and engineering purposes, to anti-sabotage and anti-terrorism measures to ensure the security of drinking water infrastructure (a security-centric view).

The first all-inclusive definition of water security was introduced at the 2nd World Water Forum in 2000, held in the Netherlands under the title "Water Security in the 21st Century," during which the Global Water Partnership (GWP) defined water security as follows:

> It is a world where every person has enough safe, affordable water to lead a clean, healthy and productive life. It is a world where communities are protected from floods, droughts, landslides, erosion and water-borne diseases. Water security also means addressing environmental protection and the negative effects of poor management.[5]

In the past few years, there have been increasingly comprehensive concepts put forward in the areas of economics,[6] hydrology,[7] and engineering.[8] Most of these definitions refer to the integrity of both water quality and water quantity, and link the role of water in the natural environment with the need for water to meet human needs. For example, water security has been defined as

> … [A] multi-dimensional concept that recognizes that sufficient good quality water is needed for social, economic and cultural uses while, at the same time, adequate water is required to sustain and enhance important ecosystem functions.[9]

The scope of governance and management of water resources comprise defining features of water security; certain definitions claim that water security should be considered on a national level, while others refer to regions or basins as being more suitable bases.[10] Some researchers[11] add a further dimension to water security; in addition to ensuring the supply of water, they also include the need for protection from the devastating effects of floods and tsunamis. Also, some definitions on water security focus on sustainability or sustainable development, with a view to achieving a balance between environmental, economic, social/cultural, and political needs.12 The most comprehensive definition, and the one that is most compatible with the principle of sustainable development, may be as follows:

> … the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies.[13]

In recent times, the Arab world and the GCC countries have become particularly interested in water security in its broadest sense related to sustainable development. Initiatives have been adopted to achieve and strengthen water security by setting frameworks and general guidelines for concerted action that will likely be implemented nationally.

This chapter reviews the main water resources and their uses in the GCC, explaining the challenges and issues facing water resources management that directly affect water security, analyzing its most important determinants today

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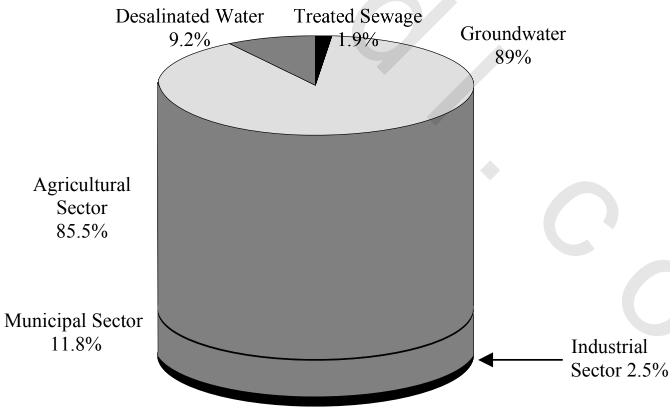
and in the future, and making key recommendations to promote water security in the region.

Water Resources and Uses in the GCC Countries

GCC countries are located in one of the driest regions in the world. With the exception of coastlines and mountain ranges, this region is essentially desert, and is characterized by low and erratic rainfall (70–150 mm per year), as well as high temperatures and evaporation rates that exceed 3,000 mm annually, preventing the existence of permanent or semi-permanent surface water. To meet their water needs, GCC countries depend greatly on groundwater resources (89 percent), desalinated water (nine percent), and less on the re-use of treated wastewater (two percent), while water use is concentrated in the agricultural (85.5 percent), municipal/domestic (11.8 percent), and industrial sectors (2.5 percent)..

Figure 4.1
Water Resources and Uses in GCC Countries, 2005



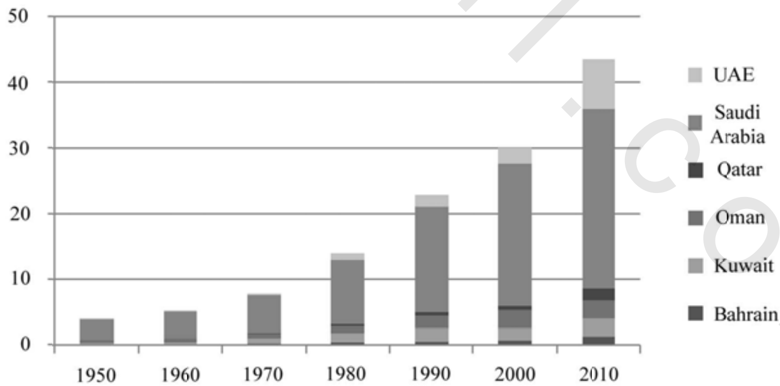
Source: prepared by researcher and based on data derived from: World Bank and AGFUND, "A Water Sector Assessment Report on the Countries of the Cooperation Council of the Arab States of the Gulf," Report No. 32539-MNA, March 31, 2005.

Since the beginning of the 1960s, and particularly in the mid-1970s, the GCC countries witnessed accelerated social, urban, industrial and agricultural development rates as a result of the discovery of oil in commercial quantities and the resultant boost in revenues. Over the past four decades, the populations of these countries have doubled more than five times; from about eight million in 1970 to around 43.5 million in 2010 (see Figure 4.2). The current rate of population growth in the GCC countries is nearly three percent,[14] which is considered one of the highest in the world.

At the beginning of the 1980s, the GCC's accelerated development and population growth was accompanied by rising water demand, which increased from about six billion cubic meters per year in 1980,[15] to more than 32 billion cubic meters in 2005.[16] In light of population growth and the increased demand for food, most GCC countries formulated ambitious agricultural policies to achieve food self-sufficiency.[17] The agricultural sector has become the largest consumer of water, accounting for over 85 percent of total water use in these countries. This sector mainly depends on renewable and non-renewable groundwater,[18] up to 60 percent (in Kuwait) or 92 percent (in Saudi Arabia) of which is used for irrigation.[19]

Figure 4.2

The Evolution of GCC Populations, 1950–2010 (Million People)

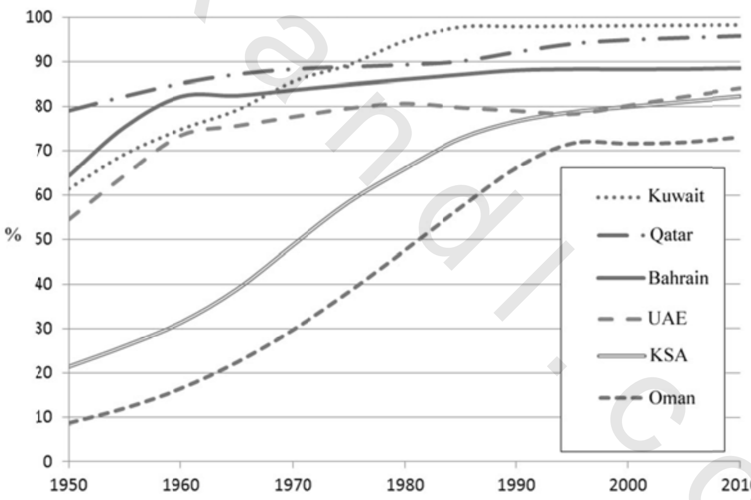


Source: United Nations Population Division (UNPD), *World Population Prospects*, 2010 Revision (New York, NY: UN Department of Economic and Social Affairs, Population Division, 2011), available at: (http://esa.un.org/unpd/wpp/index.htm), retrieved December 9, 2011.

With rapid population growth and urban development rates (see Figure 4.3), water demand in the municipal/domestic sectors of the GCC states witnessed rapid increases over time. To meet this growing demand the GCC countries resorted to desalination, upon which these states increasingly rely, as the region's groundwater quality continues to deteriorate. Desalination has become the main source of supply for the municipal sector, which accounts for around twelve percent of total water use in the GCC. Desalination capacity in the GCC countries increased from one billion cubic meters in 1980[20] to more than 9.5 billion cubic meters in 2010, and it is expected that this capacity will reach 19 billion cubic meters by 2016.[21]

Figure 4.3

Proportion of Urban Population, 1950–2010



Source: UNPD, World Population Prospects, op. cit.

At the beginning of the 1980s, treated sewage began to enter the GCC water mix, driven by an increase in water consumption in urban areas. This water began to be available for use thanks to the completion of wastewater treatment plants and sewage networks in most major cities. Presently, most countries in the region possess advanced wastewater treatment plants, and

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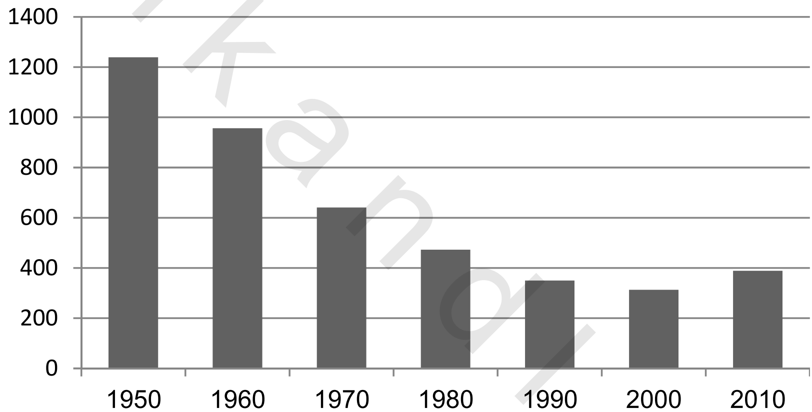
collectively in 2009 reached a processing capacity of more than 3.8 billion cubic meters per year.[22] Wastewater treatment plants process around 45 percent of the municipal water used in the GCC countries. Nearly 75 per cent of this water is treated, of which 50 percent is reused in agriculture.[23]

Water Challenges Facing the GCC Countries

The GCC states face a number of issues and challenges in terms of water sector management, as illustrated by their levels of fresh water per capita.[24]

Figure 4.4

Fresh Water Per Capita in the GCC (m^3/year), 1950–2010



Sources: population data from UNPD, *World Population Prospects*, op. cit.; data for natural and non-traditional water sources up to 2000 from ESCWA, "Updating the Assessment of Water Resources in ESCWA Member Countries," E/ESCWA/ENR/1999/13, 1999, and World Bank and AGFUND, "A Water Sector Assessment Report …," op. cit.; 2010 data for non-traditional sources of water from GWI Global Water Intelligence (GWI), "Water Market Middle East 2010" (Oxford, UK: GWI Publications, March 2009).

Figure 4.4 shows the continued decrease in individual share of fresh water in the GCC countries falling below 500 cubic meters per year (the severe water poverty line) since 1980. The relative increase in the index in recent years is attributed to an increase in desalination capacity (the index value excluding non-conventional sources was 114 cubic meters per capita in 2010). Under GCC population growth projections, this value could be cut in half by 2030, when estimates put the total population of the region at around 60 million. The main challenge faced by the GCC countries is maintaining a balance between what is available and what is needed. In other words, to find a suitable, sustainable solution to bridge the gap between supply and demand both today and in the future. In addition to this general challenge, there are several specific, pressing issues facing water management and security in the GCC.

Rapid Increases in Water Demand in the Municipal Sector

One of the most important achievements of the GCC countries has been their ability to deliver high levels of drinking water to their populations, with 100 percent of people enjoying access to safe drinking water, representing a significant contribution to the quality of life and health in these states.[25] However, accelerated demand has strained GCC water resources, forcing greater reliance on desalination and recycled wastewater, and depleting national budgets. This is due to three main factors, namely: rapid population growth and urbanization, above average per capita consumption, and a high proportion of unaccounted-for water and leakage from municipal networks. Rates of population growth (currently three percent) and urbanization (currently 87 percent) are the most important driving forces of municipal water demand in the GCC. It is expected that these rates will continue to rise in the future. Although population growth is expected to fall to around one percent by 2030, population size will remain influential as it will have reached 60 million by this time, with 90 percent inhabiting urban areas.[26]

The higher average per capita consumption (between 300 and 750 liters per day in the GCC countries)[27] reflects a variety of factors including: rising standards of living, falling awareness of water wastage, and low or non-existent water tariffs. Meanwhile, unaccounted-for water and uncalculated leakage ranges from 22 percent (Bahrain) to 40 percent (Kuwait) in the GCC countries, and in some GCC cities reach 60 percent.[28] The latter two factors (per capita consumption rate and losses) have a direct impact on gulf water security and represent the highest cost to municipal supply in the GCC countries.

Rapid Depletion of Aquifers and Deteriorating Water Quality

Heavy reliance on groundwater – both renewable and non-renewable – and the absence of appropriate water management strategies, has resulted in random use and over-exploitation of this resource, leading to reserve depletion, low water levels, and water quality degradation as a result of saltwater inflow. Currently, all GCC countries – without exception – extract groundwater resources in an unsustainable way. For example, one study suggests that the severe exploitation of non-renewable groundwater in Saudi Arabia has depleted this resource by one third.[29] In Kuwait, the United Arab Emirates, Qatar, and Bahrain, withdrawal rates of groundwater exceed their replenishment rate by between 200 to 1,400 percent.[30]

Loss of groundwater has led to many direct and indirect costs that affect Gulf society today—at the top of this list is the loss of groundwater itself as a natural asset, stripping the Gulf states of the ability to use this resource in various forms of socio-economic development activities. Other costs include: the effects on large quantities of agricultural land that must now depend on government support because of the depletion, salinization and desertification of reserves; the loss of groundwater-related features such as natural springs, the degradation of environments and habitats that rely upon them, and the lost opportunities for tourism, education, culture, arts, and scientific research associated with these natural areas.[31] Finally, the loss of groundwater sources directly affects Gulf water security, as it has resulted in the loss of a sizeable strategic reserve with which to provide drinking water for the population in times of emergency.

Inconsistency between the Agricultural Sector Requirements and the Available Water Resources

Population growth, coupled with prevailing food and agricultural policies in the GCC states, is among the main driving forces behind the increase in demand for water in the agricultural sectors of these countries, accounting for more than 85 percent of total use in these states. Withdrawal rates in the agricultural sector have swollen due to traditional irrigation methods, low irrigation efficiency (30–45%), high crop water consumption, and the absence of tariffs for agricultural water consumption.[32]

Despite this vast consumption of natural resources, agriculture represents only 2–7 per cent of GDP in Saudi Arabia, the United Arab Emirates and the Sultanate of Oman. In Bahrain and Qatar, the agricultural sector is even less important, contributing less than one percent of GDP. However, the majority of the GCC countries offer generous subsidies[33] for agriculture in a bid to increase self-sufficiency in certain products, and as a means to redistribute oil revenues. Despite these subsidies, the performance of the agricultural sector is generally low.[34] The low quality of local products mean that they are unable to compete with imported produce; this is largely due to the lack of modern irrigation technology, as well as inadequate quality control, post-harvest techniques, and marketing.[35]

The agricultural sector is the main source of groundwater depletion and quality degradation in the Gulf countries, and the current use of groundwater resources for irrigation is simply unsustainable. The problem stems from the fact that the GCC has no clear strategies to provide alternative water sources once they are fully exhausted. Hence, there is an urgent need to implement realistic agricultural policies that reflect resource availability and renewal capacities, fully utilize treated wastewater, reduce wastage, and promote modern irrigation and farming methods such as hydroponics to reduce water consumption in the agricultural sector and increase yields.

The Financial Burden of Water Support

All GCC governments adopt policies to provide cheap access to water, but such policies are invariably counterproductive, as "non-directed public support" often leads to an exacerbation of demand and imposes a heavy financial burden on national budgets, monopolizing funds that could be directed to more dynamic sectors such as education, health, and human development. This support, manifested in ultra low water tariffs, encourages excessive domestic consumption and discourages rational municipal use.

Some studies suggest that merely by meeting the demand from the municipal sector via desalination, water subsidies alone could absorb about ten percent of oil revenues in some GCC countries.[36] In Saudi Arabia, the

Minister of Water and Electricity, Abdullah bin Abdurrahman Al-Hussein,[37] indicated that 25 percent of oil and gas production in the country is used for power generation and the production of desalinated water, and that if water demand continues to rise at the same rate, this figure would reach 50 percent by 2030. In Kuwait, desalination plants are responsible for 50 percent of domestic energy consumption, and if demand continues to rise, the energy needed to power this desalination will equal oil production by 2035.[38]

Wastewater Recycling and Treatment

As in the drinking water sector, the GCC countries have achieved significant progress in providing basic sanitation to their populations. Their efforts are commendable, taking into account the accelerated population growth and urban development that these countries are witnessing. Despite the increase in the wastewater collection rate from roughly 30 percent of overall municipal consumption in the GCC countries in 1995,[39] to 45 percent today, this rate is still low according to the best practices and standards applied in developed countries. The result of this level of recovery poses threats to human health, owing to the resultant pollution of groundwater and coastal areas, and rising groundwater levels in urban areas causing damage to building foundations.

Despite the potential role of treated water in reducing the stress on water resources in the GCC countries, the recycling process is still slow and reuse rates are low compared to the quantities treated (43 percent of treated water was reused in 1995,[40] rising only to 50 percent today). There are several reasons for this, including social obstacles to the use of recycled water (health warnings, psychological dislike, and religious beliefs), and technological constraints (inefficient purification plants and fears of accumulation of heavy metals in groundwater).

In most of the GCC countries, recycled water is used in agriculture and irrigation for some feed crops, while the remaining water will is drained into valleys or the sea. This process fails to exploit water’s true economic value in the region. The recycling process for the re-use of treated sewage is still in its early stages in the GCC countries. All of these states have grand, ambitious plans to re-use treated sewage, and to use it in agricultural irrigation instead of groundwater to reduce depletion rates; this option is especially appropriate, as quantities of sewage are directly proportion to the size of the growing population. Therefore, there will always be enough wastewater to process.

The Environmental Impacts of Desalination Plants

The issue of drinking water in the GCC countries has received much political attention. In the 22nd session of the GCC Supreme Council, which was held in Muscat in 2001, the recommendations on water strategies presented by the Advisory Board of the GCC Supreme Council were discussed. This was a time when issues surrounding population increase and water security were considered top priorities, and numerous options available to the GCC countries were reviewed, including importing water from abroad. The advisory body recommended that the focus be on the desalination industry as a strategic option, and this was approved by the GCC Supreme Council at the meeting. Indeed, in view of current indicators charting the continuing deterioration in the quality of groundwater – rendering it unsuitable for household supply – the growing demand for water in the municipal sector, and the ever-increasing share of desalinated water in that sector, it is expected that desalinated water will eventually become the main source of supply for this sector throughout the GCC.

Currently, the GCC countries are experiencing significant expansion in the desalination industry, buoyed by their substantial financial means and their obvious access to the energy required to run desalination plants. Today, combined GCC desalination capacity represents more than 40 percent of global desalination capacity,[41] and the GCC countries have the highest share of desalinated water per capita in the world (desalinated water per capita ranges from 85 (Oman) to 1,000 (UAE) liters per capita per day.[42]

However, not only does such expansion carry a high financial price in terms of investment and running costs, it also has significant environmental effects. The few available studies undertaken in the Gulf region on this issue indicate that desalination plants have major, negative effects on the area surrounding them, including through air pollution which affects nearby urban areas, and harmful effects on the marine environment due to the discharge of concentrated saline solution and chemical wastes used in water treatment.[43]

Potential Effects of Global Climate Change on Water Resources

Global climate change is now a reality, after having been mistaken for random climatic changes affecting certain regions of the world. A recent report issued by Intergovernmental Panel on Climate Change,[44] suggested that the Arab region in general, and the Arabian Peninsula in particular, will be greatly affected by climate change, and the future outlook for rainfall in most global climate models shows a reduction over the coming fifty years that will have a negative impact on natural water levels in the GCC countries. Furthermore, high temperatures will lead to increased demand for water for human use and agriculture, exacerbating water crisis. The report also pointed to an increase in the frequency of unusual climate events, such as droughts and floods, and rising sea levels that may result in the inundation of coastal areas and increase the salinity of groundwater. In addition to the enormous challenges facing the management of the water sector in the GCC countries, the phenomenon of climate change introduces even more uncertainty into planning and water management.

These challenges are compounded by other several factors prevailing in the GCC countries, the most important of which are: a lack of awareness on water issues both among individuals and communities; a lack of community involvement in the decision-making process; low efficiency in utilization of water in consuming sectors; an absence of any holistic approach to managing the water sector; a failure to integrate agricultural and energy policies with water policy; weak institutional and capacity in water sector; the weak contribution of scientific research and an almost complete lack of technology transfer to develop the water sector; and, finally, weak legislative frameworks.[45]

Water Security in the GCC Countries

The Evolution of the Concept of Water Security in the Region

The concept of water security was first referred to in the Arab world at a meeting dedicated to water issues in Kuwait in 1986 entitled: "Water Sources and their Use in the Arab World," which was jointly organized by the Arab Fund for Economic and Social Development (AFESD), the Kuwait Fund for Arab Economic Development (KFAED), and the Arab

Center for the Study of Arid Zones and Dry Lands (ACSAD). The seminar aimed to accurately determine the water situation in the Arab world at that time, as well as the future prospects for water in the region. The seminar also aimed to identify obstacles to development in the water sector and the means with which to address them, as well as joint Arab efforts to secure a better future for the coming generations. The seminar addressed the issue of the limited nature of water resources compared to demand, and the problem of the agricultural sector as the biggest consumer of water in the Arab countries.

The seminar issued a statement characterizing the various dimensions of the water problem, including high population growth, accelerating social and economic development, and the disruption of the relationship between resources and demand, referring to the fact that one of the reasons behind water degradation was the lack of appreciation for the various aspects of the problem, as well as the lackluster actions taken to address the situation. The statement outlined proposed solutions at the national, regional and international levels, and noted that the ambiguity of water policies and the limited capacities of institutions working in the field were among the most important obstacles facing Arab water security. The statement stressed the need to give water attention and importance commensurate with its role in the economic and social development. Nationally, the seminar's recommendations focused on: adopting national water policies; preparing plans for water development; creating a central body with responsibility for overseeing the implementation of water policies and coordination between the relevant authorities; supporting and building capabilities of institutions operating in the water sector; preparing leading human resources in the field; and providing higher education opportunities in the field of water management. Regionally, the seminar recommended that joint water projects be undertaken, and that inter-Arab cooperation in the field should be strengthened.[46]

This seminar was the first of its kind to be held at the pan-Arab level, and exceeded – in terms of its themes and ideas – the prevailing global thinking on the topic at the time. It generated the concept of a link between water and social and economic development before the release of the Bertrand Report on Sustainable Development in 1987, which led to the emergence of the concept of sustainable development. The seminar also dealt with the issues of water policy and institutional structure in the water sector, calling for all relevant authorities to improve coordination between them and support and build human capabilities; this was far in advance of the Dublin conference in 1992, which called for the same principles and ideas. Therefore, this can be considered the true origin of the model and an approach for integrated management of water resources worldwide.

Two decades after this seminar, in 2008, the leaders of the Arab states established the Arab Ministerial Council for Water at the Arab League, in response to the changing water and food security situation, and the latest developments in climate change and their impacts on the region.[47] Hence, the Arab agenda for joint action in this area is progressing, and reflects the political will of the Arab countries to encourage the discussion of water issues from the technical to the political levels, and to promote and coordinate Arab cooperation within a joint strategy to meet water challenges and enhance Arab water security.

The Arab economic summit, held in Kuwait in 2009, tasked the Arab Ministerial Council for Water with devising an Arab strategy for water security. A strategy draft was subsequently prepared after being reviewed by a committee of experts from Arab countries and organizations in December 2010, and was approved by the Executive Office of the Arab Ministerial Council for Water in June 2011. Arab finance and economy ministers meeting in Baghdad in March 2012 also recommended the draft be approved. The strategy sets goals in the three fields.[48]

First, the economic and developmental field: providing drinking water services, agriculture and sanitation, including funding and investment or technology localization, applying the basis for the integrated management of water resources and developing non-conventional water resources.

Second, the political field: protecting the rights of Arabs to water in the occupied Arab territories, or when sharing water with regional neighbors, and promoting cooperation between the Arab countries to manage their shared water resources, in addition to implementing the obligations of the Arab countries within the Millennium Development Goals.

Third, the field of institutional development: developing human and technical capabilities, as well as social and individual awareness of the water problem in the region, including scientific research, and greater civil society participation in decision-making with environmental implications.

It could be argued that the draft of the strategy has dramatically elevated the issue of water on the regional agenda, particularly in light of the realization that achieving water security is a basic prerequisite for achieving sustainable development. The concept has evolved from the issue of securing the reserves of water required by the population and the agricultural sector, and protecting the rights of Arab countries to natural water sources, into a broader concept that is also concerned with macro-level issues and challenges surrounding water, their driving forces, and appropriate solutions including improved governance, water management, building institutional and human capacities, developing scientific research, and transferring and localizing modern technology. Hence, the issue of water security is no longer one of external interference, but is now primarily a domestic issue concerning governance, efficient resource management, and the pursuit of sustainable development goals.

In 2010, the 31st GCC Summit, held in Abu Dhabi, focused on water, energy, and food, and resulted in the issuance of the Abu Dhabi Declaration. The declaration referred to "... the importance of [the] water sector in the GCC countries and the necessity [of preparing] … a future strategy, taking into account the needs of the three axes of sustainable development," stressing that the GCC countries were currently experiencing a "significant developmental renaissance in all sectors and areas accompanied by many enormous challenges [*sic*]." The document tackled the scarcity of water resources in the GCC countries, and called for:

> … serious and concentrated steps towards a comprehensive, long-term strategy on water, to be approved by the Supreme Council of the GCC countries … taking into account the possible effects of … change on the water resources sector … the rationalization of consumption in various development sectors, mutual influences between [the] agriculture and water sectors, [and] the potential impacts of desalination operations and activities on the quality of sea water, climate change, and [the] strategic storage of water.[49]

The declaration also made a number of important recommendations in the field of water resources management, with the aim of achieving sustainability. One of the most important of these was the "linkage between insurance of water security and diversification of energy sources and food security as a vital necessity and a strategic priority for the future of the GCC countries." It recommended that the GCC states "conduct a comprehensive review of the agricultural development in the GCC countries, and … focus on the development of national agricultural policies [aimed] … at preserving water and [creating] … added value for the economy." The declaration posited that the satisfaction of these recommendations would lead to strategic advantages safeguarding the region's long-term water and energy security. It could be argued that the issuance of Abu Dhabi Declaration by the leaders of the GCC countries has made water security an issue of the highest priority for these countries.

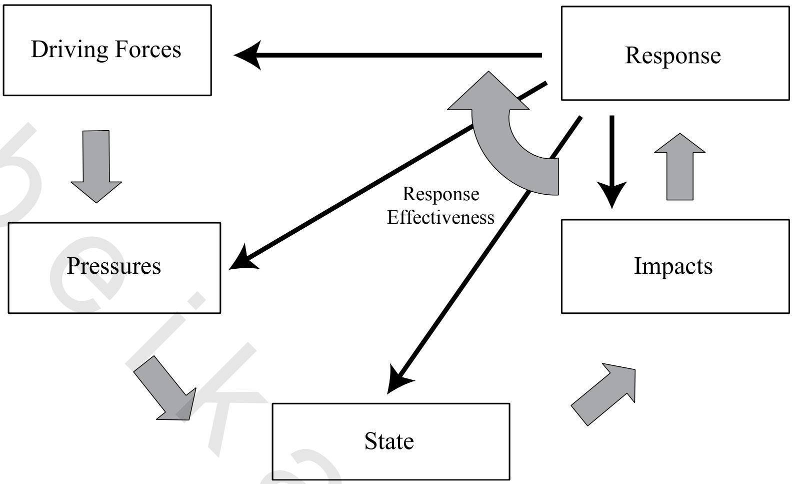
Determinants of Water Security in the GCC Countries

There are many challenging factors facing GCC communities in their pursuit of water security in its broader sense. They can be divided according to three major themes,[50] namely: the natural and hydrological environment; availability and distribution of natural water; and the socio-economic environment, comprising national economic structures and the conduct of water consumers, the various policy options adopted to deal with the water issue, and the future of the environment in light of the growing evidence that global climate change will play a major part in deciding environmental composition, in addition to other variables such as population size, development, and the impacts of the local and global economies. These factors play important roles in determining the institutions and infrastructure needed to achieve water security.

The DPSIR (driving forces–pressures–state–impacts–responses) analytical framework has been used to analyze the challenges facing the GCC water sector, and the efficiency of responses. The DPSIR model was designed to determine the effects of human activities on the environment, as well as ways to mitigate the related effects on natural resources.[51] This framework is widely used in environmental studies to gauge the impact of human activities on sustainable development.

According to this framework (see Figure 4.5) social and economic factors (such as population growth, agricultural policies, and technological advancement) are the driving forces (D) causing different types of direct pressure (P) on the state of natural resources (S), leading in turn to various environmental, health, economic and social impacts (I), to which a response is posed (R).

Figure 4.5
DPSIR Analysis



Source: UNEP, "DPSIR Framework for State of Environment Reporting," UNEP/GRID-Arendal Maps and Graphics Library, available at: (http://maps.grida.no/go/graphic/dpsir-framework-for-state-of-environment-reporting_379f), retrieved on: 29/04/2012.

The efficacy of the response to a particular problem varies, according to its application on the different parts of the analytical system. Generally speaking, responses targeted at the driving forces will be more effective. For example, when a response is directed toward the "impact" side (such as beach clean-ups and compensating fishermen working in polluted waters), it will be less effective and less sustainable than one applied to, say the "pressures" element (such as lower rates of consumption in the municipal sector, or reducing raw sewage flow into plants, etc.).

Table 4.1 applies the DPSIR analytical framework to the water sector in the GCC countries. In the table, it is noted that the most important driving forces in the water sector are: accelerating population growth; over-ambitious agricultural policies; a system of public subsidies which fails to encourage rational water consumption; weak legislation; lack of efficiency in use; and increasing wastage. These driving forces lead to a deterioration in the quantity and quality of water, a continuous increase in the cost of water supply and treatment – affecting the national budget – and to a number of health, environmental, financial, economic and social impacts.

Table 4.1

DFPSIR Analysis of the GCC Water Sector

Driving Forces	Pressures	State	Impacts	Response
• Limited natural resources and prevailing drought conditions. • High population growth rates and FDI policies. • Agricultural policies to achieve food security and socio-economic development. • Public policies encouraging water use; subsidized water tariffs. • Increase in standard of living and improving per capita income. • Inadequacy of environmental and water awareness. • Weakness and non-enforcement of water and environmental legislation. • Weakness of public institutions in water sector; multiplicity of bodies responsible for water in most countries, and lack of effective coordination among them. • Insufficient human resources in the water sector. • Technical development in water desalination and treatment, and cost reduction over time.	• Increasing water demand from various sectors. • Low water-use efficiency. • High wastage in consumer sectors. • Irrational consumption patterns, and high per capita consumption. • High volumes of waste water (sewage).	• Quantitative and qualitative degradation and depletion of groundwater due to sea water encroachment. • High cost of desalination and municipal water distribution, and low rate of cost recovery. • High cost of sewage treatment; non-recovery of costs. • Constant reduction in per capita availability of water over time.	• High salinity and periodic disconnection of drinking water. • Low productivity and eventual degradation of agricultural sector. • General budget drain of building desalination and treatment plants. • Loss of strategic reserves of groundwater for emergencies. • Depletion of oil reserves and natural gas used to power desalination. • Pollution of coastal and marine environment by effluent from treatment plants, with related health, environmental and financial effects. • pollution of coastal / marine environment surrounding desalination plants, poor ambient air quality, and increasing GHG emissions. • Excessive use of fertilizers and chemicals in agricultural sector, and related effects on health and the environment. • Desertification of agricultural land and loss of productivity due to salinization of groundwater used for irrigation.	• Expansion in desalination plant construction. • Expansion in treatment plant construction and water reuse in agriculture. • Increasing withdrawal of groundwater. • Privatization of desalination and water treatment plants to reduce costs. • Awareness campaigns to rationalize water use. • Installation of water-saving devices.

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The main response is to increase the supply of water via expansion in various sectors (desalination, re-use of treated sewage water, ground water withdrawals) – paying no attention to demand and rationalization management or cost reduction – as well as awareness campaigns to reduce water wastage in both the municipal and agricultural sectors. Hence, most of the responses are directed towards reducing the impacts of the problem, while only one concentrates on pressures (awareness campaigns).

The analytical framework shows that many of the driving forces are beyond the control of the water sector, and can only be altered by policy- and decision-making at the national level. Therefore, water security and sustainability should be considered at the highest levels in the GCC countries, as a security issue rather than a civil matter.

Conclusion

In the past few years, the issue of water security in the GCC countries has attracted increasing attention, from just being a matter of securing and protecting sufficient reserves for the population and agricultural sector, to a broader concept that encompasses additional challenges, driving forces, and potential solutions. Water security is now a domestic issue primarily dependent on governance and water resources management with the aim of achieving stable supply to serve goals of sustainable development. This shift in focus was illustrated by the Abu Dhabi Declaration in 2010, which called for a number for measures to ensure water security in the GCC countries, and for the participation of all the GCC countries in developing a common vision, framework and set of guidelines to achieve Arab water security (the *Arab Water Security Strategy*, 2011), which can then be applied at the national level in these countries.

Generally, water security is determined by conditions in three distinct environments: the hydrological environment, the social and economic environment, and the environment of the future, including its demographic variables as well as the effects of technological progress and climate change. All three provide unfavorable conditions for achieving water security and sustainability in the GCC. These states are located in a water-scarce area where natural reserves suffer from spatial and temporal volatility; yet it is also an area which is experiencing one of the highest economic growth rates in the world. The GCC countries are heavily dependent on water for certain

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development activities (particularly in the agricultural sector). Major industries consume water irrationally and inefficiently, and there is generally a low awareness of water issues throughout society. Solving water issues, however, is one of the responsibilities of government, not consumers. Existing implemented water policies, if any, are not integrated. Most of the GCC countries enjoy a good deal of flexibility in dealing with this situation – albeit at a heavy economic and environmental cost – represented by the ability to expand their desalination infrastructure to provide water for their populations, thanks to the strength of their economies, as well as their substantial financial and energy resources. However, the continued depletion and deterioration of groundwater quality will ultimately deprive the agricultural sector of a vital resource, and the economic and environmental costs of desalination will continue to mount—resulting in an accelerated drain on oil and gas resources and encouraging increasing demand from consumers.

As most of the challenges facing the GCC water sector are caused by driving forces outside the control of water sector, water security must be considered at the highest levels in these countries, taking into account population, economic and agricultural policies, in addition to public subsidies adopted by the GCC countries.

Addressing the water challenges faced by the GCC countries in order to achieve water security in its broadest sense, requires radical intervention in the social and economic environment of the GCC countries. It also requires political will, and cooperation at the administrative, scientific, and technical levels. Above all, water security requires improved governance to change the prevailing culture of wastage, transforming society from being a major part of the water problem into an essential part of its solution.

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5

National and Regional Water Security Policies in the Gulf States

Mohammed S. Tayie

The issue of water resources has acquired increasing importance during the course of the twenty-first century, with talk of impending water crises – particularly in light of the changes occurring in the Earth's climate – that represent major environmental threats to human security.

Water is essential for survival and economic progress. Fresh water availability is a significant concern in many places around the world, particularly with a global population that grows by a quarter of a million people daily. As a result, the share of water supply per capita on the planet fell from 33,300 cubic meters (m^3) per year in 1850 to 8,500 m^3 per year in 1993. Roughly 40 percent of the world's population – mostly situated in developing countries – already faces severe water shortages, and ever more countries will join this list. It is conceivable that by the middle of next century about 65 percent of the world will face water stress or scarcity.

Contemporary analyses of fresh water crises show that demand for water during the twentieth century increased ten-fold; meanwhile, the world's population has quadrupled over the past hundred years. With increasing wealth, demand for water resources has increased. Global fresh water resources per capita will continue to fall if the current rates of increasing consumption endure—by 2025, there will be more than 3 billion people living in water stressed countries.[1]

The water problem in the GCC countries is even more acute, since these countries are located in an arid zone almost completely devoid of any superficial, traditional fresh water sources – except some seasonal valleys in

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Saudi Arabia, Oman and the United Arab Emirates – these countries depend mainly on securing sources of fresh via sea water desalination, which meets over 40 percent of the total water needs of the region's population. The Arab Gulf countries rely on desalination as a major source of drinking water; it accounts for more than 80 percent, while the remaining demand is met by groundwater.[2] Thus, the concept of achieving water security in the Gulf overlaps with security-related dimensions relating to fresh water and its source, the saline waters of the Arabian Gulf. Consequently, it is not possible to talk about water security in isolation from the security of the waters of the Arabian Gulf itself.

The objective of this chapter is the study and analysis of the various dimensions of water security in the GCC countries, with a focus on policies for achieving water security across the Gulf. To this end, a key question is: what are the most prominent national and regional policies either adopted or proposed in the GCC countries to enhance water security? Other related areas of interest include: determinants of water security in the region; internal and external threats facing water security; strategies to face these threats at the national level; and policies to strengthen water security via a regional system for the Gulf countries.

The methodology of the study is based on hydro–political analysis – whereby political phenomena are analyzed in the light of the water situation. Hydropolitics is not a new concept; John Waterbury, a well-known aquaculture scientist, was the first to coin the term in 1979. Waterbury explains that the term refers to the degree of linkage between political phenomena and 'hydro-' phenomena, on the basis that such links should not be overlooked either in the process of analysis or in the implementation of water policies, especially at the national or international levels.[3]

The study is approached from an Integrated Water Resource Management (IWRM) perspective, which seeks to achieve water security alongside development goals.[4] In general, IWRM can be defined as: "A set of procedures, policies and strategies taken at the local or regional level to control water resources and uses for the benefit of a community and region."[5]

Water resource management issues can be categorized as belonging either to supply management (activities to locate and develop new sources) or demand management (mechanisms to promote more appropriate levels and patterns of water use).[6]

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The Concept of Water Security in a National Security Context

In the early 1970s those concerned with international relations and strategic studies sought to redefine and broaden the traditional concept of "security" to include 'non-traditional,' non-military threats in the realms of politics, economics, and the environment.[7]

In this context, new concepts of security began to emerge in academic circles, led by "human security."[8] Other aspects include strategic security, economic security, environmental security, water security, food security, energy security, and so on. Thus, water security therefore features as a component in a comprehensive view of national security.

Undoubtedly, water is one of the most influential resources determining human security; since it is a critical factor in human survival. Hence, securing access to water is one of the main objectives in pursuing human security. Of course, water security is also linked to food security.[9] Perceptions of water security are strongly affected by water scarcity, where shortages in water supplies are seen as a tangible indicator of a lack of water security.[10]

Definitions of water security vary among researchers, according to their intellectual tendencies and academic backgrounds. However, it could be argued that there is an acceptable and well-known definition among researchers and hydropolitics specialists: "the provision of appropriate amounts of water – of good quality that is fit for human consumption – needed to fulfill development goals and domestic requirements, as well as sufficient availability of water infrastructure to provide clean drinking water and sanitation, and the ability of the state to secure those resources and protect them from external and internal threats."[11]

According to this definition, five key indicators of water security can be identified, namely: a quantitative indicator, a qualitative indicator, an economic indicator, a military force indicator, and an indicator based on water conflicts. This analysis will not take into account the military power indicator; nor will it consider the final indicator, as the Arab Gulf states are not riparian states.

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The Quantitative Water Security Indicator

Water security is directly linked to the water balance of a given state or region, and describes the relationship between water supply and demand.[12]

The water balance is characterized by its status as either:

- balanced (when demand equals supply);
- surplus (when supply exceeds demand); or
- deficit (when demand exceeds supply).

Water security is a relative concept, as different levels of water security in different countries will be determined according to their level of development.[13] Furthermore, it differs according to the criteria by which it is determined;[14] there are a multitude of indicators and benchmarks upon which we can rely to determine the level of water scarcity, but Seckler and Silva present a number of indicators that can be used as a basis for determining water scarcity.[15]

The term "water scarcity" denotes one of two cases: The first is water poverty, which refers to areas with an annual water supply per capita of less than 1,000 m^3—the so-called global water poverty line. The classifications are as follows:[16]

- Water surplus countries: with annual per capita water resources of more than 2,000 m^3.
- Water-stressed countries: with annual per capita water resources of 1,000–1,700 m^3.
- Water-scarce countries: with annual per capita water resources of less than 1,000 m^3.
- Acute water shortage: countries with annual per capita water resources of less than 500 m^3.

However, it is not sufficient to determine water security according to available water resources per capita alone, as this indicator is falling in almost all countries of the world as a result of population increases. Therefore, the productive and economic return derived from each unit of water must also be measured. A developed country can exist with an acute shortage of water per capita (less than 500 m^3), while a developing

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country suffering from social and economic problems might not survive on less than 1,000 m^3 per capita. Therefore, many experts refuse to accept the figure of 1,000 m^3 per capita per year as a useful measure of water poverty.

Another measure is "water deficit," in which the level of demand for renewable water resources outstrips supply, creating an imbalance that is sometimes referred to as the "water gap." When such a deficit leads to economic and social disruption which threatens the security of the state, it becomes known as a "water crisis."

Some experts believe that a deficit in the water balance – irrespective of the water poverty line – is sufficient quantitative evidence of water resource scarcity.[17]

The Qualitative Water Security Indicator

According to this indicator, water scarcity denotes the limited suitability of existing water supplies to meet the demands of a developed/developing nation (home, agricultural and industrial)—namely poor water quality. Water resource experts confirm that when water is available in large quantities but is not suitable for drinking or sanitation, this can be characterized as water scarcity.[18] Specialists propose that "drinkable water" should therefore determine water security, even if water of poor quality is available in abundance.[19] A report released by the US Environmental Protection Agency in April 2006 confirms that any kind of pollution of water resources comprises a threat to water security.[20]

The Economic Water Security Indicator

According to this indicator, water scarcity is determined by the extent of the lack of available financial resources with which to create the infrastructure needed to achieve and maintain water security. Even though water of sufficient quality and quantity might be available to meet a population's needs in terms of drinking water, sanitation and irrigation, a nation may lack the infrastructure necessary to deliver these resources to end-users as a result of limited financial resources. Users are therefore deprived of water in the same way as those who face a complete lack of water resources.[21]

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In this context, experts talk of the basic human right of access to water as an expression of an economic indicator of water security. The human right to water can be measured on the basis of the two indices stated in Human Development Report issued by the UNDP in 2006, namely: the proportion of people who use pure drinking water supplies, and the proportion of people who use treated wastewater.[22]

Water Security in the Arab Gulf States

Water in the Arab Gulf states can be divided according to three main sources: the first is groundwater, including surface water wells which usually rely on monsoon rains for replenishment, and the deep wells that provide access to ancient geological formations; the second is sea water desalination and purification; and the third is the treatment and recycling of wastewater—which is somewhat of a novelty in the Gulf states and is only used for irrigation in agriculture.[23]

The following section will apply the four indicators outlined above to the Gulf states.

The Quantitative Indicator Applied to the Arab Gulf States

The Arab Human Development Report of 2009, issued by the UN Development Program, confirmed that water scarcity continues to pose a major challenge to human security in the Arab countries in general, and the Arab Gulf countries in particular. It suggests the possibility of addressing water scarcity challenges through adopting integrated water resources management (IWRM) policies, in the form of water supply and demand management mechanisms.[24]

As stated previously, the water poverty line is often considered to be 1,000 m^3 per capita per year, while if resources are below 500 m^3, the country faces an acute water shortage.[25]

According to the quantitative indicator, there are thirteen Arab countries that fall below the water poverty line, including all of the Arab Gulf states. The report, issued by the United Nations Economic and Social Commission for Western Asia (ESCWA), discusses water stress in the Arab countries, differentiating between four levels of severity: slight, significant, serious, and critical.[26] This level of water stress worsens as population growth rates rise.

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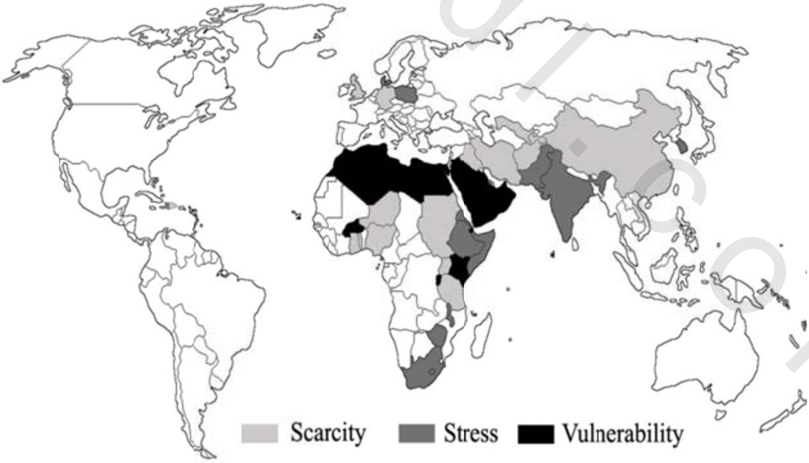
Table 5.1
Levels of Water Stress in Thirteen Arab Countries (2006)

Critical water stress (More than 10,000 persons per million cubic metres)	**Serious water stress** (Between 5,000 and 10,000 persons per million cubic metres)	**Significant water stress** (Between 2,500 and 5,000 persons per million cubic metres)	**Slight water stress** (Less than 2,500 persons per million cubic metres)
Kuwait	Bahrain	Jordan	Egypt
UAE	Iraq	Saudi Arabia	Lebanon
	Occupied Palestinian Territory		Oman
	Qatar		Syria
	Yemen		

Source: United Nations Development Program (UNDP), *Challenges to Human Security in the Arab Countries*, Arab Human Development Report 2009, UNDP Regional Bureau for Arab States (New York, NY: UNDP, 2009).

Figure 5.1
Areas of Limited Water Availability, 2008



Source: Based on World Resources Institute (WRI), 2008.

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Each Gulf country suffers from an acute water shortage, according to the quantitative indicator, where water share per capita does not exceed 500 m^3 per person per year.

Figure 5.1 shows areas of the world that experience the most severe levels of water stress according to fresh water available per capita annually in 2008, based on estimates by the UN Food and Agriculture Organization and the World Resources Institute (WRI).

The map shows that all Arab Gulf states are categorized as vulnerable in terms of their lack of water resources. There is no doubt that population trends play a key role in water demand, and this is certainly true of the Arab Gulf states. Rapid population growth has increased the severity of the water scarcity faced by these countries. Although natural factors such as intermittent periods of drought and limited reserves of fresh water can cause water scarcity, overpopulation adds the greatest pressure.

Table 5.2 shows the evolution of the populations of the Arab Gulf states. The region's population grows by two percent per annum, and the highest growth rate is found in Saudi Arabia (2.9 percent). If these rates endure, the combined population of these countries will double within roughly 26 years.[27]

Table 5.2

Demographic Indicators in the Arab Gulf States, 2009

Country	Fertility rate	Annual population growth rate	Population (million)
UAE	3.0	1.4	8.2
Bahrain	2.6	1.8	1.2
Oman	4.1	2.5	3.2
Qatar	3.5	1.6	1.6
Kuwait	4.0	1.7	2.6
Saudi Arabia	5.7	2.9	25.4
Total	**3.8**	**2**	**42.2**

Source: Secretariat General of the Cooperation Council for the Arab States of the Gulf (GCC), Population and Vital Statistics (http://www.gcc-sg.org).

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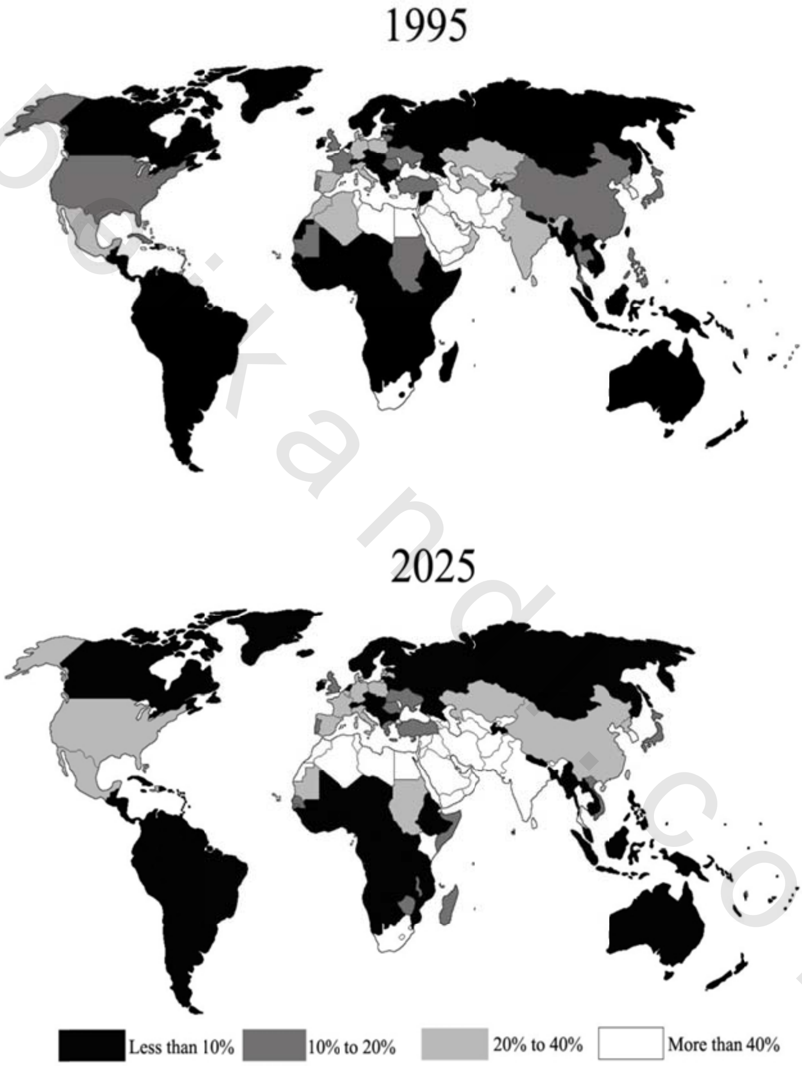
Figure 5.2

Withdrawal Rates of Available Fresh Water 1995/2025



Source: based on: http://developmentupdates.blogspot.com/2011/02/middle-east-and-mena-region.html).

Figure 5.2 shows the estimated growth in fresh water withdrawal rates between 1995 and 2025. The map shows that all the Arab Gulf states – with the exception of the Sultanate of Oman – were experiencing severe water shortages in 1995. By 2025, Oman will join the rest of the Arab Gulf states with acute water shortages with a water share per capita of less than 500 m^3 per year.

Table 5.3

Annual Renewable Fresh Water per Capita in the Arab Gulf States, 1970/2000/2030

Country	Total fresh water renewal (km^3/year)		Fresh water renewal per capita (m^3/year)		
			1970	**2000**	**2030**
UAE	0.2		897	77	56
Bahrain	0.1		455	156	108
Oman	1.0		1383	394	164
Qatar	0.1		901	177	129
Kuwait	0.02		27	10	6
Saudi Arabia	2.4		418	118	54
Total:	**3.82**	**Average:**	**680.16**	**155.34**	**86.16**

Sources: United Nations, World Population Prospects 2000 (UN, 2001); and P. Gleick, et al., *The World's Water 2002–2003: The Biennial Report on Freshwater Resources* (New York, NY: UN, 2002), Table 1.

Kuwait has almost no renewable fresh water and relies almost entirely on non-traditional sources such as desalination to meet the water needs of its people.[28]

In a study on the future of water in the Arab region,[29] the Arab Organization for Education, Culture and Science and the Arab Center for the Study of Arid Zones and Dry Lands, predicted the emergence of severe water shortages in the Arab Gulf by 2030.[30]

The Qualitative Indicator Applied to the Arab Gulf States

The problems faced by the Arab Gulf states do not relate to the quality of water resources, as these countries depend on groundwater to secure more than 50 percent of their water needs.[31] However, desalination is used to

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secure the remaining share of demand, and any pollution in the waters of the Gulf necessarily affects the water security of these states.

Hence the security of fresh water supplies is entwined with that of the salty waters of the Gulf, as the latter provides a large proportion of the water resources of the region. Therefore any consideration of water security in the region must consider the security of the Arabian Gulf itself. In general, there are three basic sources of threat to the Arabian Gulf:

The first is climate change. Global warming will lead to changes in the hydrological patterns of the Earth that determine the availability of water. Predictive models indicate a variety of complex outcomes; however, the most important implication is that most regions of the world affected by water stress will face even more severe shortages, and the ability to predict the size and character of future water resources will become ever more difficult, rendering these areas vulnerable to more extreme water crises.[32] Climate change will result in a significantly lower rate of water availability in the countries of the Arabian Peninsula due to lower rates of rainfall and high temperatures leading to increased evaporation rates in Arabian Gulf waters. Consequently, salinity will increase, requiring greater resource consumption and technological advancement in the desalination industry.[33]

The second is contamination of the waters of the Arabian Gulf. The main objective of establishing desalination plants is to provide alternative sources of water to meet domestic needs when groundwater is insufficient. However, desalination continues to increased salinity; consequently, it results in changes to the natural characteristics of the Arabian Gulf. Furthermore, the vast array of industrial activities and commercial traffic in Gulf waters and the resulting pollution will push up the costs of desalination and is, therefore, a threat to achieving water security in Saudi Arabia, Kuwait, Qatar, the UAE and Bahrain in particular, as these countries rely heavily on sea water desalination.[34]

The third is the risk of radioactive pollution of Gulf waters posed by the nuclear facilities at Bushehr on the Iranian coast. Should nuclear waste affect the quality of water in the Gulf it could necessitate substantial additional investment to ensure the quality of the desalinated water and guarantee the removal of any radioactive pollutants.

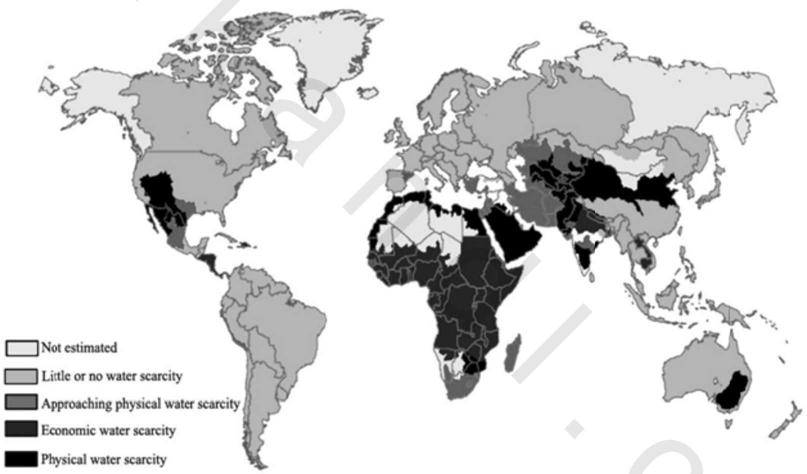
The Economic Water Security Indicator Applied to the Arabian Gulf

Water security is limited by a lack of availability or insufficiency of physical and/or economic resources with which to establish the necessary infrastructure to distribute water to users for drinking, irrigation, etc.[35]

The Arab Gulf states do not suffer any problems in this regard owing to their substantial financial resources that enable them to establish and build infrastructure to supply drinking water and improved sanitation, using plants for pumping, desalination and distillation. Figure 5.3 shows areas of physical and economic water insecurity.

Figure 5.3

Areas of Physical and Economic Water Scarcity, 2006



International water Management Institute (IWMI), "'Insights' from the Comprehensive Assessment of Water Management in Agriculture," Stockholm World Water Week, 2006, p. 8 (http://www.iwmi.cgiar.org/assessment/files_new/ publications/Discussion%20Paper/ InsightsBook_Stockholm2006.pdf).

The economic indicator, when applied to the Gulf States, shows that there is a progress in efforts to construct water infrastructure related to the distribution of clean drinking water and improved sanitation, in accordance with the two main measures outlined in the 2006 UNDP Human Development Report; namely the proportion of people who have

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access to clean drinking water, and the proportion of the population benefiting from suitable sanitation (see Table 5.4).

Table 5.4

Water and Sanitation in the Arab Gulf States

Country	Human development rank	Population using improved sanitation (%)	Population using improved sources of water (%)	
		2009	2007	2009
UAE	30	98	100	100
Bahrain	42	-	-	100
Qatar	3	100	100	100
Kuwait	63	-	-	-
Saudi Arabia	56	-	-	90
Oman	89	-	-	83

Source: UNDP, *Human Development Program*, 2007/2009 (New York: United Nations, 2007/2009).

The table shows that some of the Gulf states have managed to improve sanitation and water supply for their entire populations. These countries are Qatar, the UAE, and Bahrain.[36] Hence it is clear that the Arab Gulf states do not suffer from a lack of economic potential to improve water infrastructure such as pumping stations, water purification and desalination plants, and water supply networks.

National Water Security Policies in the Arab Gulf States

There are many different means of water management on the demand side which seek to reduce demand through promoting more rational levels and patterns of water use.[37] Researchers recommend[38] the use of modern techniques in irrigation, privatization and pricing of water, reduced subsidies on water consumption in urban areas, water quota systems and re-allocation of water resources to other sectors, and the development of greater water awareness among the public. These measures come within the framework of a new water management

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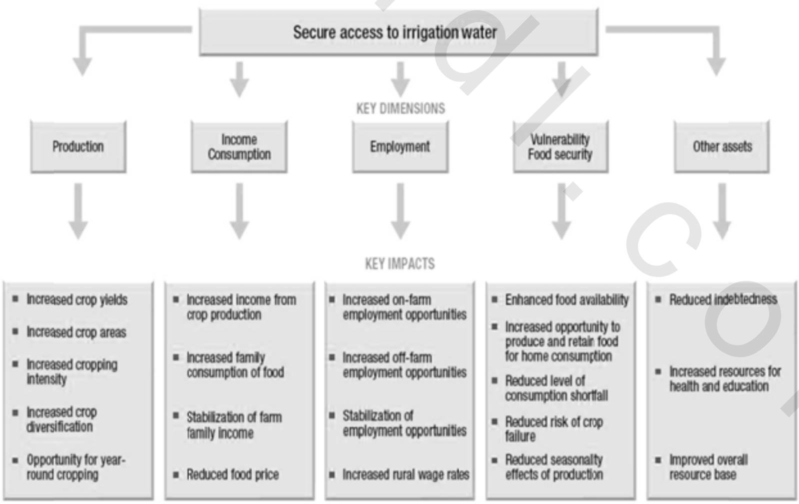
strategy from the World Bank based on demand-side management as an alternative to the prevailing trend of supply management.[39]

Modern Irrigation Techniques

Owing to the steady rise in the value of water, it is important that advanced water techniques be adopted such as drip irrigation, the use of low-cost plastic pipes, mist irrigation, and automated control systems in order to reduce consumption and increase efficiency. Rosegrant (1991) highlighted the inefficiency of most traditional irrigation systems used in developing countries, describing their efficiency to be between 25 and 40 percent.[40] Such inefficiency results in the wastage of large amounts of irrigation water. Meanwhile, if modern irrigation systems such as sprinklers and drip irrigation were used, water efficiency could reach as high as 80 percent. Furthermore, water wastage during the course of its flow from sources to agricultural land through dirt channels is significant, and could be reduced by using concrete channels or plastic piping.[41]

Figure 5.4

Poverty Alleviation and Access to Irrigation Water



Source: United Nations Development Program (UNDP), "Beyond Scarcity: Power, Poverty and the Water Crisis," *Human Development Report 2006* (New York, NY: United Nations, 2006), p. 175.

A report issued by the World Bank in 1990[42] found that irrigation systems serving more than half of the irrigated land worldwide require modernization. Furthermore, most irrigation systems in developing countries do not utilize their full capacity. Studies indicate that access to irrigation water and modern irrigation techniques can help to reduce poverty and water vulnerability (see Figure 5.4).

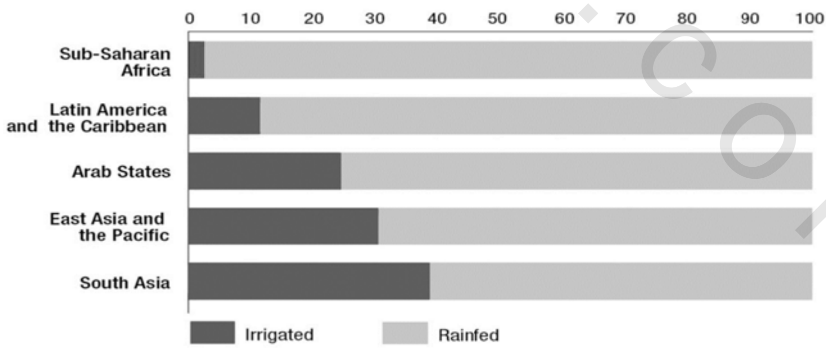
The study, prepared by Burt et. al., confirmed that the introduction of modern irrigation systems would raise irrigation efficiency and maximize the agricultural production, thereby increasing economic returns.[43]

Caruthers emphasizes the importance of taking into account social dimensions of the application of modern irrigation technology,[44] while some experts warn of related environmental impacts.[45]

Irrigation specialists now speak of four modern techniques, namely surface irrigation, subsurface irrigation, sprinkler irrigation, and drip irrigation. The decision as to which to employ depends on several factors, including the type of soil, the nature and quantity of the water source, the topography of the land, prevailing climatic factors, the type of crop, and other economic and social factors. Many studies have dealt in detail with irrigation methods, and the pros and cons of each.[46]

In the Arab countries we find that less than 25 percent of total arable land depends on irrigation. (see Figure 5.5).

Figure 5.5
Share of Rain-fed and Irrigated Arable Land in Developing Countries 1998–2002 (%)



Source: UNDP, "Beyond Scarcity: Power, Poverty and the Global Water Crisis," op. cit., p. 177.

In this context, the Arab Gulf states have gone to great to introduce modern and sophisticated irrigation techniques, but the challenge facing these countries is the need to standardize these systems of modern irrigation for use in all other agricultural sectors, and in all regions.

Using Brackish Water for Irrigation

Brackish water, found beneath deserts, inland lakes, and in the form of agricultural drainage, is used to irrigate suitable crops and plantation trees in deep sandy soil.[47] Brackish water can also be mixed with fresh water for agricultural or industrial purposes. The Arab Gulf states are a long way from exploiting the full potential of brackish water, and related policies have only been implemented to a limited extent.

Developing Water-efficient Plant Strains

In seeking to achieve food security, it is necessary to utilize genetic engineering to provide the largest possible agricultural yield with the lowest amount of available water. Researchers have taken advantage of the amazing advances in genetic engineering to develop plant species strains which require less water, are more tolerant of drought and hot climates, and which can be irrigated with water that is high in salinity. Perhaps the best examples are special species of wheat and rice, hybrid maize – which dramatically increases corn productivity – and certain resilient varieties of vegetable and fruit.[48]As a result, governments can guard against water constraints in the future at relatively low expense by increasing funding for agricultural research centers working to develop new breeds of efficient crops.

Some Arab countries have already benefitted from genetic engineering,[49] however, the Arab Gulf states are still far from developing this sector.

Crop Distribution

Research suggests that modified crop distribution is the most basic mechanism for rationalizing water consumption, either by reducing the proportion of crops that require large amounts of water, or by redistribution of crops within cultivated areas to fully exploit varying rates of water consumption in light of changing climatic and environmental conditions.[50]

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Crops differ in terms of their life cycles, water needs, and suitability to different conditions. Some crops are characterized by long life cycle, such as sugar cane, which consumes large amounts of water. Wheat, on the other hand, has a short life cycle and does not consume as much water.[51]

A study prepared by the Agricultural Reform Policy Project (APRP) of the Egyptian Ministry of Agriculture, in cooperation with the US Agency for International Development (USAID), recommended in 1998 that areas be dedicated to rice cultivation, that early maturing rice breeds be used, that water management should be improved in areas of rice cultivation, and finally that taxes should be cut on rice imports.[52]

Ahmed Sayyed El-Najjar agrees and proposes to add a stipulation that crop choice be confined to so-called "influential crops."[53] Studies also suggest that the Arab Gulf states need to adopt similar measures urgently to enhance their water security.[54]

Multi-sector Redistribution of Water

The redistribution of water based on efficiency and productivity is a key mechanism in adapting to the constraints imposed by limited water resources—although there are very few countries that are willing to divert water away from irrigation for use in industrial and domestic applications.

Given the fact that the irrigation sector accounts for roughly 80 percent of water use in the Arab Gulf states, a proportion that estimates indicate is likely to endure at least up to 2025,[55] the transfer of a relatively small percentage of irrigation water to other uses could assist in eradicating shortages in other sectors and raising productivity.

Ziauddin Elkoussy states that water allocation is now being discussed with some urgency at the regional and international levels, and within most international organizations concerned with water. Talk of water allocation has given rise to the concept of "quota efficiency," through which areas may be identified where water returns can be maximized based on economic feasibility as well as social, political and security indicators.[56]

Water Awareness: Building a Sustainable Water Culture

Efforts to educate societies through public education programs and similar initiatives have lead to significant changes in human behavior in terms of water use and conservation. Most of these efforts cost almost nothing compared with other investments in the water sector, and they should be encouraged and supported in the countries of the region. All water management efforts would be in vain without public willingness to participate directly or indirectly in water management. It is therefore necessary to build public awareness and enlightenment, distribute expertise to all who can benefit, and provide incentives for work that contributes to the sustainability and equitable distribution of clean water, irrigation water and sanitation services among all sections of society.

There is much evidence to suggest a distinct lack of awareness among the countries of the Arab world in particular, and the developing world in general, concerning the importance of water and its value to the process of development, including how to rationalize use, maintain supplies and protect water resources from pollution. This lack of awareness is manifested by infringements of crop restrictions, violations of environmental legislation, and wasteful domestic and industrial uses of water.

Large quantities of water can be saved and directed to other development uses if additional efforts are made to promote water awareness. Various actors can play a vital role in this regard; from families – by instilling the value of conservation and responsibility in children – to schools, universities, and houses of worship, and various elements of the mass media.

The *Population and Development Report* issued by the UN Economic and Social Commission for Western Asia (ESCWA) in 2003,[57] confirms that the concept of water conservation has gradually been introduced via curricula and the media throughout the Arab countries.

In the case of Saudi Arabia, for example, we find that the government understands the problems associated with a dry, harsh climate, limited sources of water, and growing water demand. It has created bodies specialized in water production and distribution, established laws and implemented measures such as the adoption of new pricing policies and methods to detect and prevent leakage. *Fatwas* have also been issued by

Islamic law to manage water demand effectively.[58] Also, subsidies for wheat production have been cut, leading to a decline of 25 percent in demand for irrigation water. Moreover, a *Fatwa* issued allowing the re-use of wastewater – particularly in irrigation – has led to the re-use of millions of m3 of treated wastewater each year. Saudi Arabia encouraged the re-use of (treated) industrial wastewater, and various plants are now committed to treating and distributing this resource.[59] Other measures have been taken to control well-drilling and monitor water consumption on farms in order to avoid excessive overuse. Farmers are encouraged to use modern irrigation systems, and work by virtue of irrigation timetables in order to minimize water demand.[60]

National Water Security Policies in the Gulf States: Managing Supply

There are many ways in which water resources may be developed and their use rationalized both in developed countries and many developing countries. Resource development projects include the construction of dams and water reservoirs, organizations to establish rights to wells, and networks of distribution canals.[61]

In this context, water specialists recommended using certain techniques via which to cope with limited water resources, including:[62] establishing tanks to collect water before reaching estuaries, rainwater harvesting using excavation and covered or un-covered ground reservoirs, and increasing strategic underground water reserves by diverting streams.

Seawater Desalination

Desalination refers to any process that removes salt and other minerals from water.[63] Leon Awerbuch confirms that current technologies allow the production of large amounts of water of a high purity through desalination.[64]

Globally, there are now more than 5,700 desalination units, with a total capacity of 100 mcm per day. Desalination plants operate in 105 countries, are manufactured by 170 companies throughout the world. The four states that rely most heavily on desalination are: Saudi Arabia, Kuwait, the United Arab Emirates, and the United States.[65]

Seawater desalination is still expensive, despite a fall in costs associated with the process, and the higher the salinity of the water the more expensive the process becomes. Moreover, the issue of the use of seawater desalination is entwined with a variety of economic and financial issues—in particular the cost of desalination compared to GDP per capita, especially in countries that do not enjoy cheap energy resources, environmental issues related to brine drainage, and manpower training and technology transfer.[66] Recent studies indicate that desalination in the future will likely be powered by solar or nuclear energy.[67]

Some studies suggest that annual demand for desalinated water in the Arab Gulf states will reach 5.4 bcm by 2030. Considering the wealth of these countries, and the fact that 97 percent of the world's water is salty, it would indeed be possible to produce this quantity of desalinated water; however, it would have negative economic effects. The opportunity costs of such an approach in the Gulf states, however, would be high, and would necessarily affect other aspects of development.[68]

Treated Wastewater Usage

With the increasing scarcity of fresh water and the growing demand from cities, increasing amounts of treated wastewater from cities could potentially be used for agricultural irrigation. With appropriate treatment and care, wastewater that is processed, purified and then reused could be of great benefit.[69]

An overview of the possibility of the use of treated wastewater for irrigation featured in a report prepared by the World Bank which concluded that the re-use of waste water could bring important commercial and environmental benefits.[70]

Treated wastewater can be used for irrigation according to the guidelines set by the World Health Organization (WHO). These guidelines necessitate the division of irrigation into 'restricted' and 'unrestricted' categories. The quality of the wastewater used depends on the application.[71]

Saudi Arabia has expanded its use of treated wastewater following a *fatwa* issued in 1978. In 1995, the kingdom re-used 15 percent of water in for palm tree irrigation. Moreover, the water used for ablutions in the Two Holy Mosques in Mecca and Medina is reused to flush toilets instead of

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using costly desalinated water. In Kuwait, 1,700 hectares (ha) of land is irrigated with treated water used to grow garlic, onions, eggplant and pepper (in accordance with WHO guidelines).[72]

The cost of processing wastewater differs according to the intended use, as well as the costs of treatment, equipment, labor, and transport. Studies conducted in the United States estimated that in 1983 the cost of the process ranged between 10¢ and $1 per cubic meter. In the Gulf states the figure was 40¢ in the early 1980s. The industrial reuse of water for cooling purposes (which requires the least amount of processing and the largest amount of water) is estimated at about 10¢ per cubic meter. The cost of water re-use for agricultural purposes is one of the cheapest, since water treatment is limited to primary treatment.[73]

Harvesting Rain Water

Collecting and diverting rain water to irrigate field crops involves the construction of reservoirs to collect the rainwater instead of allowing it to seep into the ground.[74] This plays an important role in the desert, as it provides drinking water for livestock; it is also used in isolated areas that do not have ready access to nearby water sources.

Water is usually stored in areas around rivers, or in artificial lakes, ponds, tanks, wells, rooftops, streets, etc. If the aim is to replenish groundwater, the water is stored underground. The amount of harvested water depends on the amount of rainfall, its intensity and distribution, and what can be collected.[75]

This strategy has received little attention in the Arab Gulf states, despite the fact that it can be used effectively in the coastal areas in the Arab Gulf states, which are known for their high rates of rainfall during winter.

With regard to the costs of harvesting rainwater, there is a clear disparity in cost according to the method employed. These costs have been studied by the University of Arizona, which determined that the cost per cubic meter of water ranged from 17¢ when using processed land (by removing stones and plants), and 53¢ when using plastic sheeting that fastened on stones, both based on a region with an annual rainfall of 250 millimeters. This cost is reduced to 8¢ in the first case and to 26¢ in the second when rainfall reaches 500 mm per year.[76] This method is used in

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some semi-arid areas of India and Pakistan.[77] Although many researchers confirm the effectiveness of harvesting water to increase productivity in dry areas, it is not the best solution for the production of crops in harsh environmental conditions.[78]

Strategic Storage

Strategic storage refers to reserves of water stored underground for distribution in an emergency situation to satisfy basic needs until normal production and distribution can resume.

The concept of strategic reserves is simple in countries that have natural freshwater, surface water or groundwater, and sufficient rainfall to supplement annual consumption through storage in underground reservoirs, dams or lakes. In this case, strategic stocks comprise quantities sufficient for long-term consumption ranging from four months to one year.

In the Gulf states, where water sources are scarce, the development of strategic supplies is quite different; as water resources are generally produced via desalination it is not possible to produce and store very large amounts in superficial tanks, as they require constant maintenance and attention, and may be exposed to contamination. In such cases, strategic stocks can be stored in deep underground reservoirs, where they do not require the same level of ongoing treatment as surface reservoirs.

Kuwait has extensive experience in this area, having spent exorbitant sums building storage capacity in concrete towers and ground tanks – with a capacity of approximately 2,000 million gallons – to meet demand for short periods in an emergency. So far, around 100 million Kuwaiti Dinars (KWD) have been invested in this infrastructure.

If Kuwait were to construct enough concrete water tanks to maintain sufficient strategic stocks for a year, for example, it would require around 45,000 million gallons at an estimated cost of KWD 2.5 billion. Moreover, 40 square kilometers of land would be required, based on the assumption that the reservoirs were five meters high. It would be difficult to treat and maintain such quantities in a state that is safe to drink. Even in an emergency when consumption is regulated (limited to 30 liters per person for drinking and cooking for a population of two million people), daily consumption in Kuwait is estimated at 13 million gallons. To cover

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the needs of a full year under emergency conditions, the reservoirs would need to have a capacity of 4,750 million gallons at least, at an estimated cost of KWD 260 million.

The Ministry of Electricity and Water in Kuwait commissioned the Kuwait Institute for Scientific Research to conduct a preliminary study assessing the feasibility of artificial injection into underground reservoir. The focus of the study was the Dammam aquifer at the Sulaibiya and Al-Shaqaya fields, as well as an underground water reservoir in the Sulaibiya field. So far the results of the survey at the Dammam reservoir have shown it to be technically and economically feasible. However, further investigation is required to determine what quality of water should be injected into the reservoir.[79]

Strategic storage and recovery from aquifers is a relatively new concept in the Arab Gulf. Abu Dhabi has adopted a groundbreaking pilot project – the likes of which has not been attempted in the region – for strategic storage of water by artificial injection in Liwa in the Western Region of the emirate. Feasibility studies for the project began in 2002 and were completed in 2004, and testified to the utility of the plan, and recommended a pilot project be established to inject water into five formations. The pilot project achieved an efficiency in the range of 85 percent, and following the end of the project in 2005 the Abu Dhabi Executive Council approved a further project to store sufficient water to last 90 days in an emergency situation, with the possibility of expanding the capacity to reach one year.

The strategic aquifer has the ability to store 3.5 billion gallons of water, with the potential for expansion to 30 billion gallons, while the largest surface reservoir in the UAE has a capacity of no more than 90 million gallons. The project has revealed the high economic feasibility and low cost of the infrastructure (80 fils per gallon) compared to alternatives (3.5 dirhams), the low environmental impact and land use required, and has proved the concept to be a suitable replacement for other methods of storage, with an efficiency of up to 83 percent compared to for eamplxe, 77 percent in the US.[80]

Water will now be injected into the formation, beginning this year 2013 and continuing until 2015, at seven million gallons per day. The initial cost of the project is estimated at 1.611 billion dirhams.[81] It is noteworthy that the Environment Agency–Abu Dhabi (EAD) has also commissioned a feasibility study and a pilot project for strategic storage in Shuwaib in the eastern region of the emirate.

Regional Water Security Policies in the Arab Gulf

There are many similarities among the Arab Gulf states in terms of their hydrological characteristics. They all share the same threats to their water sources, and all derive the large part of these resources from the same body of water – the Arabian Gulf. Hence, in some ways the Gulf states could already be viewed as a 'regional water system.' Therefore regional water security policies are naturally based on the inevitability of 'water cooperation' and the necessity of 'hydrological interdependence.'

International cooperation is an effective mechanism for ensuring the shared benefits of water resources, as well as containing and resolving water conflicts between states. In their 1985 study, Naff and Frey state:

> "Precisely because it is essential to life and so highly charged, water, unlike most other volatile issues of international relations, can-perhaps – even tends to – produce cooperation even in the absence of trust between the concerned actors."[82]

In the same year Caponera identified the most important principles of international water law, which encourage water cooperation.[83] In 1992 Rogers provided an analysis of the economic benefits derived from water cooperation. He concluded that such cooperation would help to achieve sustainable development.[84]

Hydrological interdependence is a key concept in international water relations. With it comes deeper relations, as cooperation in the management of shared water can bring tremendous benefits for human development on several levels including: reducing the possibility of conflict; improving the quality of shared water; achieving prosperity and securing livelihoods; and creating scope for a further cooperation in other sectors.

The countries of the European Union (EU) have achieved great improvements in freshwater standards through inter-state cooperation, leading to significant benefits for industry, human health and home users.[85]

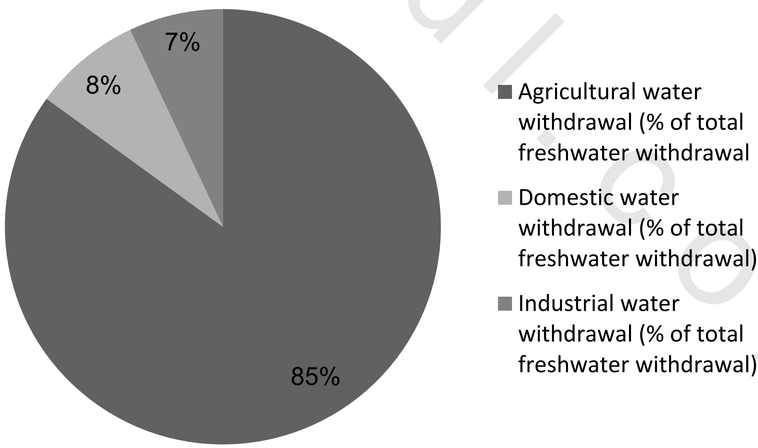
Imports, "Virtual Water" and Agriculture Abroad

All countries seek to achieve food and water security, and to provide for the requirements of their peoples without over-exploiting their natural water sources. The pattern of fresh water demand in the Arab Gulf region shows that with population growth water demand increases in all sectors: agricultural, industrial and domestic. However, agriculture consumes the vast majority of the water used in the region. About 80 percent of water used in the region is for agricultural use, and the remainder is divided between the industrial and domestic sectors. In the period 1965–1997, irrigated land in the region almost doubled, due in part to the fact that population growth has increased the demand for food.[86]

Water demand is increasing in both the industrial and service sectors to meet the demand of a growing population. While water demand has rapidly increased in all sectors, it has grown most rapidly in households. Indeed, the domestic sector now accounts for a higher share than manufacturing in some Gulf countries, at 25 percent or more in Bahrain and Kuwait (see Figure 5.6).

Figure 5.6

Use of Withdrawn Water in Arab Countries by Sector (%), 1999–2006



Source: United Nations Development Program (UNDP), *Challenges to Human Security in the Arab Countries*, Arab Human Development Report 2009, UNDP Regional Bureau for Arab States (New York, NY: UNDP, 2009).

High standards of living and consumerism have led to higher water demand in other sectors. Rising incomes often lead to increased consumption of meat, for example, and growing meat production requires even more water and grain. Gulf governments increasingly rely on food imports to feed populations that are growing faster than the pace of food production.[87]

To deal with the water–food dilemma, the Arab Gulf states import food from countries rich in water resources—which essentially represents "virtual" water, i.e., "water used elsewhere to produce foods that are exported to water-scarce areas."[88]

To this end, the Gulf states have also adopted a policy through which agricultural and arable land is purchased or leased in areas rich with water resources abroad—particularly Africa. This policy will allow the Gulf states to produce resources abroad, rather than just import them from abroad.

Regional Water Supply Management Policies

Purchasing Water from Abroad

Water imports[89] grew dramatically during the last decade of the 20th century because of the continued instability of water resources in many parts of the world, particularly the Middle East.

The idea of transferring water from one country to another has existed for some time. The supply of water from Iraq (the Shatt al-Arab) to Kuwait is one of the oldest water transfer projects in the region. It began in 1909 using a ship loaded with wooden barrels full of water, in 1939 a national company was established to transport and distribute water.[90] In 1953, a pipeline project was launched to transport the water to Kuwait at a rate of 6,165 m^3 per day. However, the lack of trust between the two governments prevented the completion of the project. However, it was resurrected in 1986, when a French company was commissioned by the Iraqi government to conduct a study of the project. An agreement was reached between Iraq and Kuwait in 1989 on the transfer of about 1,850 m^3 per day of water from the Shatt al-Arab for irrigation, and 4,315 m^3 per day from the Tigris for drinking, at an estimated cost of $1.5 billion, but the project is yet to be implemented.[91]

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A similar project was proposed to supply water from Iran. The idea is feasible from an economic perspective (since the distance between the Arab gulf states and Iran is very short), and might even be beneficial from a political perspective as well, as establishing such a project would help to build trust between Iran and the Gulf states.

The aim of the project was to provide Qatar with freshwater from the Karun river (in the southwest of Iran) via four 1,800 km pipelines reaching the Gulf coast, followed by another 200 km of pipelines under the sea to reach Qatar. The two countries entered into negotiations in 1989 and the estimated cost of the project was $13 billion. Each country was to bear the cost of extending pipeline inside its territory, as Iran would also benefit from the project by meeting the water needs of some of the areas and coastal cities through which the pipeline was to pass. Negotiations continued for many years; however, it was shelved in 1999.[92]

After the collapse of the talks with Qatar, Kuwait submitted a proposal to import drinking water from Iran. A feasibility study was prepared to discuss the various technical, economic, financial, and legal aspects of the project. The study suggested the establishment of a pipeline connecting Kuwait with a reservoir behind the Kharkha dam in the south-eastern province of Khuzestan. The proposed pipeline was 540 km in length, and would carry 300 mcm of water per annum for 30 years, with an option to double the volume to 600 mcm if needed. Iran would be paid 25¢ per cubic m^3, generating revenue of up to $75 million per year. The cost of the project was estimated at $ 2billion. The two sides agreed in January 2003 to form a joint action committee to study the various legal, economic and technical aspects of the project. However, although the two sides signed an agreement on the project in Tehran in December 2003, neither side has ratified it, thus preventing the implementation of the project.[93]

Lebanon adopted a similar scheme in the form of a project to transfer 750 mcm of water per year to the Arab Gulf states via a 1,500 km pipeline, whereby 400 mcm of water would be transferred directly from coastal springs and the remainder from four underground reservoirs located in inland basins. These reservoirs are artificially fed during times of abundance by spring water. The project aims to both strengthen water security in the Gulf, and also to prevent the wastage of water in Lebanon that runs into the Mediterranean every year for lack of a place to store it. However, the project remained just as an idea and no practical steps have been taken to turn the project into reality.[94]

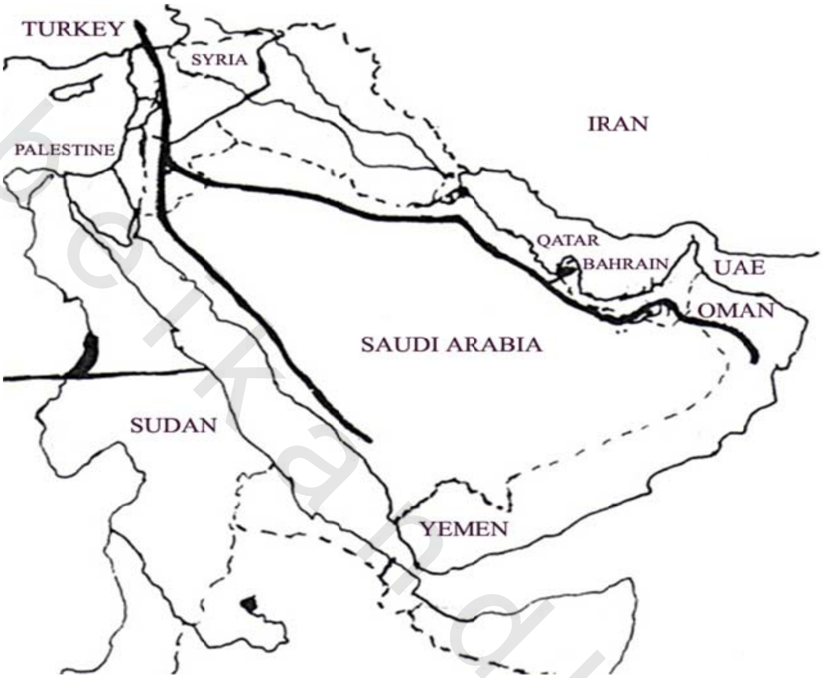
One of the most useful ideas came from the Philippines, a country that for many years has been a source of cheap labor for the Gulf states, and which is too far away to pose any external threat. US and Philippine companies proposed to export water to the Gulf countries using the huge oil tankers that return empty from Japan after delivering energy supplies, and often dock in Philippines to conduct maintenance and repairs. A Filipino official described the idea as "the other side of the oil trade between Asia and the Middle East," adding that his country could provide water from a deep aquifer to sell to the Gulf countries at a competitive price, because the transportation was already in place. The initial contract will supply 225,000 m^3 of water each day for irrigation.[95]

Perhaps the most well-known proposal is the "peace pipeline" project. It was suggested by Turkey, which is rich in freshwater resources, and proposed to supply Syria, Jordan and the Arab Gulf states. In 1987, the then Turkish Prime Minister Turgut Özal proposed for the first time the idea of establishing two water pipelines, stretching from Turkey to other parts of the Middle East. The peace pipeline would allow Turkey to share water from the Seyhan and Ceyhan rivers with other countries in the region. The project included the extension of two pipelines from Turkey to the region, as shown in Figure 5.7.[96]

Had the project been implemented, Turkey would have achieved a number of objectives, including substantial profits (estimated at $2 billion per year), and an expanded regional role as a stabilizing power in the Middle East.[97] Renewed interest in the project arose in the wake of the Madrid Conference in 1991, but a variety of economic and political factors prevented the project from coming to fuition.[98]

Figure 5.7

The Turkish 'Peace Pipeline' Project



Source: Abdulaziz Shihadeh Al-Mansur, Water Issue in Syrian Policy toward Turkey (Beirut: Center for Arab Unity Studies, 2000), p 193.

Cloud Seeding

Cloud seeding is a technique used to increase the chances of rain by introducing a mixture of ice and frozen carbon dioxide (dry ice) or silver iodide to clouds to induce rainfall."[99]

Although there have been various successful attempts in this field dating back to 1946 in the United States, there has been very little expansion in the use of this technique since.[100] Representatives of the Israeli water authority assert that more than 15 percent of the annual rainfall in Israel is as a result of cloud seeding.[101] Saudi Arabia and the UAE have recently adopted the technique to increase the amount of rainfall, but the benefits obtained so far have been limited.

Icebergs as a Fresh Water Source

This technique involves transporting icebergs from polar regions (composed of pure fresh water) to areas of water scarcity, and extracting the water for storage in coastal tanks.[102] As yet, this technology has yet to be implemented.

One study attempted to determine the feasibility of transporting icebergs from Antarctica to Jeddah, Saudi Arabia.[103] The study estimated the total cost of the project to be $34 million.[104] However, no such project has been launched.[105]

A review[106] of the costs of some alternative sources of fresh water, shows that the cost of wastewater treatment and re-use ranges from 10¢ to $1 per cubic meter, whilst the estimated cost of transferring icebergs is between $1.25 and 1.50, and the cost of desalination is between $1.39 and $2.37. According to these estimates wastewater treatment and re-use is the best option in terms in terms of economy, particularly as it will greatly reduce wastage. Furthermore, it is clear that approaches involving cloud seeding or icebergs are far from fully developed and therefore do not present viable alternatives. Desalination and sewage treatment techniques are the approaches which guarantee an increase in water supply.[107]

Conclusions

Contemporary, non-traditional problems such as climate change and radioactive pollution necessitate unconventional solutions and approaches. The efficiency and effectiveness of such policies may depend on the collective work of the Gulf countries to counter threats to water security in the region; this can only be achieved through the establishment of a Gulf organization for fresh water.

Owing to the vital importance of water to the region – to the extent that it has become a strategic commodity like oil – and since there is an Arab oil organization (the Organization of the Arab Petroleum Exporting Countries [OAPEC]), it is important that a similar organization be established to organize and managing water resources among the GCC countries; perhaps under the motto: “more water at a lower cost.”

Such an organization would include all the ministers responsible for water resources in the Gulf states, as well as experts and specialists from these countries with different political, economic, environmental, technical-engineering, geographic and geological disciplines, on the grounds that this issue has become one of truly interdisciplinary significance. The organization could undertake the following tasks and functions:

- Establish a research unit to conduct water studies, or a Gulf college for water affiliated to the organization. Such an institution could develop basic frameworks and guidelines for research on the various political, economic, social, environmental and technical aspects of the issue.
- Host conferences, seminars, workshops and training courses on various water issues, providing opportunities to develop creative solutions to water concerns.
- Organize meetings and forums bringing together public officials responsible for Gulf water affairs, civil society organizations interested in water, and water users' associations, with the aim of creating a state of partnership to achieve good governance in the field.
- Determine, test and implement innovations and research that can reduce water wastage.
- Devise and maintain a unified Gulf media strategy to raise water awareness and encourage a culture of water conservation among citizens and residents of the Gulf states.

The establishment of such organization to assuming these responsibilities would enhance regional cohesion by unifying the interests of the Gulf states. The water sector could well be the sector that brings about greater political, economic and strategic integration of the Gulf states along the lines of the European Union.

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6

Future Water Supply and Demand in the Gulf States

Nadim Farajalla

Water is vital to life, and access to water is considered by the United Nations to be a basic human right. The services derived from it represent the cornerstone around which development is shaped. Water is essential in agricultural and industrial production, and is critical for human health as well as the health of ecosystems. If water is limited, then development becomes restricted and the health of both humans and the environment is strained. Changes in climate, land use, and increasing demand have put major stress on freshwater resources.[1] According to recent studies, worldwide demand for water in 2030 will be 40 percent greater than that of today.[2] This increasing demand will be fueled mostly by population growth. World population has reached the seven billion mark and if the current growth rate is maintained as much as 60 percent of the global population may suffer water scarcity by 2025.[3] This situation will become worse as population increases, with the most water scarce countries dipping to below 100 m^3 per person per day (as shown in Table 6.1). This is well below the severe water scarcity level of 500 m^3/p/d defined by the UNESCO–IHE Institute for Water Education, at which water availability is considered a primary constraint to life.[4]

According to Bouwer, most of the population growth will be in third world countries, and more specifically in cities resulting from internal migration from rural areas and immigration across boundaries from one country to another.[5] This population-driven increase in demand for water is to satisfy:

- an increase in demand for food;
- increased energy consumption;
- human consumption; and
- industrial uses, due to increasing economic activity

Postel estimates that renewable water supply of a minimum of 2,000 m^3 per person per year are required to maintain living standards similar to those of western and industrialized nations.[6] However, many nations do not have the freshwater supplies to attain that volume.

Table 6.1

Water Availability in the Most Water-scarce Areas of the World in 2035

Country	Population 2010 (thousands)	Projected population 2035 (thousands)	Per capita water availability 2035 (m^3/person/yr)
Kuwait	2,737	4,328	4.6
United Arab Emirates	7,512	11,042	13.6
Qatar	1,759	2,451	21.6
The Bahamas	343	426	46.9
Saudi Arabia	27,448	40,444	59.3
Bahrain	1,262	1,711	67.8
Libya	6,355	8,081	74.3
Maldives	316	392	76.6
Yemen	24,053	46,196	88.8
Singapore	5,086	6,098	98.4

Source: Food and Agriculture Organization of the United Nations (FAO), "Information System on Water and Agriculture," Rome, 2011; and United Nations Population Division (UNPD), "World Population Prospects: The 2010 Revision." UN Population Division, 2011.

Worldwide, 70 percent of water withdrawals are for agriculture while 11 percent are for municipal (including domestic), and 19 percent for industrial uses.[7] The two main sources of water are surface and groundwater. Groundwater represents 90 percent of readily available water resources, with nearly one billion rural households in Africa and Asia directly dependent on it for their livelihood, while large parts of the global population relies on it for drinking water.[8] Water quantity is affected by water quality. Thus, if water is at hand but not suitable for use owing to some form of contamination, that water will not be available and might as well not be present. Thus threats to this resource are represented mainly by:

- discharges of domestic wastewater (treated and untreated);
- discharges of industrial effluent (treated and untreated);
- salinization of groundwater due to over-extraction and/or leaching of agrochemicals;
- over-pumping or over extraction; and
- climate change.

With the added demand for water and the increasing scarcity of this resource as a result of the problems described above, the dilemma then becomes how to ensure adequate quality water supply for a growing population—keeping in mind the need to ensure that water supply for economic activities is consumed in a sustainable manner.

The countries making up the Gulf Cooperation Council (GCC) reflect and even magnify the issues described. The following sections will detail the issues confronting these countries in relation to current and future supply and demand.

Water Resources in the GCC Countries

The Gulf Cooperation Council (GCC) is made up of six countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. The geographical area covered by these six nations is characterized as arid, with very high temperatures during summer and very mild winters. The annual average temperature regionally varies from 21°C during the period from October to March, and 33°C from April through September.[9] This combined with other climatic factors has resulted in a very high evapo-transpiration, reaching more than 2,200 mm/yr.[10] According to the UN Food and Agriculture Organization the average annual precipitation in the region is 90 mm, divided per country as shown in Table 6.2.[11] These facts have lead to the region being described as one of the most water scarce in the world.

Table 6.2
Average Annual Precipitation in the GCC Countries

Country	Precipitation (mm/yr)
Bahrain	83.0
Kuwait	121.0
Oman	125.0
Qatar	74.0
Saudi Arabia	59.0
United Arab Emirates	78.0

Source: Food and Agriculture Organization of the United Nations (FAO), "FAO AQUASTAT, 2012" (http://www.fao.org/nr/water/aquastat/main/index.stm).

Water Demand

The demand for water in the GCC countries follows the global trend, in that the major portion of the supply is allocated to agriculture, followed by municipal (including domestic) use, and last to industry. According to various reports over the past two decades, the average allocation of water in the GCC countries per sector was 60 percent to agriculture, 35 percent to municipal use and five percent to industry;[12] noting that Kuwait is the only country of the group to allocate more water to domestic use than agriculture.

Demand for water in the GCC countries in the decade from 1990 to 2000 showed an increase of nearly 140 percent.[13] While Qatar was to come close, Kuwait was the only country in which municipal water demand ever exceeded – as a percentage – agricultural demand. This distribution of water allocation is not expected to change significantly in the future in most countries of the region. The share of the agricultural sector is expected to drop from 63 percent in 1995 to 48 percent in 2025—but will still be the dominant recipient of this limited and scarce resource. Meanwhile, the share of available water supply allocated to domestic use is projected to rise from an average of 34 percent of total water demand in 1995, to 40 percent in 2025. Even though industrial water demand will rise most steeply, it will remain a low user. Data compiled by the FAO for the period 1995 to 2000 and projected to 2025, corroborates the trend observed by the World Bank in its 2005 report.[14] Table 6.3 summarizes these variations of demand on water per sector per cluster of years.

Table 6.3

Water Demand by Sector, 1995, 2000 and 2025 (%)

	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	UAE	Average
Domestic							
1995	38.6	77.0	6.1	39.2	9.3	34.4	34.1
2000	43.8	63.6	10.0	48.7	13.2	34.4	35.6
2025	27.8	78.6	25.4	47.4	26.7	34.4	40.0
Agriculture							
1995	53.8	20.9	93.5	56.2	89.6	63.8	63.0
2000	46.4	18.6	84.3	47.4	84.4	64.2	57.6
2025	44.5	10.0	60.5	42.3	67.4	64.1	48.1
Industrial							
1995	7.6	2.1	0.4	4.6	1.2	1.8	3.0
2000	9.7	17.8	5.6	3.8	2.3	1.4	6.8
2025	27.8	11.4	14.1	10.3	6.0	1.6	11.9

Source: FAO, 2012, op. cit.

Water Sources

According to data collected and compiled from the FAO, the main freshwater source in Bahrain, Kuwait, Qatar and Saudi Arabia is groundwater, with the former three almost totally dependent on groundwater as their only source of freshwater. Surface water is dominant in Oman and the United Arab Emirates. Table 6.4 summarizes the renewable water resources for each of the GCC countries for the year 2002.

However, the withdrawals from groundwater far exceed available renewable amounts. For example, Saudi Arabia utilizes 14,430 million cubic meters (mcm), which is nearly three and half times its renewable groundwater sources. The situation is the same in all other countries, with the withdrawal ratio being about 3:1, while the UAE far exceeds this ratio.[15] This mining of fossil groundwater sources is not sustainable, and will continue to deplete these nonrenewable sources, rendering future generations even more vulnerable to water scarcity.

Table 6.4

Annual Renewable Water Resources in the GCC Countries

	Renewable Water Resources				
	Surface (MCM/yr)	**Ground (MCM/yr)**	**Total (MCM/yr)**	**Surface % of Total**	**Ground % of Total**
Bahrain	0.2	100.0	100.2	0.2	99.8
Kuwait	0.1	160.0	160.1	0.1	99.9
Oman	918.0	550.0	1468.0	62.5	37.5
Qatar	1.4	85.0	86.4	1.6	98.4
Saudi Arabia	2230.0	3850.0	6080.0	36.7	63.3
United Arab Emirates	185.0	130.0	315.0	58.7	41.3

Source: FAO, 2012, op. cit.

When available fresh water amounts are compared to the demand by each country, it is evident that the volume of water is not sufficient to meet the demands of the various sectors. Table 6.5 shows a comparison of available fresh water to total water demand for each country. Oman is the only nation which can currently meet its demand through available resources; however, this should not be considered a comfort, as the values that are typically presented in databases are for average years. If available fresh water is diminished via reduced rainfall (droughts, etc.), the demand will not be met.

Table 6.5

Comparison of Available Freshwater to Water Demand

Country	**Total Demand (mcm)**	**Available Freshwater (mcm)**
Bahrain	443	100
Kuwait	436	160
Oman	1,407	1,468
Qatar	298	86
Saudi Arabia	22,352	6,080
United Arab Emirates	3,988	315

Source: FAO, 2012, op. cit.

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In summary, the majority of the GCC countries suffer from water deficit ranging from a maximum of nearly 660 m^3/person/year in the UAE to no a slight surplus of about 50 m^3/person/year in Oman. This deficit has forced the GCC countries to look for alternative sources of water to augment available fresh water supplies in order to meet the demands of their various sectors. As such, all (by varying degrees) have turned to seawater desalination. Use of treated wastewater has grown in recent years; while very limited use of has been made of return irrigation flows.

Table 6.6

Water Deficit by Country

Country	Water deficit (m^3/person/year)
Bahrain	-296.60
Kuwait	-106.40
Oman	49.70
Qatar	-113.40
Saudi Arabia	-522.40
UAE	-659.00

Source: FAO, 2012, op. cit.; and World Bank, "World Bank Development Indicator Database," 2012 (http://data.worldbank.org/indicator).

Table 6.7

Non-conventional Sources of Water in the GCC Countries

	Total Non-conventional	Desalinated		Treated Wastewater		Agricultural Drainage	
	(mcm/yr)	Total (mcm/yr)	%	Total (mcm/yr)	%	Total (mcm/yr)	%
Bahrain	134.2	119	88.7	15	11.2	0.2	0.1
Kuwait	397	345	86.9	52	13.1	-	-
Oman	109	86	78.9	23	21.1	-	-
Qatar	159	131	82.4	-	-	-	-
Saudi Arabia	1,450	1,050	72.4	360	24.8	40	2.8
UAE	1,242	1,008	81.1	234.5	18.9	0	0

Source: FAO, 2012, op. cit.; and World Bank, 2012, op. cit.

Desalination thus plays a prominent role in augmenting freshwater sources to meet the water demand of various sectors. The GCC countries account for nearly 60 percent of the world's desalination capacity,[16] with Saudi Arabia and the United Arab Emirates accounting for half of that. Production has increased, as has the share of the total water supply that is generated by desalination. Table 6.8 presents data for the years 1990 and 2000. It may be observed that the smallest increase in production occurred in Oman (about six percent) – the country that is closest to being totally supplied by renewable freshwater – and the largest in Saudi Arabia, at nearly 105 percent—the country with the largest area and largest population. The United Arab Emirates also nearly doubled its output. What is noteworthy, however, is that the percentage of total supply from desalination has not varied much in this ten-year period—amounting to an increase of around six percent in total and with Saudi Arabia and Oman actually experiencing a reduction. This indicates that the water supply mix for these two countries has shifted in the period 1990 and 2000 to include other sources of water—both conventional and non-conventional.

Table 6.8

GCC Desalination Production and Percentage of Total Water Supply

	1990		**2000**	
	Production (mcm/yr)	**% of Total Supply**	**Production (mcm/yr)**	**% of Total Supply**
Bahrain	56	54	76	66
Kuwait	240	79	418	90
Oman	52	37	55	33
Qatar	83	98	132	100
Saudi Arabia	495	47	1022	41
United Arab Emirates	342	63	674	81

Source: World Bank, "A Water Sector Assessment Report on the Countries of the Cooperation Council of the Arab States of the Gulf." Washington, DC, 2005 (http://siteresources.worldbank.org/INTMNAREGTOPWATRES/Overview/20577193/GCCWaterSectorReport--Englishversion.pdf).

The Problem

As stated earlier, water resources in the GCC countries are being subjected to increasing stress, mostly owing to escalating demand, but also as a result of environmental threats. The major stressors observed are: population growth, economic growth (leading to heightened living standards) and climate change.

Population Growth

The most apparent stressor is population growth. The economic boom experienced by all GCC countries has encouraged local population growth and attracted migrant workers of all professions—both blue and white collar workers. This population increase has been very rapid and explosive. Between 2002 and 2010, GCC countries' GDP grew by an average of about seven percent.[17] The fastest growth in that period was in Qatar, with an annual growth rate of 13 percent, followed by the UAE at 10.5 percent, and Bahrain at 8.5 percent. The overall population increased from slightly over 30 million in 2002 to more than 43 million in 2010.[18] Table 6.8 summarizes the population growth of the six GCC nations. This rapid expansion was reflected in the growth of urban centers, mostly owing to people (both locals and migrants) moving into them. According to Mirkin, currently nearly 85 percent of the all the residents of the GCC may be found in urban centers.[19] Kuwait and Qatar have the highest percentages of urban dwellers, at 98 and 96 percent respectively, and Oman the lowest at 72 percent (see Table 6.9).

Table 6.9
Population of the GCC Countries in 1,000s (2002–2010)

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Bahrain	642	647	672	725	811	926	1,052	1,170	1,262
Kuwait	2,070	2,127	2,189	2,264	2,351	2,448	2,548	2,646	2,737
Oman	2,303	2,336	2,378	2,430	2,491	2,561	2,637	2,712	2,782
Qatar	624	654	715	821	978	1,178	1,396	1,598	1,759
Saudi Arabia	21,463	22,334	23,214	24,041	24,799	25,504	26,167	26,809	27,448
UAE	3,255	3,401	3,658	4,069	4,663	5,406	6,207	6,939	7,512
Total	30,357	31,499	32,827	34,350	36,094	38,023	40,007	41,874	43,500

Source: FAO, 2012, op. cit.; and World Bank, 2012, op. cit.

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This growth in population has increased the demand on a scarce resource, and this is clearly shown in the average increase in demand for domestic of 53 percent over a 20-year period from 2005 to 2025,[20] the largest of which is observed in the UAE and Kuwait (see Table 6.11).

Table 6.10
Percentage of Population living in Urban Areas: Past, Present and Projected

	1975	2010	2050
Bahrain	84	89	93
Kuwait	86	98	99
Oman	30	72	82
Qatar	88	96	98
Saudi Arabia	49	82	90
United Arab Emirates	78	78	87

Source: Barry Mirkin, "Population Levels, Trends and Policies in the Arab Region: Challenges and Opportunities," Arab Human Development Report, Paper 01, 2010.

Table 6.11
Total Domestic GCC Water Demand in 2005 and 2025 (mcm)

	2005	2025 (projected)	% Increase
Bahrain	139.1	204.4	47
Kuwait	405.5	642.3	58
Oman	205	302.8	48
Qatar	80	123.6	55
Saudi Arabia	2100	3178.3	51
United Arab Emirates	943	1500.2	59

Source: United Nations Economic and Social Commission for Western Asia (ESCWA), "ESCWA Water Development Report 2: State of Water Resources in the ESCWA Region," E/ESCWA/SDPD/2007/6, New York, 2007.

The increase in demand has reduced the amount of freshwater available to the residents of the GCC countries by an average of 75 percent for the period 1970–2000, with the UAE experiencing a 93 percent reduction (see Table 6.12).

Table 6.12
Annual Renewable Water per Capita (mcm/yr)

	1970	1980	1990	2000
Bahrain	524	329	219	164
Kuwait	215	116	75	73
Oman	1,245	817	553	373
Qatar	450	218	103	85
Saudi Arabia	670	411	244	186
United Arab Emirates	864	182	107	59

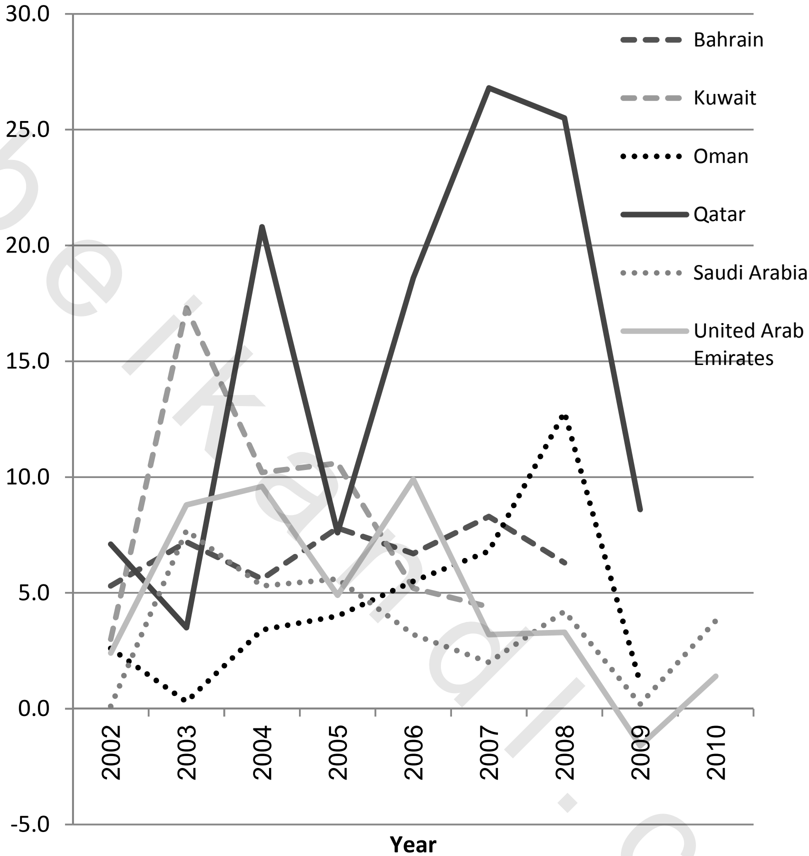
Source: World Bank, 2005, op cit.

Growing Economy

The growth in the economies of the GCC countries over the last three decades has transformed these countries in many ways. Infrastructure has been modernized, enabling most residents to have access to water supply and sanitation. In addition, life expectancy increased by nearly 10 years, reaching 74 in 2000.[21] Per capita income rose for all six countries, as did their GDP, which averaged seven percent growth in the period 2002–2010 (noting that the global economy crashed in 2009). The largest growth was witnessed by Qatar, reaching an average of 15 percent for the same period. Figure 6.1 shows the variation in GDP growth for all six countries. This GDP growth, however, was partially to blame for a 17 percent increase in water use for the same period.

The improvement in the economy also brought about an increase in the standard of living, and along with it an increase in the consumption of water that ranges (with the exception of Oman) from 300 to nearly 750 liters per person per day, which is considered amongst the highest in the world.[22] For example, daily per capita consumption of water in Kuwait rose from 208 liters in 1980 to more than 500 liters in 2000 – a 140 percent increase – while Oman's increase in consumption rose by 170 percent. These rates can be compared to 300 liters per person per day in Japan and around 400 liters in Australia.[23]

Figure 6.1
GDP Growth in the Six GCC Countries (%)



Sources: Adapted from: World Bank, 2012, op. cit.

Climate Change

The changing climate will have a major impact on the availability of fresh water in the GCC countries. According to Elasha,[24] the region will suffer from rising temperatures along with a change in the pattern of rainfall. Some parts of the region, such as parts of Saudi Arabia, may observe a trend of precipitation increase. However, the added rainfall will likely come in as short bursts resulting in higher risks of flash flooding.

Overall though, Kundzewicz, et al. indicate that the region as a whole will experience a reduction in precipitation, which coupled with rising temperatures and sea levels will have negative impacts on freshwater resources.[25] El-Quasy estimates that rainfall over the Arabian Peninsula could be diminished by 15–20 percent.[26] It is expected that if current trends endure, available freshwater would fall to 50 percent of present amounts by the year 2030.[27] Recharge of groundwater will decrease considerably, as will surface water; extreme events, such as droughts and floods, will be more common and more devastating; desalination plants will be vulnerable to rising sea levels as well as increases in sea salinity, making the desalination process more expensive;[28] infrastructure will also be vulnerable to the variable climate, with pipelines and water or wastewater treatment facilities particularly sensitive; coastal regions will be vulnerable to sea level rises, particularly in view of the extensive number of people living in coastal areas in the GCC; and water quality problems could arise, stemming from microbial and pathogen content.[29]

Rising temperatures will lead to greater consumption of water by people, animals and plants, further adding stress to a depleted and vulnerable resource. Furthermore, low flows in rivers will accentuate the problems by increasing the pollutants in rivers, streams, lakes and groundwater, thereby leading to higher treatment costs or – at times, if the pollution is too high – rendering the source unavailable for consumption. In addition, more energy will be consumed in the treatment of water with increasingly higher concentrations of contaminants. Finally, more water will be consumed for cooling people, animals, plants and equipment as a result of the rising temperatures.

Other issues

There are several other issues that add to the stress on water resources, which mainly stem from economic, financial and administrative approaches (regulations, policies, etc.) that have not been addressed in the previous sections. The following comprises a brief listing of these stresses.

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Water Management Plans and Strategies and Infrastructure Development

Most water-related strategies in the GCC countries have focused on the supply side rather than the demand side. The Abu Dhabi Declaration (at the 31st meeting of the GCC leadership) seems to have been a turning point, in that it called for a comprehensive long-term water strategy that takes into consideration all relevant issues that might impact water resources and their utilization, including:[30]

- the possible impact of climate change on water resources;
- management of water consumption in different development sectors;
- interaction between the agricultural and water sectors; and
- the potential effects of desalination operations and activities on the quality of sea water, living creatures and climate change.

The sanitary network in the GCC countries lags behind that of the water supply network, reaching a high of 60 percent coverage in Kuwait versus an average of 20–40 percent in the other countries of the Council.[31] Of the nearly 1,100 mcm of treated wastewater produced annually, only 769 mcm are reused. Bahrain, Qatar and Kuwait reuse nearly all their treated sewage, while Saudi Arabia only uses 47 percent.[32]

Dawoud and the World Bank indicate that leakage from water and sewage networks are causing water tables to rise, flooding the basements of buildings.[33] Moreover, sewage leakage is contaminating groundwater resources.

Groundwater management in most GCC countries is poor—no country, with the exception of Oman, has a clear, effective groundwater management policy. Regulation and prioritization of access to groundwater are haphazard, with no proper well licensing in place and no pricing mechanism. The uncontrolled pumping of groundwater, especially for agricultural production, has led to seawater intrusion and to up-coning of brackish water in areas more remote from the sea and ocean;[34] this is especially the case in Oman, Bahrain and Qatar.

Financial Perspective: Tariffs, Subsidies, Costs, etc.

Water supply and demand and the infrastructure involved require significant capital investment to set up, and equally significant budgets for maintenance and operation. According to the World Bank, the major financial drawbacks to most operating and maintaining this infrastructure are:[35]

- Heavy subsidization of the water sector: if current trends endure, nearly 10 percent of oil revenues across the region will be taken up by 2025.
- There is sufficient data on the production/supply side, but very little on consumption, unaccounted for water (which in some areas is up to 40 percent), cost recovery, etc.
- Tariffs are very low, barely covering 10 percent of costs (and in Saudi Arabia less than one percent).
- Tariffs target residents differently; nationals in Kuwait, Qatar and the UAE get their water practically for free, while expatriates pay tariffs which in some instances are very steep.
- Leakage from water supply networks is fast becoming a serious financial drain. For example, in the leakage and loss from the water supply network in the UAE is in the range of 20–40 percent. When this is coupled with cost of desalination of $1–2 per cubic meter the amount becomes alarming.

Desalination

As stated earlier, this process is crucial and its product accounts for a significant portion of the water consumed within the GCC countries; however, there are issues of concern within this sector as reported by Alterman and Dziuban, the World Bank, and Handley, amongst others:[36]

- The cost of desalination is still high, especially for multistage flash plants. Current estimates put the range at $1–2 per m^3. Considerable improvements have been made with reverse osmosis, and the costs of this process are reportedly nearing $0.5/m^3. Some costs reported by

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Dawoud and Abderrahman range between \$0.48 and \$2.20 per cubic meter in Saudi Arabia; from \$1 to \$1.45 in the UAE; \$1.14 to \$1.64 in Qatar and \$0.56 in Bahrain.[37] These reduced costs are also due to the fuel subsidy in each of these countries.

- The disproportional nature of the costs are exemplified by Saudi Arabia, which uses 1.5 million barrels of oil per day (mbpd) to desalinate 24 mcm of water per day.[38]
- Desalination plants are working at near capacity, but many plants were commissioned in the 1970s and 1980s and now require extensive rehabilitation, for which significant investments must be made. Some would need to be scrapped and replaced by newer plants.
- Desalinated water is appropriated to irrigating landscaped areas and for agricultural products. In Abu Dhabi only 25 percent of desalinated water is used for drinking.
- Domestic oil use is mostly taken up by desalination. For example, 65 percent of domestic oil use in Saudi Arabia is for desalination.
- Arabian Gulf salinity is increasing owing to the return of brine to the sea from desalination plants in many locations. This will increase the cost of desalination, especially in terms of operation and maintenance.

Agriculture

Most of the GCC countries subsidize agricultural production as a means to achieve some kind of self-sufficiency, particularly in crops, and also as a way of redistributing accumulated oil wealth.[39] These subsidies are typically focused on wells, fuel, trade protection, price support programs, etc. This has led to the production of poor quality crops with poor returns, making agriculture production profitable only because of the subsidies and incentives that governments have put in place. This approach has led to wasteful use and depletion of groundwater. In some areas of the region, the water table has dropped by 200 m in a 20-year period. Furthermore, in Saudi Arabia, for example, irrigation water use over a period of 20 years rose from 7.4 billion cubic meters (bcm) in 1980 to 18.3 bcm in 1999, having reached a mid-period peak of 20.3 bcm.

According to the World Bank, net irrigated areas in GCC countries have increased by 100–300 percent,[40] but agriculture contributes on average only around two percent to their GDP, with the highest contribution being around five percent in Saudi Arabia and the smallest in Qatar and Kuwait.[41] Agriculture is the largest user of water in half of the GCC countries; the allocation is as follows: 84 percent in Saudi Arabia and Oman; 64 percent in the UAE; 47 percent in Bahrain and Qatar and < 20 percent in Kuwait.[42] Nearly 85 percent of the water used in agriculture comes from groundwater sources, with nearly 80 percent from fossil – i.e. non-renewable – sources.[43] Losses of water in agriculture are high, often as a result of the traditional irrigation methods employed (flood and furrow) and also due to improper irrigation application and scheduling practices. These losses may reach 50 percent of pumped water. Less than two percent of treated wastewater is used for agricultural production—most is either used in landscape irrigation or simply discharged into *wadi* beds where they percolate into the soil or simply evaporate.

Summary and Recommendations

Water resources in the GCC countries are very scarce and are under increasing pressure from growing populations and their associated activities, as well as from climate change. No integrated water resource management plans have been effectively implemented either nationally or regionally. Groundwater is the main source of water for most GCC countries, yet no country (with the exception of Oman) seems to have developed a proper groundwater management strategy with proper access controls, prioritization, and pricing mechanisms. The focus is placed on making up the deficit through desalination. Even though the cost of desalination has come down and new technologies such as remote sensing are helping to achieve further cost reductions, most plants were commissioned in the 1970s and 1980s and now require major investment for their rehabilitation or replacement. A significant amount of water goes to the agricultural sector, with heavy subsidies encouraging poor quality produce and inefficient use of a scarce resource. Treated wastewater reuse is very limited and misdirected – most of it going to landscape irrigation and nonproductive uses. Tariffs

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are minimal, and do not cover the cost of production, treatment, conveyance, etc.

The most sustainable approach to overcome the region's water scarcity (which would handicap development) is to start by controlling demand and establishing the institutional framework to implement this approach. Such an approach is best implemented using integrated water resources management (IWRM), the focus of which would be primarily on demand management and then on the enhancement of supply. The following approaches include those that could be taken by the GCC countries individually or collectively.

Establishing an enabling environment in which all management plans would be implemented is crucial. Most GCC countries have reasonably well operating institutions and agencies that manage various aspects of their water resources; however, these institutions have conflicting jurisdictions and mandates, and often each handles one aspect of the resource to the exception of others, i.e., one agency for groundwater and another for desalination with little or no coordination as to production, conveyance, use, etc. As such, there is a need for an institution or agency that governs all aspects of water resources, starting with supply, passing through the demand aspect and ending with wastewater treatment and encompassing all the sources within—similar to water boards in many states in the USA. This agency would develop the overall water strategy for the country and would supervise and coordinate the plans and operations of sub-agencies who could handle the separate components. This would ensure that there is no duality in resource development or allocation of water, and that all activities related to the water sector are coordinated and not abortive. Furthermore, such an agency would also coordinate strategic water resource plans and their implementation with other agencies of the various countries of the GCC.

Alongside institutional changes, legal and regulatory reforms should take place to modernize laws and mainstream regulations, thereby reducing bureaucracy and improving the potential for implementation. Another key component to this aspect is the incorporation of financial incentives to promote water conservation and deter waste. A fair tariff scheme – the basic aim of which is to recover the cost of ensuring the supply of safe water – is the cornerstone around which other financial schemes may be cultivated. These include, but are not restricted to:

- Charges for water extraction.
- Incremental block rates to ensure equity.
- Variable charges at different times during the day/season.
- Provision of conservation subsidies.
- Waver of customs fees on water saving technologies.
- Tax and financial incentives to incorporate water saving technologies in developments and rehabilitation.

In addition to the above, a two pronged approach should be taken to preserve and conserve available sources. The first is to control demand and the second to enhance supply. In enhancing the supply of water the aim would be to acquire as much of the available resource as possible at the most reasonable cost. Several steps may be taken in the following areas:

Source Control

- Groundwater
- Control access to groundwater.
- Institute and/or improve aquifer recharge.
- Phase out and remove subsidies for well drillings, pumps and all other equipment and activities related to groundwater exploitation.
- Meter all existing and new wells.
- Desalination
- Improve efficiency by using modern technologies such as reverse osmosis, nano-filtration, etc.
- Reduce cost through development of co-generation plants.

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- Target brackish water for desalination as a primary effort to reduce desalination costs and environmental degradation.
- Wastewater
- Diversify the use of wastewater as a source for usage in other than landscape irrigation to include industrial use, irrigation of certain corps.
- Stormwater
- Integrate rainwater collection/harvesting schemes at various scales. For example, impose the incorporation of rainwater collection and storage infrastructure in all new and retrofitted buildings; incorporate collection and storage of stormwater in existing and new roads and in open spaces in rural and urban areas.
- Bulk Imports of Water from Regions Enjoying Water Surpluses

Distribution and Conveyance

- Network Extent
- Expand the sewage network to ensure full coverage to decrease and even prevent discharge into groundwater thereby reducing pollution and uncontrolled water rise.
- Unaccounted-for-water
- Reduce leakage through rigorous water supply network maintenance programs.
- Use modern technology in tracking water distribution – i.e. supervisory control and data acquisition systems (SCADAs).
- Prevent breaking into distribution networks and illegal siphoning of water by vigilant inspections and levying of heavy fines.

On the demand control and management side, several actions may be taken that would allow the limited resource to last longer. The following are general areas in which improvements would have significant effect, and that are applicable across the GCC countries:

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Agriculture

Since this sector is the greatest user of water, any improvement in efficiency and reduction in waste will have positive repercussions for the water sector in general.

- Introduce new crops and plants suited to the dry and hot environment and to saline water.
- Focus agricultural production on cash crops revenue from which would be able to cover the cost of water supply.
- Enforce the use of efficient irrigation techniques such as drip/ trickle and subsurface irrigation.
- Turn to conservation agriculture.
- Use soil-less agriculture including hydroponics.
- Remove subsidies on all aspects of agriculture except those that promote water conservation.
- Educate farmers on modern cultural practices to reduce wastage of water and other resources.
- Incorporate virtual water principle in assessing agricultural production costs.
- Rely on local scientific research for the development of all the above especially the International Center for Biosaline Agriculture in the UAE and International Center for Agricultural Research in Dry Areas (ICARDA), amongst others.
- Consider moving away from agriculture in certain areas and train farmers in professions other than agriculture.

Water Saving Measures

- Require the fitting of water saving devises in all new constructions and the retro-fitting of existing buildings undergoing renovation and rehabilitation.
- Impose metering throughout the distribution network.

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Community Outreach and Public Involvement

- Development of water users' associations.
- Involve communities in planning for water resource development and allocation.
- Educate communities on conservation techniques and involve members in disseminating the information and training.

Policies and Regulations

- Cost recovery and tariffs are at the core of sustainable management of water resources. Therefore structure tariffs to attain full cost recovery—introduce incremental block rates to ensure equity.
- Encourage the participation of the private sector with the aim of building up the capacity of the public sector and streamlining operations.
- Integrate water resource management into the national and regional development plans so that water availability controls development and not the other way round.

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Part III

Regional and International Food Security

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7

Challenges Facing Global Food Supplies

Mohamed Ait Kadi

"Unprecedented challenges require unprecedented solutions."

— Amin Maalouf

The global economic development that has occurred over the past 50 years has substantially improved human well being, but it has also created unprecedented social, economic and environmental problems. Furthermore, interdependencies among nations and economies have created new risks and vulnerabilities, as demonstrated by the recent food and financial crises.

Today's world is undergoing a major transformation characterized by increased globalization, fundamental shifts in economic and political power, growing global environmental problems, and potentially explosive social conflicts. The past decade alone has reversed a 100-year decline in resource prices as demand for commodities has surged.[1] The volatility of resource prices today is at an all-time high; the era of cheap food is over. Indeed, the price and volatility of different resources have developed increasingly tight links over the past ten years. Shortages and price changes in one resource can rapidly impact other resources. In this context the correlation between food prices and energy prices is now higher than at any point in the past century because of biofuels, fertilizer and transport costs.[2]

The world has also experienced several, sometimes unexpected shocks. These include the rise in energy prices in 2008 and 2010, and concerns about energy security; related food and commodity price rises; worries about water and food security and how to feed 9 billion people by 2050; declining ecosystem services and the global economic recession. Climate

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change is yet another dark cloud on the horizon which may bring the prospect of more extreme and unpredictable floods and droughts to those parts of the world that are already struggling to cope with climate uncertainties.

These problems are becoming increasingly interconnected. They cannot be solved by individual countries acting in isolation. On the contrary, they can sometimes be exacerbated when countries act alone.[3] This can be illustrated by the 2007–2008 food crisis. The year 2008 was one of extreme variability for international food prices. In the first half of the year, prices increased for nearly every agricultural commodity. For instance at their peaks in the second quarter of 2008, world prices of wheat, and maize were two times higher than at the beginning of 2003 and the price of rice was three times higher. Oil prices also rose sharply.

Uncoordinated government responses to rising prices led to enormous efficiency losses within the global food system. When food prices were particularly high, major producers imposed restrictions on agricultural commodities in order to minimize upward pressure on domestic prices. Although these export restrictions may have reduced food shortage risks in the short term, they made the global market smaller and more volatile. Furthermore, these export bans provoked panic buying in the international markets which in turn deepened the food crisis. This distrust in markets has led many countries to reexamine the "merits" of self-sufficiency and start rebuilding their national stocks and investing in agriculture in other countries to secure supplies. Large-scale acquisitions of farmland (termed "land-grabs") in Africa, Latin America, Central Asia and South East Asia have made headlines in a flurry of media reports across the world. For people in recipient countries this new context may create opportunities for economic development and improvements in livelihood in rural areas; but in the absence of a code of conduct, it may also result in local people losing access to the resources on which they depend for their food security.

Social protests and unrest have occurred in a number of countries and cities around the world. The seriousness of these incidents is suggestive of what might occur – possibly on much larger scale – in the event that future food shortages become exacerbated. This crisis should, therefore,

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be treated as an early warning sign of what is to come. If the world is having difficulty meeting global food security now, the challenges in the future loom large. We have indeed reached the age of consequences.

Heads of states and governments have listed food security as a major global risk, and consensus on a global food security agenda has emerged. It calls for: (1) increasing investments in agriculture, rural infrastructure and market access for farmers, and especially smallholders; (2) expanding social protection for the poorest in urban and rural areas; (3) enhancing the efficiencies of agricultural markets through greater transparency and equity in global trade; and (4) facilitating agriculture production responses via scientific and technological solutions.

Food Security at a Crossroads

There is growing evidence of a fundamental structural change in the global balance between food supply and demand, and this is increasingly being reflected in rising world food prices. The declaration of the UN Food and Agriculture Organization (FAO) World Summit on Food Security, held in November 2009, stated that: "to feed a world population expected to surpass 9 billion in 2050, it is estimated that agricultural output will have to increase by 70 percent between now and then." This 70 percent figure is now the most commonly used figure when estimating how much food production must increase in the next three to four decades. It is projected based on current trends in consumption and population growth.

The global system of agriculture today is very much driven by the demand side. With income growth, globalization, and urbanization, demand for agricultural products will continue to grow and shift towards high-value commodities. Up to three billion more middle class consumers will emerge in the next 20 years. The projections of the International Food Policy Research Institute (IFPRI) show that by 2050 cereal demand will globally increase by more than one-third.[4] These trends will be accompanied by very strong growth in meat consumption—especially poultry and beef. Demand for milk is also likely to increase quickly. In India, calorie intake per person is expected to rise by 20 percent over the next 20 years, and China's per capita meat consumption could increase by 40 percent.

Considering the high agricultural demand, rising prices, and other emerging challenges, the global production response has been slow. The overall productivity growth in agriculture is simply too low to cope with the pace of demand. Total factor productivity – that is, aggregate productivity, not just yields per unit of land or animals – grows by about 1.3 percent per annum in most regions and by about two percent in China. Its growth is dependent on technological progress. Between 2000 and 2006, cereal supply increased by a mere eight percent. The production response to high prices is impaired because of land and water constraints and because of neglect in agriculture innovation investments in many countries in past years. Yields grow very slowly in most regions today that have already reached high levels of production in the past. Africa actually shows the highest agricultural growth compared to other world regions, but starting from low levels. Increased production driven by higher yields (and not by area expansion) and increased productivity in the livestock sector require substantial investments in research and development, services, and input supply systems. The need for more agricultural science and technology investment is further increasing as a result of climate change and continuing population growth, and must embrace the entire value chain including enhanced food quality and safety.[5]

Different regions are facing different challenges. Long term regional perspectives indicate that: (1) Asia and Near East/North Africa will be major food importers; (2) sub-Saharan Africa could feed itself but with a low increase of per capita food ratio; (3) Latin America will be a major exporter (Brazil, Argentina) but with important ecological risks; (4) Canada and Russia could increase their export capacity; and (5) the USA and EU could also increase exports but in lower proportions.[6]

World agriculture is facing new challenges for which it is not well-prepared. The implications are that food security for the chronically poor will deteriorate in all four of its main dimensions: (1) availability of food will decrease owing to scarcity arising from declining water resources, global population increase, worsening climatic conditions, changing food demands and a shift from food to biofuel production; (2) poor people's access to food will decline owing to worsening terms of trade between wages and food costs; (3) stability of supply will be threatened as a result of the increasing prevalence of natural disasters, uncertainty regarding food prices, and national protectionism; and (4) the safe and healthy use of food will deteriorate as the poor switch to diets lacking essential micronutrients, thereby increasing child malnutrition. Increasing food insecurity might lead to more competition over water resources, migration, difficulties of supplying cities and ultimately state failures and international conflicts.[7]

Key Drivers of Global Food Supply

In responding to growing demand, global food supplies will be impaired by: (1) land and water constraints; (2) biofuels production with its strong links to markets and resources use patterns; (3) climate change acting as a threat multiplier; and (4) declining agricultural productivity. These factors could add up to an uncertain future for global food security.

Growing Scarcity of Water and Land

Feeding the world's growing population and finding the land and water required continues to be a basic yet sizeable challenge. It is an enormous task, as many countries lack the luxury of unused resources. Indeed, some regions face severe and increasing resource scarcity. South Asia and the Near East/North Africa regions have exhausted much of their rain-fed land potential and depleted a significant share of their renewable water resources. More than 1.2 billion people today live in river basins where absolute water scarcity or a trend of increasing shortages are serious concerns. Expanding land under cultivation is possible in sub-Saharan Africa and Latin America but will require adequate farming practices, increased investments and sustainable management of natural resources.[8]

The world's agricultural production has grown between 2.5 and 3 times over the last 50 years while total cultivated area has grown by 12 percent. More than 40 percent of the increase in food production came from irrigated areas, which have doubled in size.[9]

Demand for the world's increasingly scarce water supply is rising rapidly, challenging its availability for food production. Two-thirds of the world's population lives in areas that receive a quarter of the world's annual rainfall. Agriculture accounts for 70 percent (2,700 cubic kilometers) of total global withdrawals from rivers and aquifers available

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to humankind, with huge variations across and within countries. To produce enough food to satisfy a person's daily dietary needs takes about 3,000 liters of water, which represents approximately 1 liter per calorie.[10] Already some 30 developing countries are facing water shortages and by 2050 this number may increase to over 50 countries, a majority of which are in the developing world. This water scarcity could become a very serious obstacle to increasing food production.

Water availability for agriculture is a growing constraint in areas where a high proportion of renewable water resources are already being used, or where trans-boundary water cannot be negotiated. Increasing water scarcity threatens irrigated production in some of the world's most important agricultural areas. In low and medium income countries with fast population growth, the demand for water is outstripping supply. Rising demand from both agriculture and other sectors is leading to environmental stress, socio-economic tension and competition over water. Where rainfall is inadequate and new water capacity development is not feasible, agricultural production is expected to be constrained more by water scarcity than land availability.

Groundwater has provided an invaluable source of water for irrigation and other purposes, but has proved almost impossible to regulate. As a result, locally intensive groundwater withdrawals are exceeding rates of natural replenishment in key cereal producing locations. Excessive water pumping has rendered groundwater levels in China, India, Iran, Mexico, the Middle East, North Africa, Saudi Arabia and the USA critically low. Because of the dependence of many key food production areas on groundwater, declining aquifer levels and continued abstraction of non-renewable groundwater present growing risks to local and global food production. In Yemen, for example, groundwater withdrawals exceed recharge by 400 percent, threatening the fundamental wellbeing of its citizens.[11] With 25–27 million irrigation wells, groundwater irrigators in South Asia extract over 300 cubic kilometers of groundwater every year, which provides supplemental irrigation to 70–75 million hectares (ha) of land. Private investments in groundwater wells have added more irrigated area to South Asia in the past 40 years than public investments in dams and canals added in the previous 200 years. A booming groundwater irrigation economy is a unique aspect of South Asia's waterscape. It has

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become so central to South Asia's food security and agrarian livelihoods that its governments cannot afford to dismantle it. On the other hand, its environmental impacts are potentially so pernicious that they cannot afford to allow the groundwater boom to keep continue unchecked, as it has in recent decades.

In regions where natural resources are stretched, agricultural production must compete with growing needs for water from other users. Expanding cities, industries and services have priority in terms of water supply. Locally, this translates into a reduction in the share of water available to agriculture. Municipal and industrial water demands are growing much faster than those of agriculture, and can be expected to sap from allocations to agriculture and ultimately threaten natural groundwater sources. Demand for fresh water for cities and industry has doubled over the past 20 years, and is projected to increase by a factor of 2.2 from 900 cubic kilometers (km^3) in the year 2000 to 1,963 km^3 by 2050.

In other places, it is land – not water – which is the limiting factor for agricultural production. Agriculture currently uses 11 percent of the world's land surface. Global cultivated land per person has gradually declined from 0.42 ha to less than 0.21 ha during the last five decades.[12] Cultivated land per person in low income countries is less than half that of high income countries and its suitability for agriculture is generally lower. In large areas of Eastern and Southern Asia, including parts of India and China, demographics and demand for agricultural products are putting unprecedented pressure on limited resources. In parts of sub-Saharan Africa, in particular in Nigeria and Eastern Africa, land fragmentation has reached unsustainable levels, leaving farmers with crop areas much below what is necessary to ensure self-sufficiency. The expansion of urban areas and land required for infrastructure and other non-agricultural purposes is expected to continue, as we live in an increasingly urbanizing world. In China, for example, if in 2050 the entire population enjoyed a level of automobile ownership equivalent to that of the United States in the 2000s, it would require 13 million hectares of good farmland for roads corresponding to about half of the 29 million hectares currently producing 120 million tons of rice to nourish the Chinese people.

The Fate of Biofuels

The allocation of crops to non-food uses, including animal feed, seed, bio-energy and other industrial products, affects the amount of food available to the world. Globally, only 62 percent of crop production (on a mass basis) is allocated to human food, versus 35 percent to animal feed (which produces food indirectly as meat and dairy products) and three percent for bio-energy, seed and other industrial crops. A striking disparity exists between regions that primarily grow crops for direct human consumption and those that produce crops for other uses. North America and Europe devote only about 40 percent of their croplands to direct food production, whereas Africa and Asia typically allocate over 80 percent of their crop land to food crops.

Originally promoted as a way of decreasing dependence on fossil fuels and avoiding the carbon emissions generated by them, biofuel production has now been recognized as having strong links to agricultural markets and land and water use patterns. The first generation of biofuels currently in commercial use – biodiesel made from vegetable oil and ethanol made from sugar cane or maize – raise major concerns with regard to their increasing competition with food crops for land and water, as well as their role in food price volatility. According to the United Nations Environment Program (UNEP), about 118 to 501 million hectares "would be required to provide 10% of the global transport fuel demand with first generation biofuels in 2030. This would equal 8% to 36% of current crop land, including permanent culture."[13] In the long run current first generation biofuels production on cultivated land is not tenable, as the world's limited arable land resources are essential to meet future food demand.

Worldwide, there is rapid expansion of corn and vegetable use for fuel.[14] Many governments have set fixed mandates specifying the amount of biofuels to be produced, regardless of food and fuel prices. According to the FAO, biofuel production is projected to more than double from 2007–09 to 2019 and biofuel demand is expected to grow fourfold from 2008 to 2035.[15] In addition, biofuel support is predicted to increase from $20 billion in 2009 to $45 billion by 2020 and to $65 billion by 2035. Biofuel production has absorbed a rapidly increasing share of the US maize crop—today close to 35 percent of US maize production is used for biofuels. The US National Academy of Sciences found that even if all the maize and soybeans produced in the USA in 2005 had been used for bio-ethanol production, it only would have replaced 12 percent of the country's gasoline demand and six percent of its diesel demand[16]

The second major demand growth category has been the use of oilseeds—including vegetable oils for biodiesel production, oilseed meals for livestock production and vegetable oils for human consumption. The percent of total world use attributed to industrial and biodiesel usage has increased sharply since the mid-2000s. Rapeseed has been used extensively for biodiesel in Europe. Worldwide, nearly 33 percent of total rapeseed is now used for industrial purposes, compared to 17 percent in 2004–05. Industrial uses of soybean oil expanded to 16 percent of the world total by 2010–11 from just four percent in 2004–05.

From the late 1970s to the early 1990s, world food prices gradually declined by almost half and then stagnated until 2002. During the period 2002–2007, world food prices increased by some 140 percent owing to a number of factors including increased demand for biofuel feedstock and rising fuel and fertilizer prices. Estimates indicate that agricultural prices will rise by 30 percent by 2020 as a result of biofuel targets. The High Level Panel of Experts on Food Security and Nutrition, established by the UN Secretary General in the aftermath of the 2007–08 food price crisis, recommended that governments abolish biofuels targets, subsidies and tariffs. The G20 countries recognized the need to adjust biofuel mandates when market situations warrant interventions. They did not, however, make more definitive statements about biofuels and their links because of disagreement between large producers (like Brazil) and net food importers (like China) on the importance of these links. Given the trajectory of the biofuel debate so far, food and energy markets will continue to interact in the future, creating fast-changing market opportunities for producers of feedstock crops like sugar cane and maize, regardless of whether they are supplying the food, feed or fuel sectors.[17]

Threats to Agriculture from Climate Change

Climate change acts as a threat multiplier, making the challenges of food security much more difficult. It will affect all facets of society and the environment, both directly and indirectly, with strong implications for water and agriculture today and in the future.

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) has shown that climate is changing at an alarming rate, causing temperature rise, shifting patterns of precipitation and more extreme events (droughts and floods). Climate models project substantial regional changes in runoff and stream flow – and hence in water availability – for the 21st century. Robust projections of these models imply decreasing water availability in southwestern North America, the Mediterranean region, and southern Africa, and increasing water availability in high-latitude North America and Eurasia, the La Plata Basin of South America, eastern equatorial Africa, and Indonesia. In general, regions of projected decreasing water supply tend to be the regions of contemporary water-supply stress, and regions of projected increasing supply tend to be those where water shortage is not a major issue for water managers.

Ongoing climate change will also affect the frequency of droughts. It is expected that an increase in drought frequency will occur in many regions—such as the Mediterranean region, where drought has been a problem historically. Additionally, we have reason to watch for increased frequency of floods, particularly in humid regions (although not necessarily only in those regions).

In addition, the AR4 has gathered scientific evidence and expert opinion on the expected impacts of climate change on agricultural systems.[18] The report notes that climate change is already having an impact, for instance, through changes in patterns of variability and associated changes in rainfall distribution. It anticipates with high confidence that projected changes in the frequency and severity of extreme climate events, together with increases in outbreaks of pests and diseases, will have significant consequences for food security. Climate also affects food production through rises in sea level that risk inundating coastal agriculture, and via reductions in glacier cover that might drastically change the hydrology of rivers critical for irrigating large agricultural areas.

The AR4 finds that Africa is highly vulnerable to climate change, because of multiple stresses and low adaptive capacity. Projections

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indicate an increase in arid and semi-arid land in some countries while others will become wetter but with changes in seasonal patterns. In Asia, potential changes in the monsoon and in glacier and snowmelt are perhaps the greatest threats. Sea-level rise is also of great concern as coastal and deltaic areas are often heavily populated and intensively cultivated.

Recent research strongly suggests that rising temperatures in the second half of the 20th century and early years of the 21st century, and accompanying changes in precipitation, have already had observable effects on agriculture. Under optimal management, when the mean temperature is less than 22°C, a 1°C change in temperature has a small but positive impact on yields; but as the average temperature exceeds 25°C, the effect becomes negative, causing declines of roughly 30 percent in yields.[19] During a drought, the yield declines begin at lower temperatures and can be greater than 40 percent. Although growing season temperature changed only slightly in North America from 1980 to 2008, it increased dramatically in other parts of the world—particularly in China and Europe. For maize, for example, climate change had essentially no effect on US yield trends, whereas it substantially slowed yield growth in Brazil, China and France. The growing area has shifted northward for maize in the United States, rice in China and wheat in Russia.

Overall, research suggest that calorie availability will not only be lower than in the no-climate-change scenario- it will actually decline relative to 2000 levels throughout the developing world. Climate change will also result in additional price increases for key crops - rice, wheat, maize and soybeans.

Declining Agricultural Productivity

Over the past five decades growth in world food production has been dependent primarily on increasing crop yields, firstly in the developed world and then, with the onset of the "green revolution," in the developing world. Much of this increase has come about as a result of expanding irrigation and fertilizer use, complemented by improved genetic potential as well as expansion of double and triple cropping in irrigated rice production systems.

However, decades of underinvestment in agriculture and agricultural research and innovation have slowed productivity growth. Over the last decade there has been evidence of a clear slowing in cereal yield growth, particularly of rice and wheat, a leveling in fertilizer use, and constraints on expansion in water use. Annual growth in cereal yields worldwide has declined from about three percent in the 1960s and 1970s to less than 1 percent since 2000. Sustaining yield growth of the three principal cereals under increasing resource constraints will be essential to meeting growing world food demand over the next four decades.

Intensifying crop management, together with bred-seed and efficient use of inputs such as fertilizer and water, will be needed to provide enough food for the growing population of the 21st century. Further and more sustainable gains in crop yield levels require improvements in soil quality, as well as precision management of other factors. Global food security will depend on gaining greater insight into the physiological basis of crop yield potential, analyzing the processes involved in the relationship between soil quality and crop productivity, and understanding the interacting environmental factors that affect crop yields.[20] The last decade has seen huge gains in our knowledge of how plants grow and synthesize useful products, and in our ability to use this information. Genome sequences of major crop species are now available or close to completion, while functional genomics is providing critical information on the role of genes and their products. Generic markers have enabled scientists to detect previously hidden genetic variability, and genetic engineering is expanding the ways in which microorganisms, plants and animals can be used for human and environment benefits. These advances are allowing researchers to improve plant breeding methods, construct safer and more effective pest control strategies, and develop plants with improved agronomic traits and nutritional characteristics. They also provide the basis for breaking through present yield barriers.

Food Self-sufficiency: An Elusive Target

Food security, as a concept, originated only in the mid-1970s. The initial focus, reflecting the global concern leading to the World Food Conference in 1974, was on the volume and stability of food supplies. Food security was then defined as "availability of adequate food supplies of food stuffs

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to sustain a steady expansion of food consumption and to offset fluctuations and prices." Until almost the mid-1980s most countries sought to meet their food needs from domestic supplies. This quest for food self-sufficiency was the result of the following factors:[21]

- The food crises and famines that raged in several parts of the world, particularly in Asia before the Green Revolution of the early 1970s.
- The hopes entertained by the Green Revolution; thanks to increased production and productivity, some countries significantly reduced undernourishment, or even enjoyed a food surplus.
- The number of people suffering from undernourishment was reduced from about 870 million people in the 1960s to about 770 million in 1995/96 when it again began to increase.
- The inherent risks of dependence on international trade in agricultural products, given the volatility of prices and the effects of protectionism.
- The Cold War and threats related to food embargos; when looking to gain political independence countries were concerned about their food self-sufficiency.

Given that water and land resources are unevenly distributed, food self-sufficiency is an elusive target in countries facing growing scarcity of these resources. Furthermore, as incomes grow and dietary regimes diversify most countries inevitably become net importers of agricultural products when domestic production can no longer meet demand.

The expansion of globalization and international agricultural trade in the 1980s led many countries to move away from the food self-sufficiency objective and rely more on the international market to cover their food needs. Thus, domestic production, combined with international trade flows, determine domestic food availability, whilst per capita income and domestic prices determine the ability of consumers to pay for that food.

Ideally, the liberalization of agricultural trade widens the entire spectrum of economic possibilities, offering countries the potential to efficiently allocate their water resources and to make the most of their comparative advantages. In addition, international trade is supposed to

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help diversify risk, as agricultural production varies quite a lot from year to year in a single location, but overall world production tends to vary much less. In reality, these aspects of trade do not work as well as they could. Indeed, today's agricultural markets exhibit the following three characteristics that affect their reliability:[22]

- First, export markets for the main staple commodities – rice, maize, wheat and soybeans – are highly concentrated in a few countries (or are very "thin"). Nine countries account for 90 percent of the world's wheat exports and just five countries account for 85 percent of the world's exports of rice. In fact, together Thailand, India and Vietnam produce 66 percent of all milled rice. This high concentration puts importing countries at risk and limits the world's capacity to cope with shocks. Any incidence of poor weather or other events causing production shocks will immediately affect global prices and price volatility. Similarly, any policy changes in any of the top exporters – such as trade bans or other restrictions on exports – will significantly affect the levels and volatility of prices. Research suggests that such policies explained almost 40 percent of the increase in the world market price for rice during the 2007–2008 food price crisis.

- Second, the world's stocks of cereals are now at historically low levels. This situation leaves the world vulnerable to food price spikes and threatens the proper functioning of markets.

- Third, appropriate and timely information on food production, stock levels, and price forecasting is sorely lacking. When information deficits lead to overreactions by policy makers, the result can be soaring prices. In the 2007–2008 and 2010–11 food price crises, many countries responded by cutting exports or boosting imports in ways that worsened price increases.

In the contentious debate over countries' food policies, one conclusion garners support from all sides: the need to boost agricultural productivity to both smooth food prices and strengthen global trade by increasing the number of food exporting countries. More productive farming in more countries would not eliminate the need for other measures to ensure a healthy global system of food trade, but it could help export bans become a measure of last resort instead of a panicked first reaction. The issue is not only one of prices increasing too quickly, but also of risky volatility and of inappropriate policy responses around the world posing threats to free trade and possibly even to political stability in some countries.

Conclusion

The long term prospects of the global food supply situation show that:

- Agricultural production needs to almost double by 2050.
- Long-term abundance of agricultural commodities is not guaranteed, but there is no reason to be Malthusian and predict famines.
- The constraints related to the scarcity of basic resources (soil and water), biofuels, climate change and declining agricultural productivity involve potential risks of shortages.
- Food self-self sufficiency is not an option.

This confluence of pressures raises uncertainties about our ability to produce and distribute enough food to feed nine billion people in 2050.

Is it even possible to feed nine billion people? There is certainly no lack of authoritative global assessments of global food security challenges. Most of them respond that it is indeed possible to produce enough food to feed nine billion in 2050, but only if we are able to produce more food and more variety, mainly through higher yields in an environmentally friendly manner, with higher prices on inputs and better prices and fair access for consumers. Furthermore, these objectives must be accomplished under climate change conditions.

It is a truism to state that this can only be achieved by mobilizing all kinds of agriculture and utilizing all sources of water, with much better coordination and partnerships between the major actors involved: farmers, market operators, authorities and consumers. The political and economic governance of the food system must be improved to increase productivity and sustainability.

Increasing food production is a necessary, but not the sole condition. The globalization of markets has been a major factor shaping the food system over recent decades and the extent to which this continues will have substantial effect on global food security.

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Food Security Strategies in the Arabian Gulf Region

Nadim Khouri, et al.[*]

Arab Gulf countries are heavily dependent on food imports. This dependency is expected to continue to rise as a result of rapidly growing populations, improving living conditions, sustained economic/industrial development and depleting natural resources. Moreover, climate change is expected to have a major effect on the region.

To meet their food needs, Gulf countries must rely on international markets, which makes them vulnerable to the vagaries of global food production, trade policies and commodity prices. This is exemplified by the food crisis of 2007/2008, which led Arab Gulf countries to adopt strategies that include building up national strategic food reserves, scaling up subsidies, and acquiring land abroad for agricultural investments through bilateral deals. These measures may have some drawbacks in the longer term; e.g., prices remaining volatile, socio-economic disturbances impacting land deals, trade being affected by international events or conflicts, etc. What is needed is perhaps a multi-pronged food security strategy that builds on elements

* This paper was prepared by a joint ESCWA–IFPRI team composed of Vito Intini (Team Leader), Clemens Breisinger, Ivana Brnovic, Fidele Byringiro, Olivier Ecker, and Kenneth Iversen, under the overall guidance and leadership of Nadim Khouri. Michelle Battat (FAO) and Arani Kajenthira (Harvard Kennedy School) provided valuable advice and insightful contributions.

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of the above measures while integrating them in a GCC-wide approach. The analysis contained in this paper leads into a number of promising strategic directions including: (i) assessing the pros and cons of building a regional food reserve to reduce the risk of market disruptions; (ii) investigating challenges and opportunities for a region-wide procurement system based on innovative financial instruments; (iii) consolidating agricultural R&D systems and enhancing their impact; and (iv) achieving more efficient water use through assessing water footprint of production, consumption, and trade patterns.

Other crucial elements of a comprehensive food security strategy not specifically addressed in this paper are: the analysis of food subsidy and social protection reform options; promoting comprehensive agricultural and economic development in the areas where comparative advantages lie; and encouraging changes in consumption preferences and nutrition patterns. In addition, given GCC countries' reliance on food production from (often developing) countries with large agricultural potential, smart and cost-effective strategies should be examined on how GCC countries can best engage with such countries.

Background

At a first glance, the Arab Gulf states[1] do not seem to have major food security problems. A recent food policy report produced by the International Food Policy Research Institute (IFPRI) classifies them all as countries with a low risk of food insecurity in comparison to the rest of the region (Figure 8.1).[2] This is because all GCC countries show a relatively strong export performance (especially in terms of oil) compared to the demand for food imports, high and growing per capita incomes, and relatively low levels of malnutrition in the international comparison.

However, when looking behind the aggregate numbers, GCC countries are affected by some "vulnerabilities," especially in a more volatile world, including high levels of food import dependency and a low share of agricultural production.

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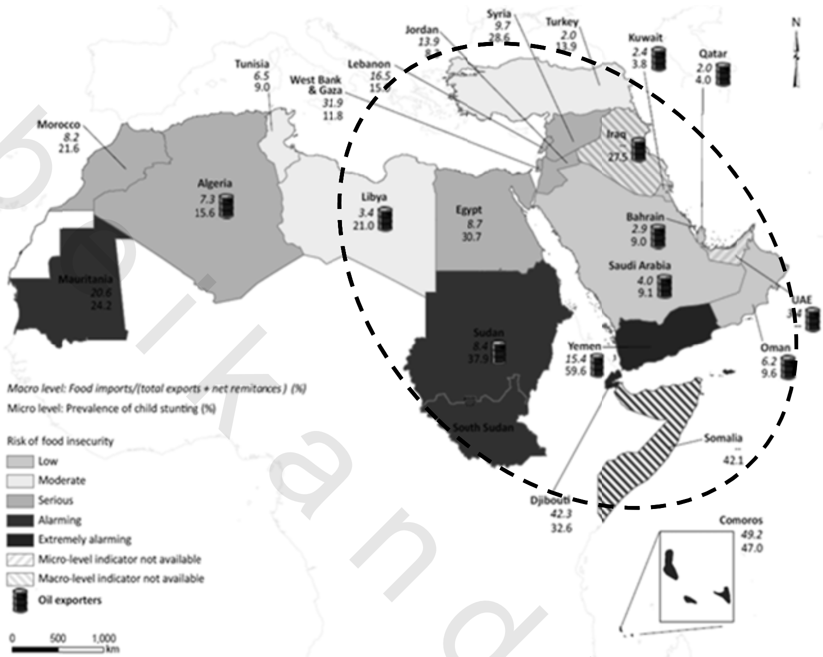
Figure 8.1

Food Security in the Arab World and Turkey



Source: Breisinger, et al., 2012.

Total regional consumption of main food produce such as staples, fruits and vegetables (F&V), meat, eggs, fish, dairy, sugar, and oil has regularly increased from less than 31 million metric tons (mt) in the period 2000–2005 to about 35.5 million mt in 2008, with the share of consumption of cereals hovering at around 44 percent of total GCC food consumption,[3] compared to 26 percent of F&V, and 14 percent of dairy products.[4]

Wheat and rice dominate within the region's cereal consumption patterns.[5] Self-sufficiency ratios are higher in the meat, dairy, and F&V sectors, which also tend to be characterized by less volatile markets.

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Table 8.1
GCC Food Balance in 2008

	SSR (%)	Available to consume	Balance		Imports		Exports		Production
ITEM		**Qty**	**Value**	**Qty**	**Value**	**Qty**	**Value**	**Qty**	**Qty**
Cereals (total)	15.9	15,760.5	3,940.4	13,251.3	4,082.1	13,798.8	141.7	547.6	2,509.3
Wheat and flour	59.2	3,358.5	440.9	1,378.8	509.8	1,587.5	68.9	137.9	1,989.7
Maize	7.6	2,322.9	537.4	2,147.3	541.3	2,162.2	3.9	14.9	175.6
Rice	0.0	2,270.8	1,583.2	2,270.8	1,624.5	2,349.3	41.2	78.6	0.0
Barley	0.4	7,692.9	1,392.3	7,662.7	1,394.9	7,675.9	2.6	13.2	30.2
Potatoes	74.3	657.8	66.3	169.1	82.1	224.8	15.8	55.7	488.8
Pulses (total)	1.7	127.9	63.5	125.7	77.4	147.3	14.0	21.6	2.2
Vegetables (total)	70.3	4,869.3	513.5	1,447.6	616.8	1,664.5	103.3	198.9	3,421.7
Fruits (total)	65.1	4,294.8	924.9	1,500.8	1,089.7	1,852.0	164.8	351.3	2,794.0
Sugar (refined)	0.0	1,757.8	624.5	1,757.8	1,172.9	2,859.4	548.4	1101.7	0.0
Fats & oils (total)	0.4	495.7	340.2	258.1	674.5	580.1	334.4	322.4	2.0
Meat (total)	44.4	1,933.9	1,900.5	1,077.1	2,045.9	1,153.0	145.4	75.9	857.8
Red meat	40.2	435.2	740.5	260.4	786.0	285.1	45.4	24.7	174.8
Poultry	45.5	1,498.7	1,160.0	816.7	1,259.9	867.9	99.9	51.2	682.0
Fish	81.7	461.1	145.4	84.2	430.3	202.6	284.9	118.4	376.9
Eggs	89.6	259.8	92.4	27.0	130.4	59.9	38.1	32.9	232.8
Milk & dairy prod.	25.1	4,899.7	1,788.6	3,669.8	2,392.4	5,052.6	603.8	1382.8	1,229.8
TOTAL	**33.5**	**35,518.3**	**10,400.2**	**23,368.5**	**12,794.5**	**27,595.0**	**2,394.6**	**4,209.2**	**11,915.3**

Notes: Qty (thousand mt); value (million USD); self-sufficiency ratio (SSR) is the ratio between domestic production and availability.

Source: staff calculations from Arab Organization for Agricultural Development, "Arab Agricultural Statistical Yearbook," 2009.

Agriculture accounts for only 1–2 percent of the overall GCC GDP and employs less than four percent of the active population in Kuwait and Qatar.[6] The following constraints affect the sector: (i) environmental

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constraints and water scarcity that limit commercially viable primary production potential;[7] (ii) increasing reliance on food imports (60–90 percent of total food demand is met by imports) and consequent exposure to external food price shocks and volatility along with risks of imported inflation and irregular availability of cereals on international markets;[8] (iii) challenges in acquiring farmlands in land- and water-rich countries characterized by poor governance of such resources. The impact of some of these constraints is expected to deteriorate even further given the region's demographic growth (over two percent, although decreasing, equal to about twice the world average)[9] and increasing urbanization patterns,[10] as well as its trends in dietary characteristics.[11]

Table 8.2

Arable Land and Agricultural GDP in GCC Countries

Country	Arable land (%)	Contribution to GDP (%)
Saudi Arabia	1.7	2.7
UAE	0.8	0.9
Kuwait	0.8	0.3
Qatar	1.6	0.1
Bahrain	2.9	0.5
Oman	0.1	1.4

Source: FAO, Bloomberg, as reported in Alpen Capital Group. "GCC Food Industry," June 28, 2011 (http://www.alpencapital.com/Me-gcc-food2011.htm? height=400 &width=900).

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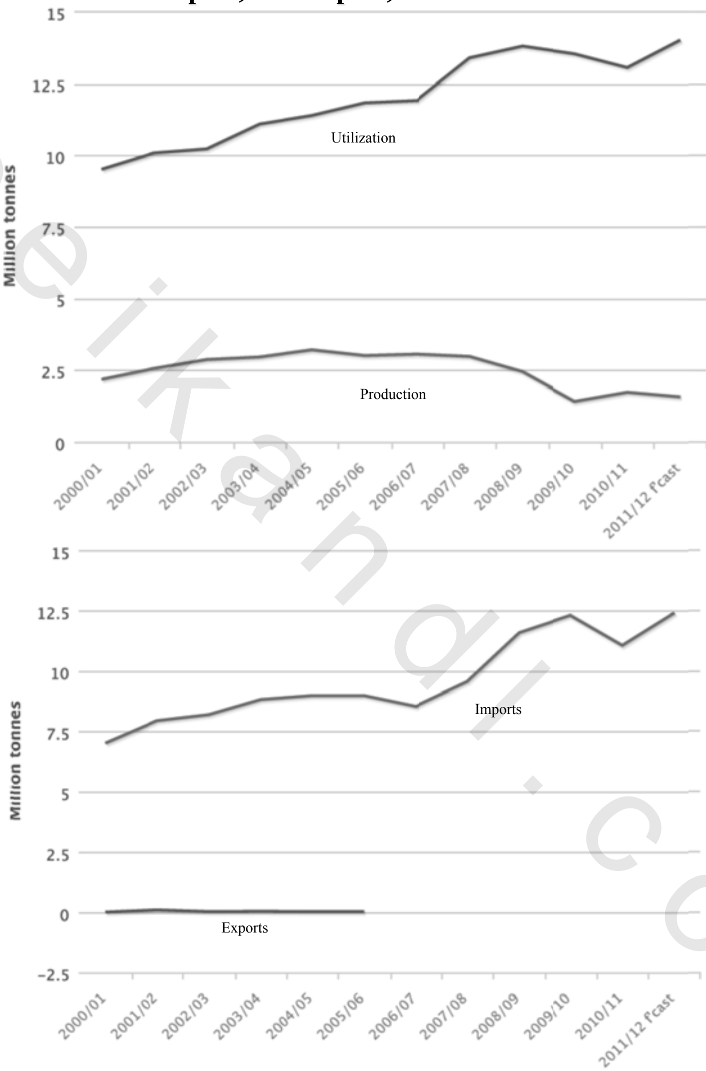
Figure 8.2
Trends in Cereal Production, Utilization (consumption), Import, and Export, Saudi Arabia



Source: Data from UN Food and Agriculture Organization (FAO), Central Bureau of Statistics.

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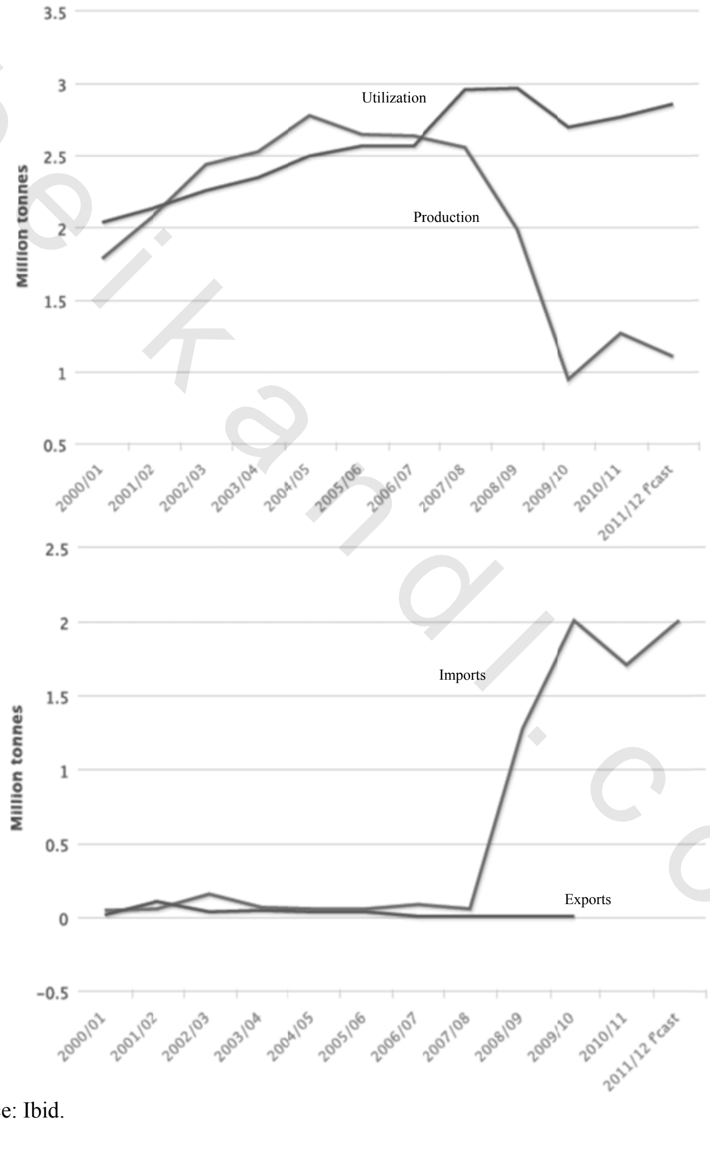
Figure 8.3
Trends in Wheat Production, Utilization, Import, and Export, Saudi Arabia



Source: Ibid.

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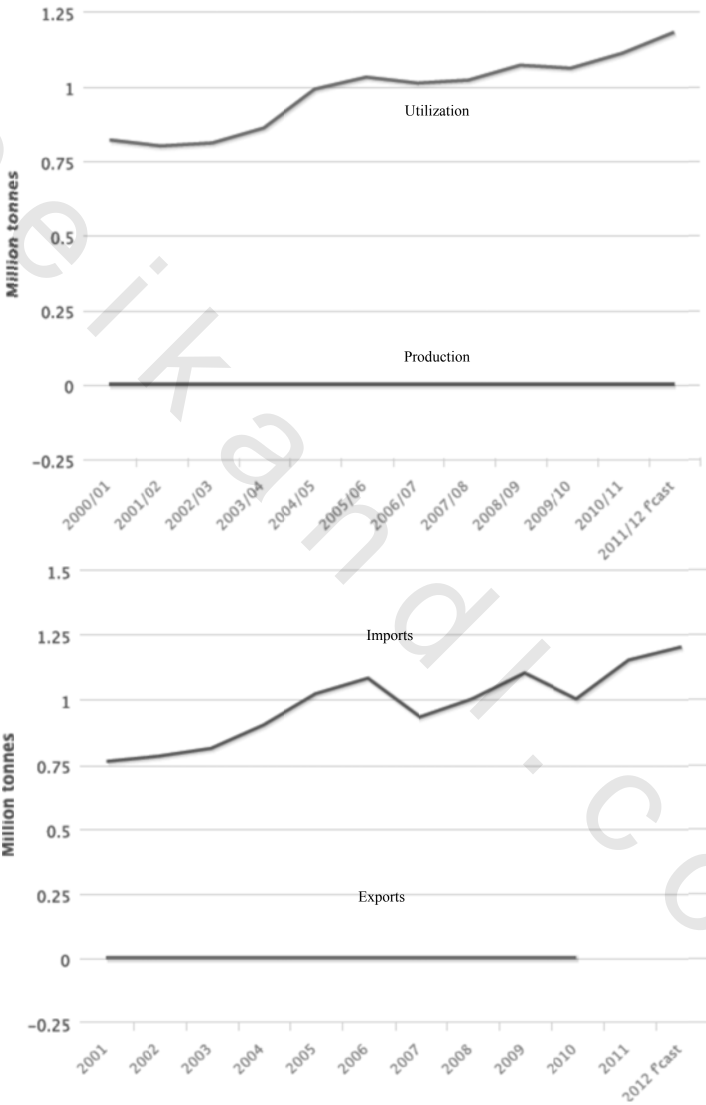
Figure 8.4
Trends in Rice Production, Utilization, Import, and Export, Saudi Arabia



Source: Agricultural Market Information System (AMIS) Statistics database [prototype]; (http://statistics.amis-outlook.org/data/index.html), accessed on March 25, 2012.

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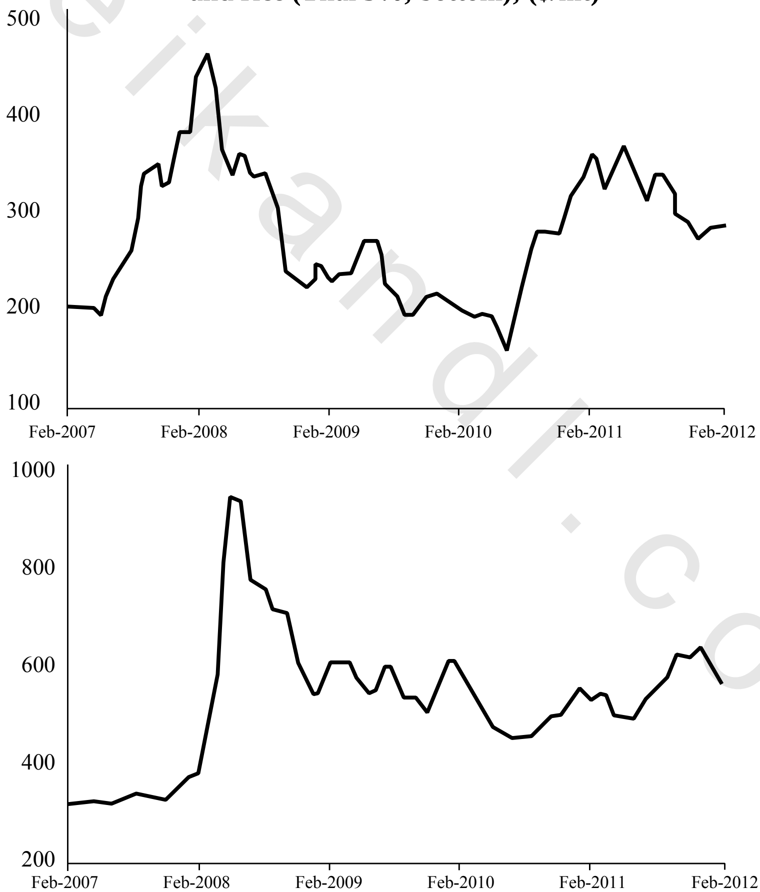
As a result, the food import bill has constantly increased over the last decade, with Saudi Arabia and the UAE accounting for almost half (equal to US $5.8 billion) and over one quarter ($3.5 billion) of the bill, respectively. With food normally accounting for more than 20 percent of the consumer price index (CPI), GCC inflation spiked in 2008 as a result of the food crisis.[12] In addition, these countries have pegged exchange rate regimes that, on the one hand, provide macroeconomic stability but, on the other, limit autonomy of their monetary policy, thereby limiting the array of choices to neutralize inflation transmission channels from imported food and mainly relying upon non-market administrative measures to mitigate inflationary pressures such as subsidies and other transfers.

The GCC states are price-takers, and therefore their consumers are relatively more exposed to international price fluctuations. All these countries have pass-through effects of an increase in world food prices with coefficients above 0.2 (Bahrain and Qatar are above 0.3) and, in the case of the UAE, above 0.4.[13]Most reports predict that the volatility of global food prices is likely to remain high in the years to come.[14]

The most recently reported cereal prices (February 2012) have remained higher than the pre-2008 crisis level (2.27 times 2005 average prices).[15] The high pass-through effects are likely to have relatively higher impacts in the cereal sector, since demands for wheat (by the Arabs) and rice (by the Asian Diaspora) are relatively inelastic, resulting in limited substitution even when prices are high.[16] However, from an overall microeconomic perspective, the share of household expenditure is relatively lower in the GCC countries thereby reducing the overall impact of food price rises (see Figure 8.5). Moreover, from a macroeconomic perspective, and consistent with IFPRI's food security typology for the Arab world, recent cereal price hikes do not constitute a problem for GCC countries, as a co-movement of oil and cereal prices has been noticed when the oil price is above $50.[17] In this situation, the inflow of oil revenues is much higher than expenditures on cereal imports, resulting in a decisive surplus in the balance of payments.

The major determinant of micro-level food security is poverty, and a key indicator is the nutritional status of children. Despite the relatively high per capita GDP, child malnutrition persists in many Arab Gulf states, and the Human Development Index (HDI) values are lower than expected when considering per capita GDP levels. For example, in Saudi Arabia, Bahrain and Oman, around nine percent of children are estimated to be malnourished (Figure 8.1); and while Qatar and the UAE have the highest and third highest per capita incomes globally (2008, purchasing power parity), they only rank 37 and 30, respectively in the 2011 HDI.

Figure 8.5
Price Trends for Wheat (US hard red winter, top) and rice (Thai 5%, bottom); ($/mt)



Source: World Bank, “Commodity Markets Review,” no. 121, February, 2012.

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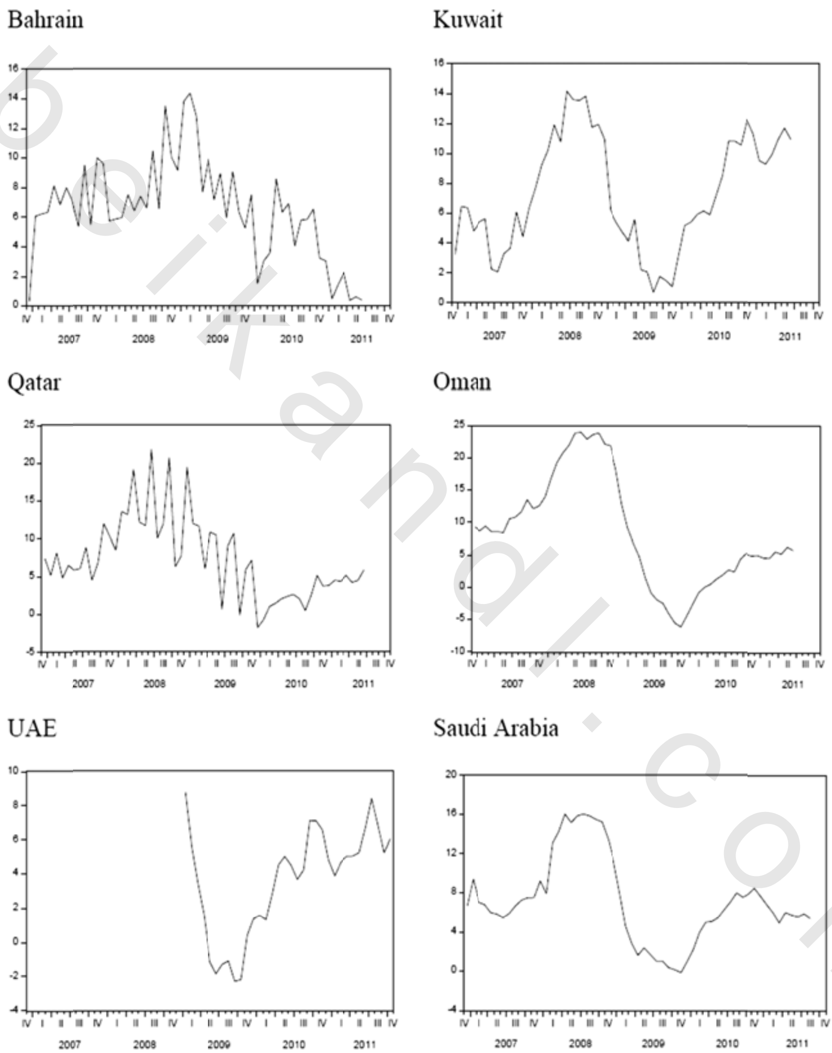
Figure 8.6
Food Price Trends in GCC Countries
(December 2006 – April 2011, % change year-on-year)



Source: E. Ianchovichina, et al., "How Vulnerable are Arab Countries to Global Food Price Shocks?" World Bank, 2012.

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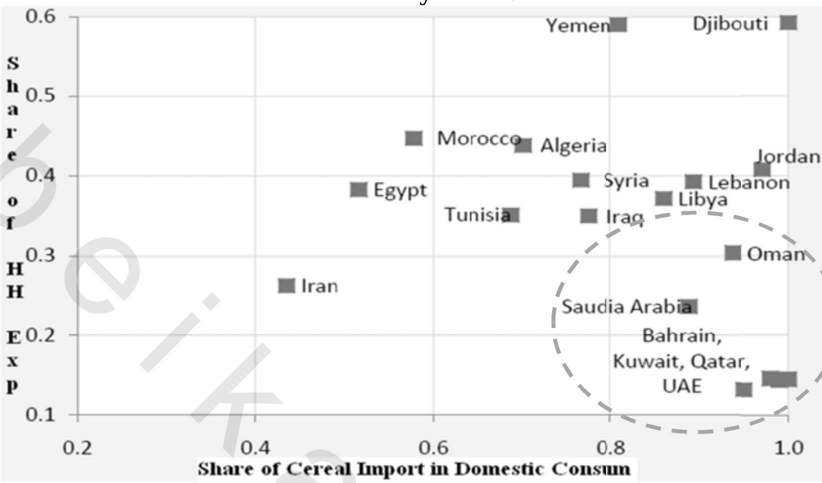
Figure 8.7

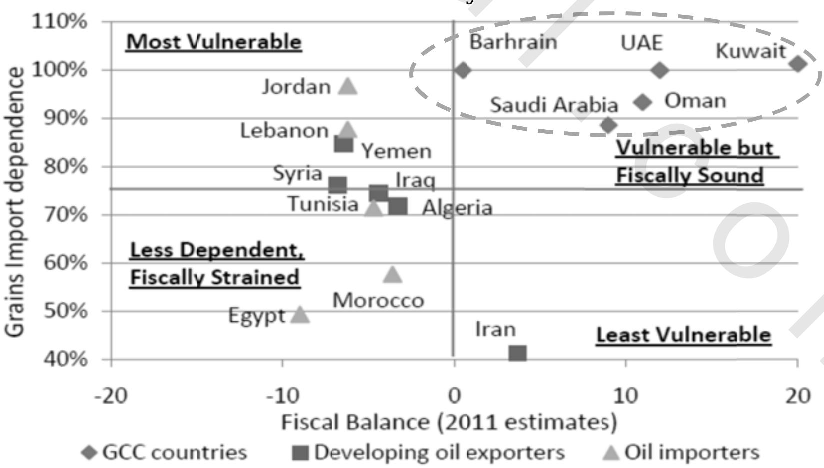
Household- and Country-level Vulnerabilities



Notes: Share of household (HH) food expenditure in total HH consumption.

Source: adapted from World Bank, "Regional Economic Update: MENA Facing Challenges and Opportunities," Middle East and North Africa Region, 2011.

Figure 8.8
Macro-level Grains Vulnerability of MENA Countries



Source: adapted from World Bank, op. cit., 2011.

Table 8.3

GDP per Capita (PPP, 2005 US$) and HDI, 2011

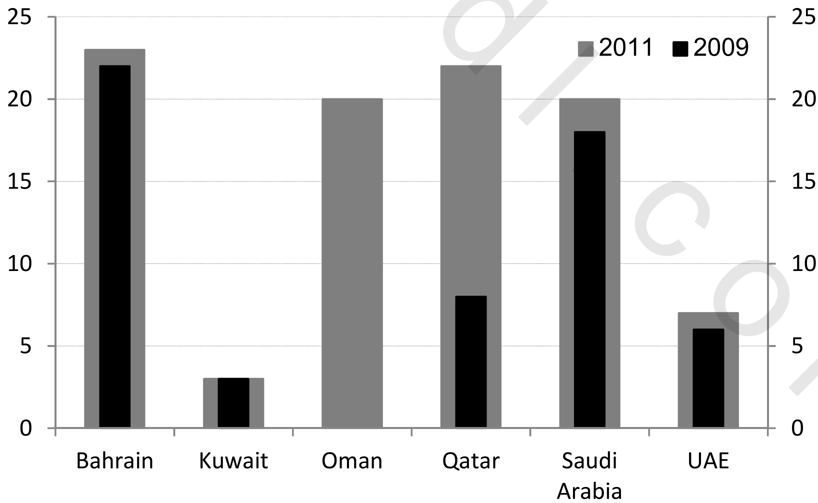
	GDP per capita			HDI	
	Value	*Rank*		*Value*	*Rank*
Bahrain	23,755	44		0.806	42
Kuwait	-	-		0.757	63
Oman	24,646	41		0.702	89
Qatar	77,108	1		0.825	37
Saudi Arabia	20,565	50		0.760	56
UAE	51,361	3		0.835	30

Notes: GDP data available for 209 countries and HDI data for 174 countries.

Source: Based on World Bank, "World Development Indicators 2012" (http://data.world bank.org/data-catalog/world-development-indicators), and United Nations Development Program (UNDP), "Country Profiles and International Human Development Indicators" (http://hdr.undp.org/en/data/ profiles/), accessed March 2012.

Figure 8.9

Perceived Food Insecurity (% of population)



Source: Based on "Gallup World View" (2012).

Table 8.4

Government-supported Initiatives following the Food Crisis

	Economic Support		Consumer Support			Production Support					
	Reduction/suspension of taxes and tariffs	Food Reserves	Price Controls/ Subsid.	Cash Transf./Wage Increases	Food Ration/stamps	Input Subsid.	Subsidized Credit	Land Deals	Support Price	R&D and Extension Services	Infrastructure
KSA	√	√	√	√		√	√	√	√		√
Bahrain		√	√		√	√	√	√	√?		√
Oman		√	√	√		√	√	√	√?	√	
Qatar	√	√	√			√	√	√			
Kuwait		?	√	√	√	√	√	√		√	
UAE	√	√	√	√		√	√	√			√

Source: ESCWA data.

Data from the Gallup World Poll suggests that at least one-fifth of the people in Bahrain, Oman, Qatar, and Saudi Arabia consider themselves food insecure. The level of perceived food insecurity suggests a consistent deterioration over the recent period, with the share of food insecure people increasing by 1–3 percent in Bahrain, Saudi Arabia, and the UAE, while it almost tripled in Qatar. This deterioration is likely to be a result of the combined effects of the global crisis and food price spikes.

To address these various sources of food insecurity, government-supported initiatives have drastically expanded in the wake of the global financial crisis, which caused steep job losses in the GCC countries because of their high exposure to credit financing (particularly domestic property loans) and global markets.[18] The labor market was hardest hit in Dubai because of the sharp contraction in the real estate sector. The job cuts have been particularly tough for many expatriates, who typically lack

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social security and unemployment benefits and are most likely to be affected by price surges.[19]

Main GCC agricultural policy support actions have included:

- Unregulated well digging.
- Subsidized inputs (fertilizers, seeds, veterinary services, and, in the case of Saudi Arabia, farmland).
- Consumer price support.
- Lower taxation for farmers.

Price stabilization through food subsidies has been the favored approach in the past. However, this does not remove the price risk; it only transfers the risk to the government and tax payers through subsidy payouts, which often tend to be untargeted and inefficient.

The most recent literature[20] has identified three thrust areas to pursue in order to improve food security in the GCC and wider Arab region: (i) strengthening safety nets, and access to education and health (including family planning) services; (ii) enhancing agricultural production through investment in infrastructures and R&D based on economic, social, and environmental sustainability principles; and (iii) reducing exposure to market volatility through a mix of government- and market-based interventions. In the remaining part of this study, we will utilize these thrust areas as a multi-pronged analytical toolkit that could be used to enhance food security through a regional lens.

After investigating future trends in the region's food security, we will analyze potential key components of a GCC-wide food security strategy. The paper will then attempt to assess the pros and cons of building a regional food reserve as an instrument to tackle potential cereal market disruptions. Next, it will investigate challenges and opportunities for a region-wide procurement system based on innovative financial instruments. The final two sections of the study will focus on the consolidation of agricultural R&D systems, and an analysis of current water use through assessing water footprint and water balance of production, consumption, and trade patterns in the region.

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The Future of Food Security in the Arab Gulf Region

Food import dependency in Arab Gulf states will further increase in the future; the size of the increase will depend mostly on external factors. Figure 8.10 shows how demand (the higher series) and production (the lower series), in monetary terms, are likely to change under four different scenarios: the first scenario describes an optimistic outlook, where population growth in Gulf countries and globally is modest and economic growth is high.[21,22] The next series depicts a scenario where population growth and economic growth in Gulf Arab states and the rest of the world follow the same trend as in the past (business as usual, no climate change effects), while whereas the next two scenarios take the effects of climate change into account (using two different models). Results show that even under the optimistic scenario, the annual value of cereals consumed in the Arab Gulf states will increase from $2.5 billion in 2010 to about $4.5 billion in 2030, up to $6.1 billion by 2050 (in real prices). Under the business-as-usual scenario, the consumption of cereals in Arab Gulf States will almost triple to $6.8 billion.

The effects of climate change will further raise the value of cereals consumed in Arab Gulf states, while the local production of cereals under all scenarios will lag behind rapidly rising demand. Compared to the business-as-usual scenarios, the annual value of cereals consumed in Arab Gulf countries is projected to increase by $1–1.2 billion by the year 2050, depending on the climate change scenario. The production side cannot keep up with this rapid increase in demand. Under all four scenarios, cereal output increases because of assumptions about technological change and the increase in cereal prices. Yet, cereal output only reaches $1–1.3 billion in 2050, or $5–6.7 billion less than projected aggregate demand.

The total annual demand for food commodities consumed in the Arab Gulf states is projected to more than triple from $14 billion to $44 billion between 2010 to 2050. Figure 8.11 shows the results for different food commodity groups from the business-as-usual scenario, excluding the impacts of climate change. The strongest increase in demand from the Arab Gulf countries is projected for meat and F&V. In relative terms, the top three items are meat, vegetables and sugar, for which demand is projected to be about 3.5 times higher in 2050 than in 2010. These results are mainly driven by the fact that (a) populations grow, (b) per capita incomes increase,

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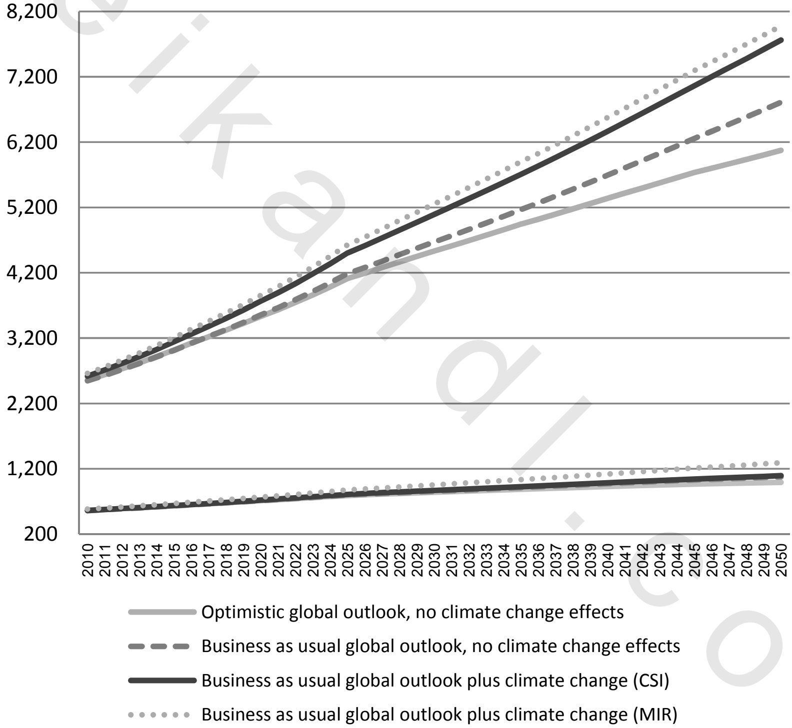
and (c) consumption shifts from staple crops such as cereals to more high value foods such as meat and vegetables. These three effects occur in the Gulf Arab states and in the rest of the world, thus increasing the world market prices for foods and therefore also the domestic prices in the region. If climate change effects are also taken into account, the costs of importing food to the region will likely further increase.

Figure 8.10
Projected Cereals Demand and Supply for Gulf Countries (in million USD, 2010–2050)

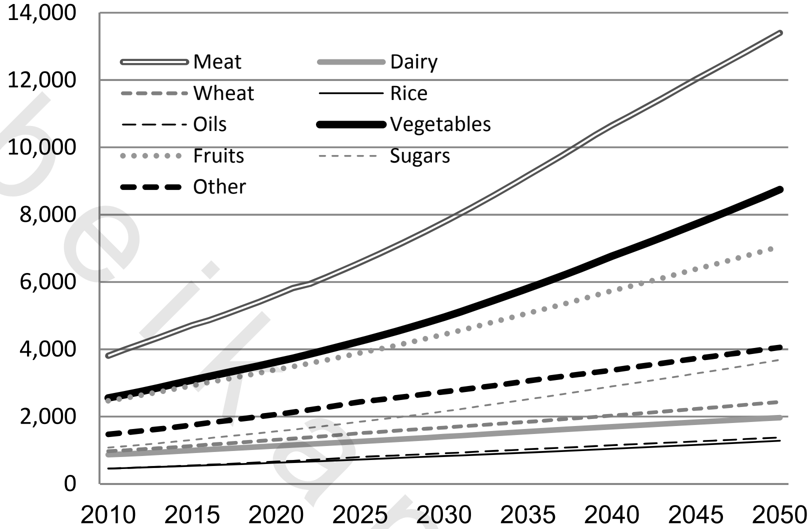


Notes: Arab Gulf countries include GCC plus Yemen. CSI and MIR are two out of 22 global climate models used in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

Sources: Authors' compilation based on Nelson, G.C., et al., "Food Security, Farming and Climate Change until 2050: Scenarios, Results and Policy Options," IFPRI Research Monograph no. 172, 2010.

Figure 8.11

Projected Food Demand in Gulf Countries (million USD, 2010–2050)



Notes: Gulf countries include GCC plus Yemen.

Source: Ibid.

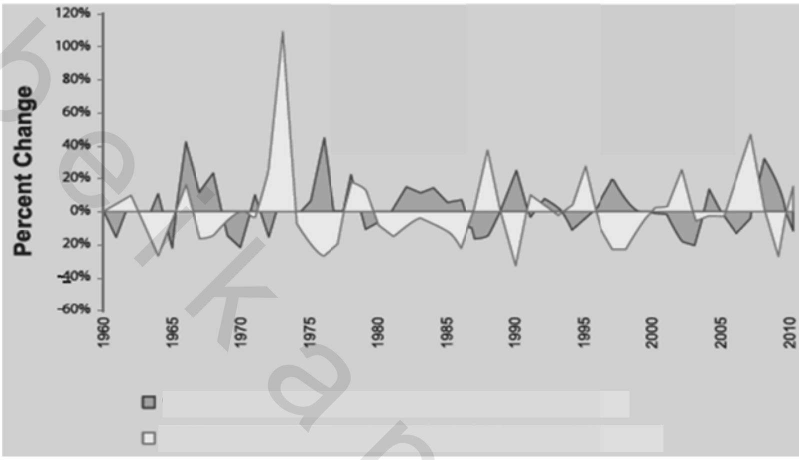
However, the Gulf states spend little of their earnings from exports and remittances to import food (Saudi Arabia spends only four percent, Bahrain 2.9 percent, the UAE 3.4 percent, Oman 6.2 percent, Kuwait 2.4 percent and Qatar two percent). Thus, while the value of exports keeps up with the increasing costs of food imports, no change in macro food security is expected.

Do GCC Countries require a Regional Strategic Reserve?

Cereals are the food group that was most affected by the 2007–2008 food crisis. Conventional wisdom has it that many concurrent factors contributed to the crisis, among which serious deficiencies in the quality of information, particularly with respect to the levels of global stocks (stock-to-use and major exporters' stock-to-disappearance ratios)[23] and short-term forecasts. All spikes observed in the last four decades have been associated with low stock ratios (Figures 7.12).[24] This, together with market thinness,[25] lack of capacity in analyzing early warning signs, uncoordinated and nervous policy actions, has contributed to excite the markets even further.

Figure 8.12

Speculative Trends of Changes in Wheat Stocks and Prices



Notes: correlation is –0.8.

Source: World Bank as reported in United Nations Food and Agriculture Organization (FAO), "Near East Food Security Update," 2012.

Wheat accounts for more than half of GCC cereal consumption. Only Saudi Arabia imports around two million mt, and is projected to import over three million mt of wheat after the phase-out of domestic wheat production taking place from 2016 onward.[26] The region relies primarily on South Asia (India and Pakistan) for rice imports, and the EU, Australia and Canada for wheat imports.[27] Given regional economic and production characteristics, as well as the world grain market trends, the region is highly vulnerable to both supply and price risks.[28]

As in many countries, there is little information on stocks in GCC countries. Oman and the UAE seem to have each established national cereal reserves equivalent to 3–6 months of their national demands. Saudi Arabia has a policy of holding wheat reserves of at least six months of domestic consumption that can rely on 12 silos with a total storage capacity of about 2.5 million mt.[29] Over one million tons of rice is imported (mainly from India) annually to Saudi Arabia, and rice reserves amount to less than one fifth of this quantity. Many GCC countries are planning to increase their storage capacity (double in the cases of Bahrain and Qatar, and more than three times for Oman; see Figure 8.13).

Table 8.5

Cereal Stocks in Saudi Arabia (million metric tons)

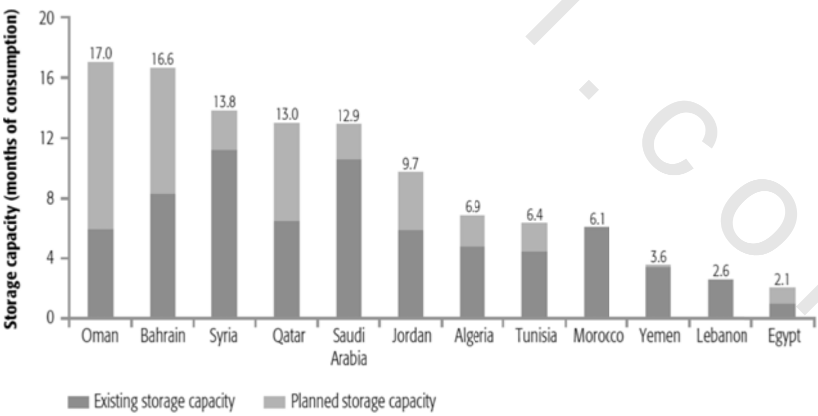
	2008–2010	2011[i]	2012[ii]
Cereal	3.5	3.4	3.3
Wheat	1.4	1.9	2.2
Rice	0.2	0.2	0.2
Barley	1.8	1.3	0.9

Notes: (i) estimate; (ii) forecast.

Source: UN Food and Agriculture Organization (FAO), "Food Outlook," Rome, November 2011.

Figure 8.13

Planned Increases in Storage Capacity in the Arab World



Source: United Nations Food and Agriculture Organization (FAO) and World Bank, "The Grain Chain, MENA Region," 2012.

Historically, however, national food stocks[30] have not shown great success in reducing price volatility – and particularly price spikes – in view of their often limited capacity when compared with the size of the markets they are supposed to calm, and the limited market information pool they are based on. Storage in the Arab region costs on average of \$2.15 per mt/month.[31] Based on available data, Saudi Arabia has storage costs slightly below this benchmark (\$1.9), while in Qatar the average is over \$3.3.[32] Therefore, if Saudi Arabia imports three million tons of wheat per year (likely lower-end scenario soon after 2016) and wants to keep its current 10-month average of strategic stocks, this will result in at least \$50 million per year in storage costs.[33]

Reducing import risks would clearly entail a multi-pronged strategy that includes trade openness,[34] functioning and integrated supply-chain logistics and infrastructures, and an effective procurement and hedging strategy. These three thrust areas show the potential importance of international or regional coordination mechanisms. In addition, some think tanks and scholars, including IFPRI,[35] have suggested, as a forth pillar, that an international food reserve would help prevent overshooting of cereal prices based on the following three-pronged approach:

- An small international physical stock for food emergencies composed of basic grains dislocated in strategic locations around the world and managed by the World Food Program.
- A global reserve to ease excessive national hoarding and able to quickly respond to supply shocks.
- An international fund or virtual reserve that operates on the financial markets to curb excessive speculation and price volatility.

This long-awaited international food governance is far from implementation.[36] However, regional cooperation among GCC countries on IFPRI's above-proposed policy actions could prove itself as an intermediate option. A regional grain reserve would provide GCC countries with critical lead-time to secure alternative wheat supplies in times of crisis. Despite being the largest importer of wheat, the Arab region holds only a small share of the world's wheat stocks. Such reserves, if equipped with sufficient capacity, would allow inter-temporal arbitrage that would normally smooth supply responses and would also offer psychological relief that may prevent hysteric hoarding.[37] Therefore, the following questions naturally arise: could GCC countries move in this direction by establishing a regional reserve given that they historically view food security as a national security issue? Would such a reserve help stabilize the regional market? And what are its preconditions?

The first consideration to make is that determining the optimal level of strategic reserves is difficult, as it depends on the combination of underlying factors such as extent of import dependency, vulnerability to supply and price shocks, rigidity of demand, availability of alternative food items, tolerance to risk, etc. Thus, building a comprehensive model to support decision making on stock sizes under different scenarios would be the best first option to support decision making. In the absence of such a tool, we can draw on global experiences. It is broadly accepted worldwide that reserves should be equal to at least three months of domestic consumption, so as to give enough lead-time to import and distribute new stocks purchased from international markets. The second consideration is that the optimal location for the storage is usually at the port of entry, so as to tap into economies of scale. Third, it is of the utmost importance that a set of clear principles and rules are established, including a domestic price ceiling that will trigger the release of reserves, target reserve levels, purchasing modalities, rate of replenishment,[38] viable ownership models, and so on.[39] Fourth, the independence and wider governance arrangements of the agency that manages the reserves is crucial in order to allow it to professionally and effectively administer them (although based on politically-driven strategies and principles).[40]

In the case of the GCC, setting a price band would not make much sense, as the threshold price aims at stabilizing the price for producers. Therefore, a price band would be more easily administered as it would only have a ceiling that will trigger the drawdown. It is also advisable to select a relatively high level of the ceiling which would prevent the reserve from turning into a safety net instrument rather than a supply stabilization tool.

Table 8.6

GCC Logistics Performance Index Comparisons

Country	LPI	Customs	Infrastructure	International shipments	Logistics competence	Tracking & tracing	Timeliness
Korea, Rep.	3.64	3.33	3.62	3.47	3.64	3.83	3.97
UAE	3.63	3.49	3.81	3.48	3.53	3.58	3.94
Bahrain	3.37	3.05	3.36	3.05	3.36	3.63	3.85
Kuwait	3.28	3.03	3.33	3.12	3.11	3.44	3.70
KSA	3.22	2.91	3.27	2.80	3.33	3.32	3.78
Brazil	3.20	2.37	3.10	2.91	3.30	3.42	4.14
Mexico	3.05	2.55	2.95	2.83	3.04	3.28	3.66
Qatar	2.95	2.25	2.75	2.92	2.57	3.09	4.09
Oman	2.84	3.38	3.06	2.31	2.37	2.04	3.94

Source: World Bank, Logistics Performance Index database, March 2012.

Since Saudi Arabia is the largest cereal market in the region and has the largest reserve capacity and a lower average cost, it would make sense that the potential regional reserve system centers around such a country. However, from a logistics standpoint this country is not among the region's top performers and lags behind the UAE, Bahrain, and Kuwait. Indeed, recent analysis suggests that the Kingdom's costs of port logistics, inland transport, and management are about 50 percent higher than those of its neighbors.[41] Investment to improve logistics infrastructure in the Kingdom will not only reduce cereal import supply chain costs – which would offer great opportunities for smoothing domestic fluctuations – but will also benefit other industries that are likely to use the same transport corridors and storage facilities.

Policy makers will need to carefully assess the potential impact of public stocks on private grain traders. Public stocks will have to be rotated

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in order to minimize spoilage (i.e., releasing reserves and replenishing them with new stocks). These releases will have to be conducted in a way to avoid crowding out effects[42] by: (i) releasing grains at market prices; (ii) re-exporting the released grains so as not to impact the domestic market;[43] (iii) auctioning the stocks among the private traders; (iv) combining the strategic grain reserves with food aid for other Arab and African countries that are mostly vulnerable such as Sudan or Yemen.[44]

The reserve could be governed jointly by the GCC countries with the support of specialized international agencies. The management body of the reserve would have legal custody of the reserve stocks and would be responsible for the following:

- Setting a high enough price ceiling so that it will not disrupt market dynamics and will only address serious price spikes.[45]
- Monitoring international and regional market conditions and early warning indicators on a continuous basis.
- Adjusting price ceilings according to changes in market conditions.
- Managing stock rotation.
- Establishing a balanced mix of physical and virtual reserves.
- Having sufficient multi-annual funding so that market operations can be effectively carried out.

The regional stock and related food security information systems could also support other food-insecure Arab countries with more limited administrative and financial capacities during crises.

The Potential Role of Financial Instruments

In principle, physical stocks can be more efficient and effective if they function in coordination with a system of "virtual reserves" that are managed through financial instruments. Risk management using financial instruments has become a quite common strategy. Several industries have embraced the use of futures markets to manage price risk. For example, the airline industry frequently uses forward and futures contracts to fix the price of fuel in the future in order to increase the predictability of cash flow.[46]

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Financial instruments may be grouped into two main categories: exchange traded contracts (futures and options)[47] and over-the counter instruments (forwards and swaps). The table below summarizes the purpose, advantages and disadvantages of these different financial instruments. Selection of the appropriate instrument must be tailored after identification and quantification of the risk, since there is no "one-size-fits-all" solution for risk management.

Table 8.7

Snapshot of Relevant Financial Instruments.

Instrument	Purpose	Benefit	Disadvantage
Futures	• Hedge price risk • Lock in value of inventories or finance part of storage costs	• No need to negotiate contract specification • Minimal counterparty risk • Delivery is not necessarily implied	• Working capital is frozen up in margins • Possibility of profiting from favorable spot market developments is lost
Options	• Obtain protection against unfavorable price movements while retaining possibility of benefitting from favorable ones	• Available in standardized form on exchanges • No funding risk: the costs of protection are known up-front • Possibility of benefitting from favorable price movements	• Up-front premiums can be expensive, especially in times of volatile prices
Forwards	• Facilitate planning and marketing • Lock in future prices	• Tailor-made for the needs of the contracting parties • Ensures physical market delivery of the commodities needed	• Major counterparty risk • Possibility to profit from favorable spot market developments lost • Pricing not transparent
Swaps	• Guarantee income streams of operations • Obtain easier and cheaper access to capital by securing future cash flows • Lock in long-term prices	• Combination of price-hedging and securing investment • Long-term and tailor-made • Less-strict margin calls • Low administrative burden and known counterparty	• Counterparty risks • High design/set-up costs • Difficult to assess the "fair" price for the deal • Possibility of benefitting from favorable price movements may be lost

Source: Adapted from UN Conference on Trade and Development (UNCTAD), "A Survey of Commodity Risk Management Instruments," 1998.

Financial instruments are increasingly used by grain-importing countries with the aim of locking in volume, quality, and price of imports 3–18 months in advance of delivery. This can help counterbalance short-term speculation and therefore smooth prices. Futures and options are the two main types of financial instruments commonly used in agricultural commodity markets.

Recent studies suggest that spot prices tend to be discovered in futures markets and therefore futures could potentially be used to address excessive spikes in grain prices through their signaling effects. Although such derivatives are seldom used in the region, other governments have successfully used them as risk management tools.[48] They can either be managed directly by government institutions or by private partnering companies within a clear reporting and oversight mechanism.

The World Bank, FAO and IFAD[49] present an interesting simulation for Egypt, which imported seven million tons of wheat from November 2007 to October 2008, at a cost of around $2.75 billion. Simulations show how Egypt could have reduced the import bill by using either futures or options, and a discretionary or non-discretionary approach to hedging.[50] They estimated that Egypt could have reduced the import bill by around $600 million during that period.

The main obstacles to the use of financial instruments for food price risk management are: financial capacity, technical skills,[51] volume of trade, liquidity and access to credit, stable import needs, and low exchange rate fluctuations. All of these obstacles could be overcome in the GCC countries, which have fiscal space, an educated labor force, a fixed exchange rate policy, and a low share of domestic production that does not vary according to climatic trends.[52]

A particular challenge related to the use of financial instruments in the GCC countries is how to ensure they are Shariah compliant. Although the elimination of risk is desirable under Islamic law, conventional derivatives contracts are not accepted by many Shariah scholars. However, it should be noted that Shariah compliant derivatives exist and therefore the instruments highlighted in this paper are relevant in the Shariah context, but their specific format should be developed by the Islamic banking community.

Figure 8.14

Shariah Compliant Derivatives

From the standpoint of Islamic law, financial contracts must satisfy a number of requirements, which are often not present in conventional derivatives. Most Shariah scholars maintain that derivatives are priced according to assets that are not in the possession of the seller, therefore violating the *hadith* principle. Shariah also prohibits *gharrar* (exposing oneself to excessive risk) and *riba* (paying or receiving a premium or interest). Legal scholars also claim that derivatives encourage speculative behavior akin to gambling (*maisir*). Despite these objections, scholars and practitioners acknowledge the important benefits of hedging instruments and the opportunity cost imposed by the lack of Islamic hedging tools. Recently, so-called synthetic derivatives, which are close equivalents of conventional derivatives have been developed. Another important step has been the Tawawwut (hedging) Master Agreement which standardized Shariah compliant swap-based hedging transactions. Users of derivatives should demonstrate that their transactions constitute true hedging behavior and the use of derivatives is more likely to gain the approval of Islamic scholars if changes in asset value can bring some kind of benefit to both parties.

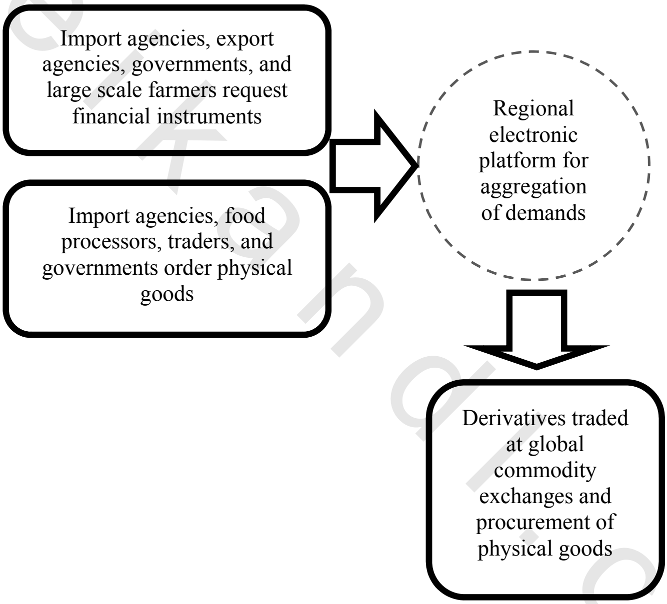
Source: A. Jobst and J. Sole, "Operative Principles of Islamic Derivatives: Towards a Coherent Theory," IMF Working Paper, WP/12/63, 2012.

A regional approach could help overcome the remaining barrier related to the volume of trade, since financial contracts are often traded with large volumes that might be too large for the smaller GCC countries. For example, wheat future contracts are of a minimum of 5,000 metric tons, which is similar to the total monthly wheat import of Bahrain. A regional approach can also provide other benefits in terms of economy of scale for training, research and operational cost. The regional approach might also be valuable for negotiations, especially in terms of over-the-counter instruments which are negotiated bilaterally.

The GCC countries could also make joint use of the global commodity exchanges in order to hedge their food price risk. A regional approach might be useful to obtain the necessary volume of trade and would offer cost reductions. Research in supply chain management has focused increasingly on strategic management of procurement operations through purchasing consortia where different entities combine their individual needs to gain the increasing pricing, quality and service advantages associated with volume buying. Electronic purchasing consortia, employing ICT-based communication infrastructure, enable the efficient coordination of different entities at a low transaction and communication cost.[53]

Figure 8.15

Regional Aggregations of National Demands



Such systems are already in practical use for various purposes and could be adjusted to serve as a platform for risk management for different import and export agencies, farmers, governments and other entities that seek to hedge their food price risk. The different entities would place an order for a quantity of a specific commodity to be hedged. The orders from different entities would be aggregated before derivatives are traded on a global commodity exchange. This would enable small and large entities alike to manage their food price risk, without incurring large upfront investment and overhead costs. GCC countries face a number of supply and price risks and therefore a mix of various hedging instruments with different maturity mix could serve their purposes.

An integrated electronic platform could also include the procurement of physical goods. The regional approach will have some implications on the terms of procurement as the countries will have to coordinate procurement needs and tender dates. The regional electronic platform could facilitate this coordination between countries. Orders for physical goods could also be channeled through an electronic system and after aggregation orders could be placed on the global markets. This would facilitate price risk management as well as to ensure the delivery of physical goods.

A Region-based Agricultural R&D System

Worldwide, investments in agricultural research and development (R&D) proved to have high rates of return (RoR). The median of RoR estimates is 48 percent for research per year, and 62.9 percent for studies that improve extension services. These estimates have not changed significantly over time.[54] However, current trends show a misleading picture of global public investments because the increasing financial contribution to R&D in agriculture has been concentrated in just a few countries.[55] As agricultural development is highly dependent on R&D, a key component of the regional strategy proposed in this paper is thus a joint agricultural innovation system in the Gulf region that may also benefit other food insecure Arab countries.

In the past two decades, much has been done in GCC countries to stimulate regional research and innovation. A regional GCC patent office has been established for technical and scientific research and to facilitate technological transfer. The International Center for Agricultural Research in the Dry Areas (ICARDA), through its Arabian Peninsula Regional Program (APRP) has not only been dedicated to research, but also to strengthening institutions and capacities, developing human resources, and information technology. Countries have been individually investing in national food security programs, in infrastructure such as Agro-Industrial Parks in Qatar, in education through partnerships with international universities, research centers and international organizations.

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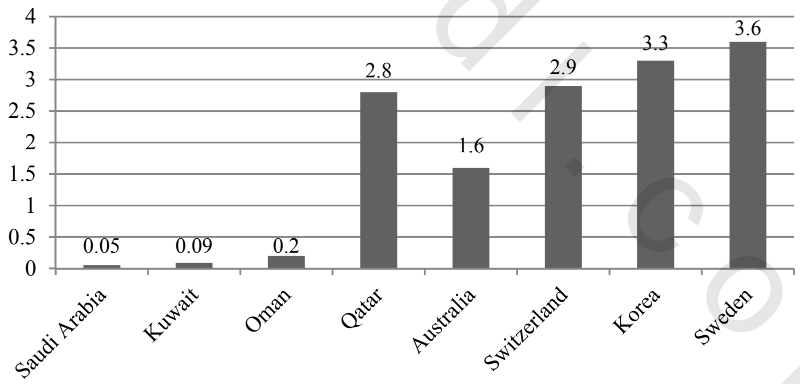
Despite these initiatives, innovation system indicators in GCC countries show low performance. The first challenge facing agricultural R&D is the lack of data on public spending. Despite this constraint, the limited evidence suggests that R&D public investment in agriculture is significantly low. In the absence of specific data, overall R&D public spending has been examined.[56] Here, it emerges that GCC countries have allocated significantly low expenditures to R&D. For example, in 2007 selected Gulf states spent (as a percentage of GDP) 0.05 percent on R&D (Saudi Arabia), 0.09 percent (Kuwait), and 0.2 percent (Oman). With the exception of Qatar, the region spends well below developed countries in this area (Figure 8.16). ICARDA's study of national innovation systems in GCC countries shows that the lack of financial resources in Bahrain, UAE and Oman represents a major constraint. APRP has been supported by two international funds – the International Fund for Agricultural Development (IFAD) and the OPEC Fund for International Development – and only one Arab fund, the Arab Fund for Economic and Social Development.

Figure 8.16
R&D spending as % of GDP (2007)



Sources: Data for Saudi Arabia and Kuwait from: World Bank, "Research and Development Expenditure (% of GDP)"; (http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS). Data for Oman and Qatar are unofficial estimates from T. Andersson, "Natural Resource Dependency and Innovation in the GCC Countries," IGI Global, 2012; others are from J. Cukier, "Big Variations in R&D Spending," OECD Factblog, May 27, 2010; latest available year is 2007.

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Private R&D in agriculture is also limited. Economies characterized by capital-intensive industries and services provide generally less, if not insufficient incentives for private sector R&D investments.[57] A very limited private sector engagement in total R&D expenditure is observed. In Saudi Arabia, private sector spending in R&D activities reached a mere 10 percent of the total in 2007, with a predominant concentration in the oil sector.[58, 59]

The knowledge and innovation rankings of GCC countries are significantly low. The UAE and Qatar are among the Gulf countries with somewhat higher ranks in the knowledge economy index, while Oman and Saudi Arabia are ranked the lowest.

Excluding growers and extension agents, the number of researchers in agriculture in the region appears significantly low for its population. On the quality of the scientific research institutions, some countries perform better, namely Qatar and Saudi Arabia, while Bahrain showed the lowest performance.

Effectiveness of innovation systems does not only depend on mere investments and individual researchers but also on the environment in which they operate. An effective innovation system provides an enabling environment for actors across the chain to interact and coordinate collective actions.[60] To assess the environment for an agricultural innovation system in GCC, the indicators presented in Table 8.9 are examined.

Table 8.8
GCC Rankings on Knowledge Economy and Competitiveness

Country/Index	Knowledge Economy Index KEI	Pillar 1 : Education	Pillar 2: ICT	Pillar 3: Innovation	Quality of scientific research institutions	University-industry research collaboration
Bahrain	49	60	40	80	112	101
Kuwait	52	76	46	70	83	99
Oman	66	86	76	71	63	53
Qatar	44	67	27	48	32	38
Saudi Arabia	68	80	52	86	37	37
UAE	45	79	21	46	53	39

Sources: World Bank Institute, knowledge assessment methodology [KAM] (www.world bank.org/kam), 2009. Quality of scientific research institutions and university industry research collaboration were taken from: Klaus Schwab (ed.), "Global Competitiveness Report 2009–2010," World Economic Forum, Geneva, 2009.

Table 8.9

An Agricultural Innovation System: Regional Indicators

Knowledge transfer	Openness to international research, accumulated knowledge and expertise: • Increasing imports of knowledge and expertise through partnerships with foreign universities, research centers and experts. • The provision of training for researchers, growers and extension agents. Developed by ICARDA's APRP, there exists a system in place for knowledge transfer across the chain in the region, although at an embryonic stage, that could be strengthened further.
Linkages and infrastructure	Mixed picture with promising initiatives on the ground: • Establishing a network for researchers and scientists in the region via regional programs such as that of ICARDA. • University–industry research collaboration in agriculture is relatively weak. • ICT is a critical platform for innovation systems and some countries have made a significant progress in ICT, notably Qatar and the UAE. • In the current inter-regional cooperation dialogue with the EU's INCO-NET (international cooperation network), GCC countries are defining common interests and research areas where food and agriculture are on the menu.[61]
Policies and governance	Weak policies, but some institutional set-up in place. General lack of governance persists: • Research in agriculture in most countries remains traditional, with a lack of vision and priorities. No clear distinction between research policies and those meant to enable adoption of improved technologies and practices. The research agendas are not based on a commodity chain approach.[62] • The GCC patent office has granted over 1,800 patents to date, with only 0.01 percent of those related to agricultural activities, including water improvement and chemical related activities.[63] Data on granted patents in the three national patent offices is not available.

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Regional cooperation in research and innovation can enhance the pool of resources, in particular specialized financial resources and know-how. In other words, the high risks of investments in R&D and innovation are significantly reduced through diversification of resources, and efficiencies are achieved through the resulting economies of scale.[64]

One of the examples of a cross-border cooperation system in research and innovation is the European Union. The European innovation system comprises an overall framework and various programs which have led to the creation of several supporting funds – the European Institute for Innovation and Technology and the European Research Council – and several other coordinating mechanisms. The European model confirms that innovation occurs in an institutional, political and social context and that learning is facilitated by a regional research and innovation governance framework.[65]

GCC countries have great potential for regional cooperation in research and innovation. Besides geographic proximity and the social and political contexts set through the Gulf Cooperation Council, the countries have financial resources and have shown their openness toward striving for knowledge generation and transfer.

These establishments would satisfy three main pre-conditions for effective coordination:[66] appropriate incentives through the joint R&D fund; a committed and capable leadership of high-level decision-makers and regional experts; and an enabling environment, through the regional program, where stakeholders would interact and coordinate their activities. Consolidation of financial resources across sectors needs to be encouraged to tackle the complexity and multi-sector nature of food security effectively. Contributions should not only come from the six governments, but also from the GCC quasi-public development funds, *ad-hoc* research funds and the private sector.

In an attempt to get an idea of a benchmark for an R&D fund in agriculture, we compare the GCC countries with Australia,[67] a country with a research intensity ratio of five percent,[68] spending on R&D totaling 1.6 percent of GDP, and with 6.5 percent of its total R&D expenditure allocated to agriculture ($723 million).[69] We compared the size of Australian R&D expenditure to total R&D expenditure of the four GCC countries (with available data).[70] We found that Australia spent US $9.8

billion more on total R&D than the four GCC countries combined. Australian R&D spending in agriculture alone was equivalent to 75 percent of the total expenditure on R&D by the four GCC countries lumped together. Finally, if we were to take Australian R&D expenditure in agriculture as a minimum yearly contribution to the joint R&D fund, the GCC countries would each be required to contribute roughly $120 million per year. If all the funding institutions, both public and private, joined forces and consolidated their payments to the joint R&D fund for agriculture, this minimum target could be met.

A regional fund could provide two types of services:

- Competitive grants/loans to stimulate and create demand for innovative research in agriculture; fellowships for PhD and post-doctoral research in agriculture at foreign universities to enhance knowledge transfer to the region; support to foreign researchers willing to focus on research in the GCC; grants/loans for agricultural research in reputable institutes abroad with established capital from GCC countries.

- Grants/Loans to enhance absorptive capacities (similar schemes exist in the Arab Fund for Economic and Social Development). Funding of feasibility studies and project preparations, seminars and conferences, institutional support and training, general studies and research.

R&D system performance is linked to strong governance. Examples of strong governance referred to here are independent legal entities with their own governing boards, and various mechanisms to ensure accountability. Autonomous governance would involve representatives of each participating sector in its governing board and supervisory board. The governing board would have responsibility for all strategic decisions, aligned with the objective of the fund to safeguard resources for research and extension in agriculture. This board should be accountable and legally liable to a supervisory board comprised of members and beneficiaries. The composition of the governing board should include a wide range of skills and competences—from specialized knowledge in agriculture to the expertise required to oversee all the functions performed by the fund.

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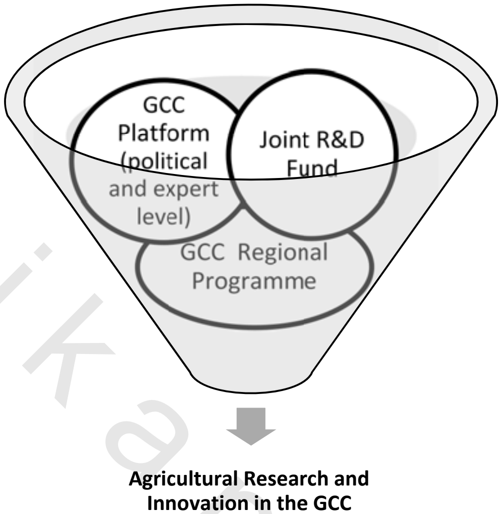
Figure 8.17

Framework of a GCC Agricultural Innovation System



1. **GCC R&D Fund for Agriculture** to ensure increased financial support for R&D activities based on regional priorities in agriculture.
2. **GCC Platform for Agriculture at political and expert level** to decide on research priorities and research policy instruments for the region.
3. **Expansion of ICARDA's Arabian Peninsula Regional Program** to further build on the areas and priorities decided by the GCC Platform for Agriculture.

To ensure coordination and consensus-based priority setting, a platform of regional experts and high-level political representatives is desirable. However, the sustainability of the system is not guaranteed without stable public sector support.[71] Therefore, political support and commitment are critical in defining policy frameworks and institutionalizing various coordination mechanisms. The main role of the platform would thus be to set priorities and regional strategies for agricultural research, as well as to revise them based on regular progress assessments.[72]

The network established by ICARDA's program could serve as a starting point for region-wide governance of scientific and technical expertise. Building on the established coordination mechanisms of this program, a stronger platform will allow actors from across the chain to further strengthen regional research capacities and human resources through education and training, and to improve agricultural extension. This program should also involve the private sector across the chain (besides growers, producer organizations, agro-processors, importers, input suppliers, other credit agencies, standards agencies, etc.) and ensure their presence at all levels of coordination.

Some of this coordination should emerge spontaneously once appropriate incentives are put in place (sustainability of funding through the joint R&D fund), as well as regional priorities and strategy have been defined through policies and instruments. Innovations do not require thorough advanced planning. Once the enabling environment has been established, creative actors across the chain guide adaptation and elicit changes in their organizations.[73]

The Water–Food Security Nexus

Most of the water utilized in GCC countries comes from rain, springs, groundwater reserves, and increasingly from desalination, while to a lesser extent from treated wastewater. The agricultural sector accounts for the overwhelming majority of the withdrawal of water resources, followed by the domestic and then the industrial sectors. While water demand is rising rapidly in all sectors, it is increasing the most in the domestic sector as a result of population growth and changing living standards.

Without rainwater,[74] GCC countries are water deficient by more than 19 bcm meaning that they are withdrawing more water than they are replenishing. This is worrisome, particularly with regards to groundwater resources, as they are the main source of water that most GCC countries rely upon. With the advent of climate change, additional pressure on water resources is expected.

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Table 8.10
Water Resources Availability in GCC (MCM/yr)*

Type of water resources		Bahrain	Kuwait	Oman	Qatar	KSA	UAE	Total
Rainfall		63.1	2156.0	38690	857.7	126,800.0	6,521	**175,088**
SGW**	Surface water	4.0	0	1,050	0	2,200.0	150	**3,404**
	Groundwater	112.0	20.0	1,300	58.0	2,200.0	120	**3,840**
Non-conventional	Wastewater	61.9	250.0	37	58.0	547.5	289	**1,243.4**
	Desalinated	102.4	420.2	109	180.0	1,033.0	950	**2,794.6**
SGW+ non-conventional		280.3	690.2	2,496	296.0	5,980.5	1,509	**11,252**
Total supply with rainfall		343.4	2,846.2	41,186	1,153.7	132,781.0	8,030	**186,340.3**
Withdrawal	Agricultural	159.2	491.9	1,168	262.0	20,830.0	3,312	**26,223.1**
	Industrial	20.3	23.3	19	8.0	710.0	69	**849.6**
	Domestic	177.9	448.3	134	174.0	2,130.0	617	**3,681.2**
Total withdrawal		357.4	963.5	1,321	444.0	23,670.0	3,998	**30,753.9**
Balance	without rainfall	-77.1	-273.3	1,175	-148.0	-17,689.5	-2,489	**-19,501.9**
	with rainfall	-14.0	1,882.7	39,865	709.7	109,111.0	4,032	**155,586.4**

Notes: (*) million cubic meters/year; (**) surface and ground water.

Source: UN Food and Agriculture Organization (FAO), Aquastat Database, 2012 (http://www.fao.org/nr/water/aquastat/main/index.stm), accessed February 2012.

Average GCC per capita water consumption hovers at around 800 m^3 per year (which is higher than Japan or China) while there is much less total renewable water per capita. Regional water demand is expected to double by 2030. This prospect, together with low groundwater recharge ratios, heralds a gloomy picture.

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Table 8.11

Water Resources and Withdrawal in GCC (2003–2007 average)

	Annual Renewable Water per Capita (m^3)	Annual Water Withdrawal per Capita (m^3)
Bahrain	125.3	386.0
Kuwait	8.2	441.0*
Oman	546.7	515.8
Qatar	49.2	376.9
Saudi Arabia	94.1	928.1
UAE	27.7	739.5

Notes: (*) Data for 1998–2002.

Source: FAO, Aquastat Database, op. cit.

Compared to other countries, the GCC states tend to have a large water footprint, which is not in line with the prevailing scarcity of water resources.[75] For example, the GCC water footprint is much larger than most other countries reported in Table 8.13, when agriculture is not taken into account, while these are not water scarce countries.[76]

Table 8.12

Water Footprint: World Comparisons (1996–2005)

Country/ Region	Production (m^3/yr/cap)			Consumption (m^3/yr/cap)			Total
	Agriculture	Industry	Domestic	Agriculture	Industry	Domestic	
GCC	589	27	116	1835	75	118	2761
ESCWA	978	64	75	1463	40	64	2683
Australia	7001	22	58	2128	129	58	9395
Brazil	2647	46	56	1926	46	56	4775
Germany	637	42	27	1259	140	27	2131
Netherlands	336	18	10	1259	198	10	1829
Turkey	1629	37	63	1510	70	63	3370
USA	3289	246	111	2398	334	111	6489

Source: M.M. Mekonnen and A.Y. Hoekstra, “National Water Footprint Accounts: Production and Consumption; Vol. 1: Main Report,” Research Report Series No. 50, UNESCO-IHE, University of Twente, The Netherlands, 2011.

Water footprints related to agricultural activities take the largest share of the total water footprint of the region, accounting for 88 percent (with the highest rates in the UAE, Oman, and Saudi Arabia) despite the fact that the sector contributes only 1–2 percent of the region’s GDP. The

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water footprint related to agricultural, industrial and domestic sectors for the period 1996–2005 in the GCC was 22.2 bcm per year, of which 27 percent was from rainfall, 50 percent from ground and surface water, and the remaining 23 percent from desalination and wastewater.

Table 8.13
Water Footprint in the GCC (1996-2005)

	Agriculture	Industry	Domestic	Total
Production (m^3/yr/cap)				
- Rainfall	200.4	--	--	200.4
- SGW(*)	349.8	1.4	12.0	363.2
- Wastewater	39.2	26.0	103.9	169.2
- Sub-total	589.4	27.4	115.9	732.8
Consumption (m^3/yr/cap)				
- Internal	478.2	13.6	117.9	609.7
- External	1357.3	61.6	--	1418.9
- Sub-total	1835.4	75.3	117.9	2028.6
Total water footprint	**2424.8**	**102.7**	**233.8**	**2761.3**

Notes: (*) = surface and ground water.

Source: Mekonnen and Hoekstra, op. cit.; and ESCWA calculations.

The largest segment of the water footprint of the region results from the consumption of goods and services – 73 percent of the water footprint – while productive activities account for the remaining 27 percent.

The virtual water flow for the period 1996–2005 for the GCC was positive and amounted to about 33 billion cubic meters per year or approximately 1,000 cubic meters per year per capita.[77] Keeping in mind the fact that GCC countries are well below the severe water scarcity threshold of 500 cubic meters per year per capita in terms of water availability, the importance of virtual water for the region becomes apparent. Of the above virtual water flow, about 73 percent is accounted for by rainwater (mostly as a result of imported rain-fed products such as cereals), 15 percent by surface and ground water, and 12 percent by wastewater. The largest share of the virtual water flows

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in the GCC is related to international trade in agricultural related products (96 percent), while trade in industrial products represented the remaining four percent.[78]

Table 8.14
Virtual Water in the GCC (1996–2005)

	Agriculture		Industry	Total
	Crops	Livestock		
Water import (m^3/yr/cap)				
- Rainfall	756.8	243.9	--	1000.7
- SGW(*)	218.9	27.5	9.6	256.0
- Wastewater	103.6	9.3	118.0	234.0
- Total	1082.3	280.7	127.7	1490.7
Water export (m^3/yr/cap)				
- Rainfall	164.5	39.5	--	203.9
- SGW(*)	73.7	9.1	4.9	87.8
- Wastewater	28.9	2.3	75.6	106.8
- Total	267.1	50.9	80.5	398.5
Balance (m^3/yr/cap)				
- Rainfall	592.4	204.4	--	796.8
- SGW(*)	145.1	18.3	4.7	168.1
- Wastewater	77.7	7.1	42.5	127.2
- Total	815.2	229.8	47.2	1092.2

Notes: (*) = surface and ground water.

Source: Mekonnen and Hoekstra, op. cit.

There is a question of to what extent the prevailing water scarcity is reflected in the price of water in the GCC countries and in their production patterns. Given the fact that externalities and scarcity are seldom included in the price of water, most particularly for agricultural water, it cannot be expected that production and trade patterns will automatically account for regional water scarcity patterns.[79,80] Therefore, the import of virtual water is often unrelated to relative water scarcity.[81]

Moreover, as a development tool, irrigation can also have developmental opportunity costs, as it involves the transfer of resources from other activities to subsidize the schemes, though without adding significantly to domestic value added.[82] The resources mobilized to promote irrigation – financial and others – could be used more effectively in supporting other economic areas

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such as agricultural R&D, agro-processing, or in assisting producers of such commodities as fruit and vegetables or fisheries so they could adopt more efficient production techniques.[83]

Figure 8.18

Fertilizers and Water Returns

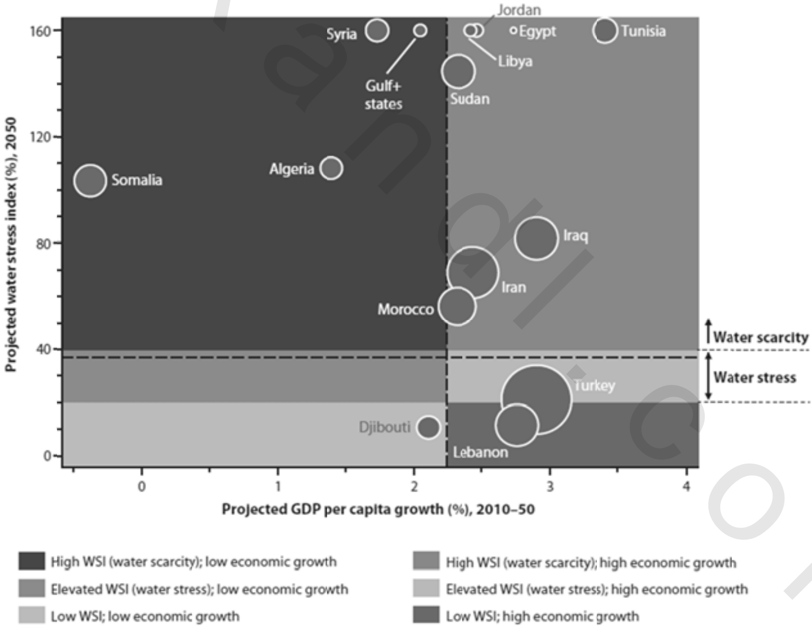
Although the application of fertilizers can improve yields and returns to water, this is not always an economically viable option, particularly in dry climatic zones, as some fertilizers – e.g., nitrogen – do not respond well when annual rainfall is below 900 mm. Irrigation poses serious environmental risks (increased salinity, drop of the water table, etc.) and high costs, while the use of desalinated water, despite becoming gradually competitive with groundwater withdrawals, is not a viable alternative either because one needs to add high energy, the environmental impact of its processing cycle, as well as high transport costs to inland areas. Thus, small increases in yield levels would have to be expected, which would not be sufficient to generate enough gains to pay for the cost of fertilizers let alone other costs such as irrigation and water.

Projections of IFPRI's IMPACT model indicate that the Gulf+ countries (GCC+Yemen) are following a growth path of inefficient water use, where water stress levels are far above regional and world averages. In addition to sea water desalination, improving water use efficiency and waste water recycling should be considered within a package of measures to promote sustainable growth.[84]

Figure 8.19 shows the relationship between projected water stress in 2050 and projected long-term economic growth from 2010 to 2050. Water stress in a country is measured by the Water Stress Index (WSI)—an index developed by Veolia Water (2010). A country is considered "water stressed" if the WSI value is between 20 and 40 percent, and "water scarce" if the index value is above 40 percent. The volume of a bubble is proportional to the total internal renewable water resources per capita in 2010. The dashed horizontal line represents the global average WSI value projected for 2050. The dashed vertical line represents the global average economic growth rate projected for 2010–50.

The GCC countries will hence have to switch in the long run from productive efficiency to allocative efficiency. Productive efficiency implies that current users would endeavor to use their water more efficiently through the adoption of techniques such as drip irrigation to replace flood irrigation while, on the other hand, allocative efficiency requires that the available water is used in areas where it could be the most efficient. Thus, water would have to be re-allocated within agriculture as well as to sectors such as industry or domestic, where it would have a much greater value and could generate more income from a unit of water than cereal production[85,86] (see Figure 8.20 for an example).

Figure 8.19
Water Stress and Economic Growth Outlook



Notes: Gulf+ states include GCC and Yemen.

Source: C. Breisinger, O. Ecker, P. Al-Riffai, and B. Yu, "Beyond the Arab Awakening: Policies and Investments for Poverty Reduction and Food Security," IFPRI Food Policy Report no. 25, 2012, based on IFPRI's IMPACT model estimation.

Figure 8.20
Allocative Efficiency

Wheat yields in the GCC and other selected countries are as follows: Kuwait (3.5 mt/ha), Oman (3.6), Qatar (3.0), Saudi Arabia (6.5), United Arab Emirates (2.6); and then Canada (2.8), France (7.0), United States (3.1) and the world average (3.0).[87] Wheat production in Canada, France and USA is largely rain-fed, while in GCC countries it is irrigated. Generally speaking, under irrigated conditions yields tend to be well above average and in our case they will be assumed at an average of about 5 mt/ha, assuming that an adequate amount of fertilizers is used. This production will require about 7,500 cubic meters of water per hectare. At an average 2012 price of $300 per mt of wheat, the value added to each cubic meter of water is thus $0.2 ($1,500/7,500 m^3). In contrast, about 333 cubic meters of water are needed to produce one mt of melons. In 2011, one ton of melons was worth $575,[88] for a value added of about $1.7 for each cubic meter of water consumed, which is nearly ten times more efficient than producing wheat. This is an example of allocative efficiency that could be expected by switching crops.[89, 90]

Table 8.15
Water Use Efficiency for Selected Commodities

	Wheat	Beef	Poultry	Milk	Melon	Oranges	Aluminum
Yield*	5,000	210	1.6	7,000	30,000	20,000	1,000
Price ($/Ton)	300	4,500	2,000	421	575	750	2,203
Water (m^3/kg)	1.5	20.6	5.5	0.748	0.333	0.4	0.005
Total water consumed	7,500	4,317	8.8	5,236	9,990	8,000	5
Total value**	1,500	945	3.2	2,945	17,250	15,000	2,203
Value added per unit of water ($/m^3)	0.20	0.22	0.36	0.56	1.73	1.88	441
Efficiency to wheat	---	1	2	3	9	9	2,203

Notes: (*) kg/hectare for crops, kg/animal for livestock and output for aluminum; (**) $/hectare for crops and $/ton for livestock and aluminum.

Sources: UN Food and Agriculture Organization (FAO). FAOSTAT, 2012 (http://faostat.fao.org/default.aspx); M. Krieth, "Water Inputs in California Food Production," Water Education Foundation, 1991; G. Lucier and L. Glaser, "Vegetables and Melons Outlook," VGS-3445, ERS, USDA, Washington DC, 2012; and A. Earle, "The Role of Virtual Water in Food Security in Southern Africa," Occasional Paper No. 33, Water Issues Study Group, SOAS, University of London, UK, 2001.

In most parts of the region, water consumption is not properly billed and therefore is heavily affected by generalized free-riding problems. Moreover, indiscriminate incentives – such as price support, subsidized credit, and energy subsidies (Table 0.16) – encourage excess water use for irrigation. Consequently, water consumption continues to increase.

Table 8.16
Water Irrigation Subsidies

	Price Support	Subsidized Credit	Energy Subsidies
Saudi Arabia	X	X	X
Bahrain		X	X
Oman	X	X	X
Qatar		X	X
Kuwait		X	X
UAE	X	X	

Source: Breisinger, et al, "Food Security and Economic Development in the Middle East and North Africa," IFPRI Discussion Papers 985, 2010.

Traditionally, governments have focused on increasing the supply of fresh water by identifying and developing new sources of water supply, regardless of cost. GCC countries have been increasingly turning to options such as desalination[91] and treatment and reuse of wastewater[92] to complement the usual methods of water supply, i.e., groundwater pumping, rainwater and runoff harvesting, and so on. However, now emphasis should be increasingly devoted to managing water demand through innovative policies and programs that promote more desirable patterns and levels of water use.

Water would need to be priced at a rate that reflects its scarcity in order to encourage productive efficiency. Doing so would encourage farmers to switch to productions that are less water intensive or crops that have a higher market value. Such a move would constitute a first step towards a gradually more radical allocative efficiency.

Moreover, a number of water-saving initiatives can be taken as follows:

- Adopt regulations and subsidies to help shift from flood irrigation to modern water-saving technologies such as drip, sprinkler, fertigation, and hydroponic irrigation. These modalities allow localized application of both water and fertilizers resulting in their savings and lower environmental impact.
- Water cost recovery through metering and billing.
- Heavily invest in wastewater collection, treatment, and redistribution.[93]
- Raising awareness and community participation.

Closing Remarks and Next Steps

Given the globalized markets characterizing the cereal sector and consequently the limited capacity of the small GCC countries to effectively stabilize them, the regional level takes particular prominence because of the interconnectedness of challenges and markets in the GCC region.

A multi-pronged and multi-scale strategy is therefore advisable to effectively address food security concerns in this region. Analysis conducted in this paper leads into the following strategic directions: (i) assessing more thoroughly a regional food reserve to reduce potential market disruptions; (ii) investigating opportunities for a region-wide procurement system based on innovative financial instruments; (iii) consolidating agricultural R&D systems and enhancing their impact; and (iv) achieving more efficient water use and governance through assessing water footprint of production, consumption, and trade patterns.

The implementation of viable safety nets and sustainable land deals abroad are crucial complementary tools for an effective and comprehensive food security strategy. If well-targeted, safety nets may be less costly than establishing strategic reserves,[94] but they do not protect consumers from potential cereal supply shortages and resultant panic that often results in hoarding or pilferage in times of acute crisis. Knowing that such reserves are available may prevent potential panic and reduce future market disruptions.

Below are some immediate key steps to move in the proposed direction, divided into two main clusters:

1. Data Collection, Feasibility Studies and Future Research Activity

- As a matter of priority, consumer price statistics and price monitoring systems in the GCC should be strengthened in order to allow a proper analysis of price trends and their impact on the vulnerable income groups.
- Systematically use such data for the design and implementation of evidence-based and accurately targeted safety net systems.
- More research is needed in analyzing food price transmission channels and dynamics, as well as their tendency toward downward stickiness in the GCC countries.
- Conduct a feasibility study on the potential realization of a GCC-wide grain reserve including suitable governance options.
- Conduct a feasibility study on the opportunity of establishing a GCC-wide harmonized and, eventually, joint cereal procurement system based on an integrated platform.
- Further investigate the basis risk constraining potential hedging strategies for specific cereal markets in the GCC.
- More research is also needed on the trade-offs between water use in agriculture, residential and industrial use, taking into account new technologies available for wastewater treatment and reuse.
- Make more systematic use of water footprint and water balance analytical toolkits in the food security policy discussion.
- Finally, regional dietary patterns of over-consumption of food items such as sugar, cooking oil, and meat with high fat content can increase the risk of obesity, coronary disease, diabetes mellitus, and colon cancer. This is an area that deserves closer investigation.

2. Short- and Medium-term Policy Actions

- Small GCC countries such as Qatar and Bahrain could benefit from importing cereals on vessels shared with larger countries such as Saudi Arabia or the UAE.
- Consolidate grain purchases around a few reliable traders that can reduce risks of non-compliance with procurement contracts.
- Target investment in key bottlenecks in supply-chain logistics and infrastructures.
- Have a regional discussion and adopt clear proposals on how to make commodity-based financial instruments compliant with cultural and religious criteria, and start reforming the legal and regulatory framework accordingly.
- Increase budget allocations and strengthen the governance of the regional agricultural R&D system, capitalizing on already existing initiatives such as ICARDA's APRP, in support of sustainable agricultural and water-saving R&D activities.
- Gradually move towards economically and environmentally viable water governance arrangements, including better cost recovery through metering and billing.
- Sustainable and evidence-based strategies should be further examined on how GCC countries can best engage in land deals with developing countries endowed with large agricultural potential.
- But first and foremost, a food security regional platform could be created and could serve as a vector for policy discussion of all the above-mentioned actions that may eventually feed into a region-wide food security strategy.

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PART IV

WATER AND FOOD SECURITY IN THE UAE

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9

Water Security in the UAE: Challenges and Opportunities

Mohammed Dawoud

Scarcity of renewable water resources is a global challenge facing many countries, especially those located in the world's arid and hyper-arid zones. Statistics indicate that global water resources total around 1,386 billion cubic meters (bcm). Freshwater constitutes just a small percentage of this (around three percent), while the overwhelming proportion is salt water in the seas and oceans. Sixty-nine percent of that fresh water is in ice form, which only leaves 31 percent of the total fresh water that is readily accessible. Of this, 30 percent is non-renewable groundwater and only two percent is renewable, as shown in Figure 9.1. Thus, more than one billion inhabitants in developing countries suffer from a lack of drinking water and sanitation.[1]

Water resource preservation has therefore become one of the world's major contemporary challenges, particularly in arid countries like the United Arab Emirates and the other GCC states. Studies indicate that the GCC states are experiencing a water deficit that reached 15 bcm in 2008, a figure which is expected to increase to 35 bcm by 2030.[2] Hence, since the establishment of the federation in 1971, the UAE government has not only realized the importance of water and its role in economic, agricultural and demographic development, but also invested in the water sector, resulting in the establishment of the necessary infrastructure to develop these resources sustainably, including wells, dams to store rainwater, desalination plants, distribution networks and wastewater treatment plants. This required substantial capital investment, as well as significant operational costs that were borne by the state.

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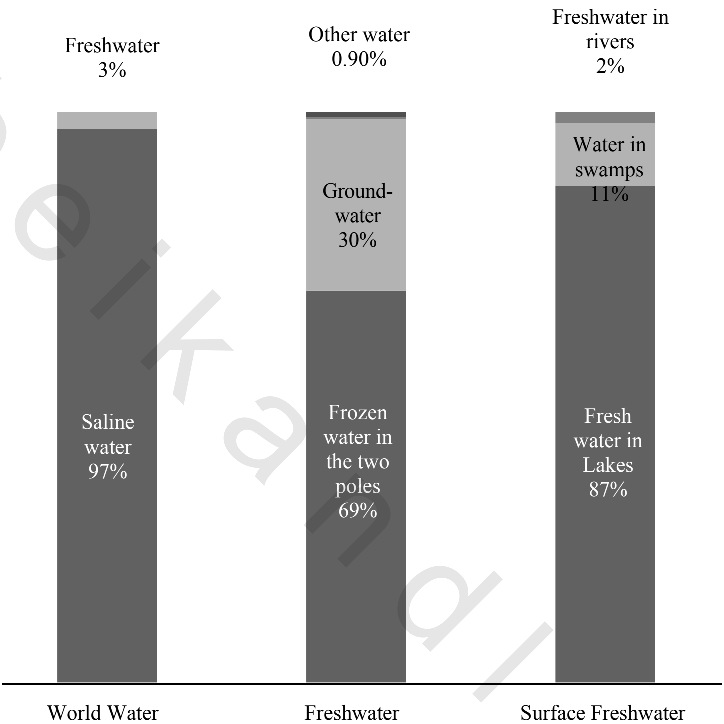
Figure 9.1

Global Water Balance and Fresh Water Available for Use



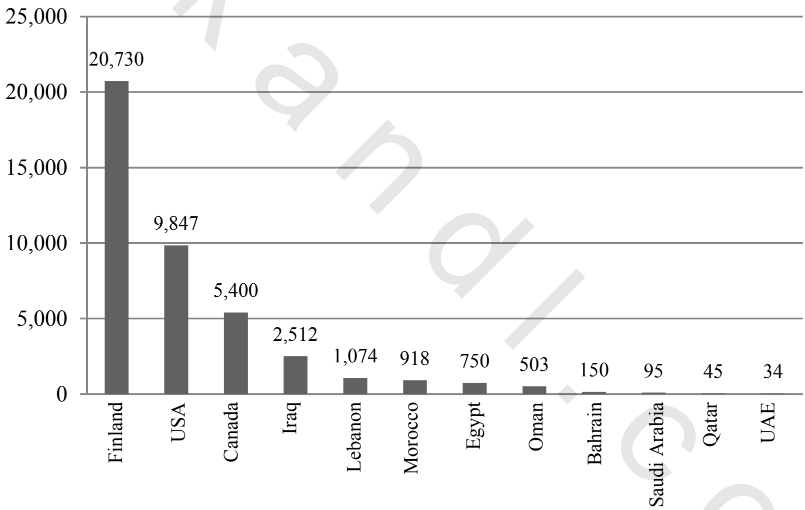
Source: UNESCO, *Water for People, Water for Life*, United Nations World Water Development Report, 2003 (Paris: UNESCO Publishing, 2003).

The UAE is located within an arid zone and has scant renewable water resources owing to poor rainfall and the absence of permanent flowing surface water sources such as rivers, freshwater lakes or flowing valleys. Total renewable water from natural sources in the UAE is estimated at 33 cubic meters per capita per year, according to a World Bank regional report on development in the Middle East and North Africa in 2007[3] —a low quantity by international standards as shown in Figure 9.2.

The UAE falls well below the water poverty line (1,000 cubic meters per capita per year), although some researchers believe that, in arid zones, renewable water resources from non-natural sources such as desalinated water or treated wastewater, should be included. Nonetheless, this would only raise the figure to 320 cubic meters per capita per year. This lack of renewable water presents a host of challenges for the government, which must provide the fresh water needed for rapid economic and social development, whilst at the same time ensuring environmental protection, public health and food security.

Figure 9.2

Comparative Renewable Water Resources from Natural Sources in the UAE (m^3 per Capita per Year)



Source: UNDP, *Human Development Report 2006* (New York: UN, 2006).

Conventional Water Resources in the UAE

Surface Water (Rain, *Wadis* and Dams)

When rain falls over the UAE, especially in mountainous areas, some of the rain water accumulates on the surface, after which it begins moving down the slopes through minute channels, quickly accumulating in larger channels or *wadis* that snake towards main drainage basins. The *wadis* are dry river beds which contain water only during heavy rainfall when there is surface runoff. When water does flow into them it can cause flash floods, particularly following short rain storms in mountainous areas of the northern and eastern parts of the UAE.

Measurements carried out by the UAE Ministry of Agriculture and Fisheries in 1993, and the Ministry of Environment and Water in 2005, show that the Western Region of Abu Dhabi is characterized by severe drought and an absence of floods. This is due to the scarcity of annual rainfall (40 millimeters), a high rate of evaporation (3,360 millimeters per year), an absence of vegetation and the highly permeable and porous sand dunes that cover most of the surface of the area. In the north, topographical maps and aerial and satellite images show 70 dry drainage basins in the northern Al-Hajar mountain range and the Musandam Peninsula, including 58 basins within the UAE. These valley basins range in size between five square kilometers (like Fujairah's Wadi Dhadnah) and 475 square kilometers (such as Wadi Bih in Ras Al-Khaimah). Some large valley basins witness more than one flash flood per year, while others may not experience flooding for many years. The annual flood water contribution to water resources of the UAE, as estimated by the Ministry of Environment and Water in 2009, ranges from 23 to 138 million cubic meters [mcm] (see Table 9.1). These quantities of water are not insignificant, and contribute to replenishing groundwater and improving its quality.

Some *wadis* run across the border between Oman and the UAE, passing through a dozen catchment areas, and the average total annual flow of these *wadis* is approximately 7.6 mcm per year. Sometimes the trans-border flow is huge and may lead to damaging floods. The estimated replenishment of groundwater aquifers is about 30.9 mcm per year. Usually, rainfall occurs in the months of January, February and March, and there is a cycle of above average rainstorm frequency, every 3–4 years.

Studies have shown that the lowest rates of rainfall to cause runoff was 75 millimeters per year on the mountains of Oman and 90 millimeters per year on Jebel Hafeet in Al-Ain, UAE, during the period 1981–1992.[4]

Table 9.1

Estimates of Surface Runoff in the UAE

Name of Water Basin	**Area (km²)**	**Average Annual Rainfall (mm)**	**Surface Runoff, million cubic meters (mcm)**	
			3% Rate of Rainfall	**18% Rate of Rainfall**
Mai	61	130	0.24	1.42
Ghalilah	76	136	0.31	1.86
Mada	95	130	0.37	2.22
Zikt	100	148	0.44	2.66
Naqab	107	137	0.44	2.63
Al-Wurayah	137	145	0.60	3.58
Hatta	164	145	0.71	4.28
Wahala	195	121	0.71	4.25
Al-Makassar	214	140	0.90	5.39
Ham	291	140	1.22	7.33
Al-Qor	340	150	1.53	9.18
Al-Bih	476	121	1.72	10.35
Al-Toyen	503	133	2.01	12.04
Lamha	1,236	125	4.64	27.81
Qada'a	1,362	120	4.90	29.42
Other basins in the UAE			2.26	13.59
Total basins in the UAE			**23**	**138**

Source: UAE Ministry of Environment and Water, "United Arab Emirates Water Conservation Strategy," UAE, 2010.

However, a significant rain storm (e.g., 30 millimeters) would be more than enough to create surface runoff in any *wadi* catchment area. The results of studies carried out on the UAE's *wadis* illustrate that the highest risk of flooding occurs in the Shik, Sidr and Al-Ain Al-Fayda *wadis*, and that the lowest risk of flooding is in Al-Khokeirah and Al-Mreikhat. The average annual depth of surface runoff during the study period ranged between five and twenty millimeters, and the proportion of the rain that formed this runoff was, on average, seven percent—between three percent (*wadi* Jebel Hafeet) and eighteen percent (the *wadis* of the Omani Hajar).[5]

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Projects to construct dams at the exits of the *wadis* in order to capture and store surface runoff in the *wadis* have attracted great attention in the UAE recently due to their potential importance to groundwater replenishment, compensation for limited supply, and prevention of rainwater loss. These projects capture rain and flood water falling on the mountains and highlands that would otherwise flow quickly towards the low-lying areas and the coast, destroying farms and washing away the surface layer of agricultural soil, leading to a deterioration in soil fertility.

The UAE government has already constructed several dams, the most important of which: Al-Shuwaib Dam in Al-Ain City, Rashid Dam on the outskirts of Hatta, in addition to five other large dams at Wadi Ham, Wadi Bih, Wadi Izin, Wadi Gema and Wadi Al-Ghail. Also, 23 other locations were selected for study and the construction of dams: Wadi Qada'ah, Wadi Al-Qor, Al-Fara', Wadi Hefna, Wadi Al-Toyen, Wadi Wahla, Wadi Safta, Wadi Al-Wurayah, Wadi Al-Baseer, and Wadi Al-Naqab (Al-Hbous), Wadi Siji, Wadi Zikt, Wadi Al-Mawrid, Wadi Ghalilah, Wadi Al-Ferfar, Wadi Al-Motarid, Wadi Shawkah, Wadi Ashwani (Kadar), Wadi Hazf, Wadi Shaam, Wadi Ramth, Wadi Safad (Al-Qariyah) and Wadi Shaba. The storage capacity of the catchment dam depends on many factors, most importantly the drainage basin area—the more drainage basin area the more dam's ability to store water. Water harvesting rates by dams is attributed in the first place to rainfalls—the volume of the water harvest rises with the increased rainfall.

The Ministry of Environment and Water cares for dams and their maintenance. A big number of dams were built to store large quantities of rainwater. The specialized department of the late Sheikh Zayed bin Sultan Al Nahyan has constructed about 57 dams and a water barrier in the Northern Emirates in three phases consisting of 28, 27, and 2 dams. The total number of dams in the state is about 114 dams, with storage capacity estimated at 118 mcm. Moreover, in terms of infrastructure development, the UAE intends to construct about 70 new dams in the eastern and northern regions, with the aim of enhancing groundwater storage and building an integrated system of infrastructure for the development of water resources in the country to counter environmental and water challenges. The dam projects aim to achieve the following objectives:[6]

- Replenishing aquifers with the surface runoff.
- Raising groundwater levels and improving its quality.
- Stopping the inland intrusion of the seawater, and reducing the impact of seawater pollution of coastal aquifers.
- Providing a source of surface water for agriculture and drinking and for the purpose of development.
- Providing protection against floods and minimizing their impacts.
- Maintaining agricultural soil and preventing flood-related erosion.
- Using sediment accumulated behind dams to improve agricultural soil.
- Serving the environmental, climate and tourism.

The levels of groundwater replenished by dam sites are monitored through observation wells used by the Ministry of Environment and Water to monitor levels in different areas. Observation wells contribute to determining groundwater levels and readings are taken monthly, using electronic devices, and stored in the Ministry's database. This enables the efficient and rapid collection of accurate information.

Since their construction, the dams have played a significant role in reducing the risks of flash floods and protecting homes, roads and farms. Their beneficial role in feeding groundwater is clear from the low concentration of total dissolved salts in groundwater, as well as the high water levels in observation wells established specifically for this purpose. It is also clear from radioactive isotope studies analyzing samples of water from the dam sites.[7]

The total storage capacity of the dams in the UAE is about 118 mcm. The results and data of the studies carried out by the UAE Ministry of Environment and Water point out that the largest nine dams in the state stored about 178 mcm of water in the period 1982–2000. This amount increased to about 211 mcm in 2007, as shown in Table 9.2.[8] Constructing and maintaining dams involves high capital investment costs, which are met by the state as a result of the UAE government's belief in the importance of such projects. Table 9.3 illustrates the magnitude of government investment in the construction of dams in the period 2001–2004.

Table 9.2
Dams in the UAE

Dam	Location	Dam Type	Date built	Height (m)	Length (m)	Lake Capacity (m^3)	Stored Water until 2007 (m^3)	Area Benefited
Ham	Fujairah	Cumulus	1982	16	2800	7,700,000	27,500,000	Fujairah/Kalba
Al-Bih	Ras Al-Khaimah	Cumulus	1982	18	220	7,500,000	44,567,000	Al-Breirat/Al-Nakheel
Gulfa	Ajman	Concrete	1984	8	235	250,000	4,505,000	Mzeirea/Masfout
Izin	Ras Al-Khaimah	Cumulus	1982	10	110	500,000	9,713,000	Izin/Al-Hamraniyah
Al-Ghail	Ras Al-Khaimah	Concrete	1982	4.5	26	15,000	206,200	Al-Ghail
Hazf	Ajman	Cumulus	1991	11	850	3,000,000	7,660	Mzeirea/Masfout
Al-Owais	Fujairah	Cumulus	1991	18	230	3,500,000	17,000	Dhadnah
Al-Toyen	Fujairah	Cumulus	1992	23.5	342	18,500,000	34,750	Al-Toyen & Al-Hamraniyah
Al-Wurayah	Fujairah	Cumulus	1997	33	367	5,200,000	900	Al-Bidiyah/Khor Fakkan
Al-Basirah	Fujairah	Cumulus	1999	8	885	1,600,000	3,450,000	Diba

Source: Mohammed A. Dawoud, *Water Sources and their Importance in the UAE* (Abu Dhabi: Sultan Bin Zayed's Culture and Media Centre, 2011).

Table 9.3
Capital Cost for the Construction of Dams in the UAE (2001–2004)

Year	Dam Set	No. of Dams	Storage Capacity (mcm)	Cost	
				AED Million	$ Million
2001	Zayed, phase 1	27	5.9	210	57
2002	Zayed, phase 2	28	7.1	320	87
2003	Zayed, phase 3	2	0.4	28	7.6
2004	Zayed, phase 4	1	0.1	6	1.6
Total				**564**	**153.2**
Average storage cost per cubic meter of rainwater				**42**	**11**

Source: Ministry of Environment and Water, op. cit.

The Ministry of Environment and Water is currently planning to build a further 68 new dams to collect flood water, bringing the number of total dams in the state to 182. This program will contribute to increasing the availability of fresh surface water supplies and the rates of aquifer replenishment, improving their quality and reducing the deterioration of their resources. Investment costs for the construction of these dams are expected to be roughly AED228 million, as estimated by the Ministry and illustrated in Table 9.4.

Table 9.4
Projected Capital Costs for the Construction of New Dams

Year	Dam Type	No. of Dams	Storage Capacity (mcm)	Cost	
				AED Million	$ Million
2012–2013	Concrete	15	0.31	51	14
2012–2013	Cumulus	36	2.28	163	44
2012–2013	Rock	3	0.21	14	4
Total				**228**	**61**

Source: Ministry of Environment and Water, op. cit.

Groundwater

Groundwater is the main source of – and the only natural – water used in the UAE, despite the over-exploitation of some aquifers, and the degradation of their water quality. There are many aquifers in the UAE; both shallow and deep.

Shallow Aquifers

Shallow aquifers are the most common in terms of productivity. They consist of newly formed sand, sediments and sandstones eroded as a result of the wind and other factors (weathering) occurring in different eras, but most notably the (present) Quaternary period. Water-bearing layers constituting shallow aquifers in the Emirate of Abu Dhabi include: Quaternary aquifers directly underlain by the Lower Fars formation; Quaternary sands and gravel directly underlain by Upper Fars formations; coastal and inland marshes (*sabkhas*); and Quaternary sand and gravel directly underlain by both Lower and Upper Fars formations (Jebel Hafeet area). In the Northern Emirates there are a number of other water-bearing formations constituting shallow aquifers, including: sandstone aquifers; natural cumulus aquifers; coastal and inland *sabkhas*; and alluvial aquifers.

Deep Aquifers

Deep aquifers consist of cracked limestone bedrocks, volcanic rocks (ophiolitic) and carbonate rocks. The carbonate rock layers are formed at great depths. They have been neither widely discovered nor exploited. Among the most important deep aquifers in the UAE are: the Al-Juwaiza aquifer, a volcanic rock aquifer (ophiolitic), and cracked limestone bedrocks all in the northern emirates; limestone bedrocks to the south of Al-Ain City and the Simsima aquifer, both in Abu Dhabi; and a cracked alluvial aquifer in Fujairah.

The productivity, volume and quality of groundwater from an aquifer depends on its location, the depth of its water-bearing formations, the various characteristics of each aquifer and the size of the aquifer, as shown in Table 9.5.[9] These aquifers are divided into two types according to their replenishment rates.

First are non-renewable aquifers, replenished over the course of thousands of years. This water accumulated during the formation of rock layers in previous ages. Geological studies indicate that there are important events that replenished these aquifers—between 32000 and 26000 BC as well as in the period between 9000 and 6000 BC.

Second are renewable aquifers recharged by dams and rainfall in *wadis*. Some studies conducted by the Ministry of Environment and Water and the Environment Agency–Abu Dhabi estimate that these aquifers' annual recharge rates range between 140 and 190 mcm of water annually.[10]

There are large amounts of groundwater in various aquifers in the UAE, totaling around 675 bcm, of which fresh water constitutes no more than 25 bcm (about three percent) as shown in Figure 9.3. The estimated volume of shallow aquifers is about 470 bcm. However, Table (9-6) shows the estimates of total underground water storage by quality in the UAE.

Table 9.5
Aquifer Types, Productivity and Quality of Water in the UAE

Aquifer Depth	Aquifer Type	Emirate/Region	Type of Water	Productivity
Shallow aquifers	Sand	Northern emirates	Fresh	Medium–High
	Natural cumulus	Northern emirates	Medium brackish	Low–High
		Abu Dhabi	Medium brackish	Medium
	Sabkha	Northern emirates	High brackish	Medium
		Abu Dhabi	High brackish	Medium
	Alluvial	Northern emirates	Medium brackish	Medium
	Al-Juwaiza	Northern emirates	Medium brackish	Low
	Ophiolitic	Northern emirates	Medium brackish	Low
	Cracked limestone	Northern emirates	Fresh	High
Deep Aquifers	Limestone	Abu Dhabi	Medium–High brackish	Medium
	Cracked alluvial	Fujairah	Medium brackish	Low
	Simsima	Abu Dhabi	Medium brackish	Low

Source: Ministry of Environment and Water, op. cit.; and the Environment Agency–Abu Dhabi (EAD), "Statistical Bulletin of Water Resources in the Emirate of Abu Dhabi," Abu Dhabi, 2010.

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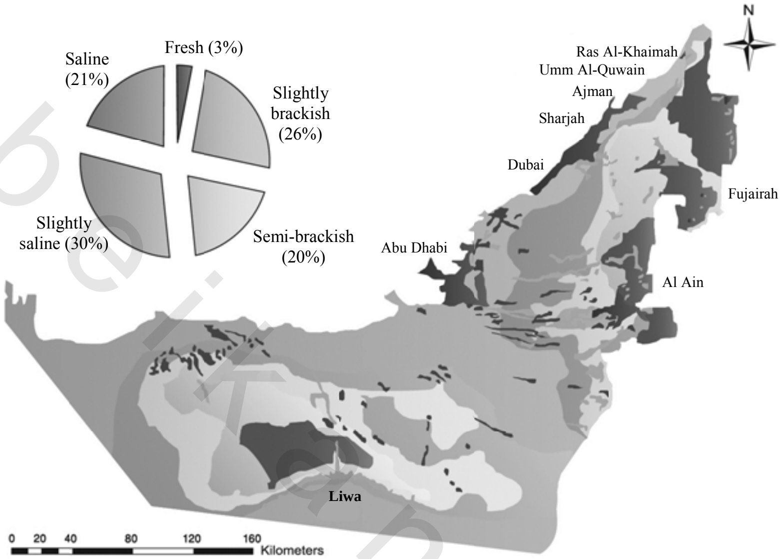
Figure 9.3
Underground Water Storage and Quality in the UAE



Source: Ministry of Environment and Water, op. cit.

According to recent data,[11] and at current abstraction rates, fresh and brackish groundwater resources will be depleted in around 50 years' time. When it comes to those reserves found in shallow aquifers, this is an absolute certainty. Therefore, it is necessary to ensure that this vital resource is appropriately and sustainably managed. Nowhere is this more important than in the areas of agriculture and the 'greening' of public spaces. These two areas represent the greatest two consumers of groundwater in the UAE. Therefore, national policies to manage and develop water resources in an integrated manner must be developed in order to ensure the sustainability of these vital resources.[12]

Table 9.6

Estimates of Total Underground Water Storage and Quality in the UAE

Water Quality	**Underground Storage (BCM)**							
	Abu Dhabi	**Dubai**	**Sharjah**	**Ajman**	**Umm Al-Quwain**	**Ras Al-Khaimah**	**Fujairah**	**Total**
Fresh <1,500 mg/l	18.5	0.03	0.53	0	0.03	0.55	0.26	20
Slightly brackish 1,500–5,000 mg/l	188	0.54	0.46	0	0.12	0.92	0.15	190
Medium brackish 5–10,000 mg/l	147	0.50	0.05	0.01	0.1	0.19	0.04	148
Slightly saline 10,000–15,000 mg/l	114	0.40	0.02	0.05	0.06	0.01	0.01	115
Saline 15,000–20,000 mg/l	56	0.05	0.04	0.01	0.03	0.01	0.01	56
Medium saline 20,000–25,000 mg/l	54	0.05	0.05	0.01	0.34	0	0.01	54
Strongly saline 25,000–40,000 mg/l	67	0.04	0.03	0.06	0.02	0.01	0	67
Brine >40,000 mg/l	90	0.4	0.03	0.02	0.4	0.01	0	90
Total	**735**	**1.65**	**1.26**	**0.16**	**0.41**	**1.7**	**0.5**	**740**

Source: Ministry of Environment and Water, op. cit.

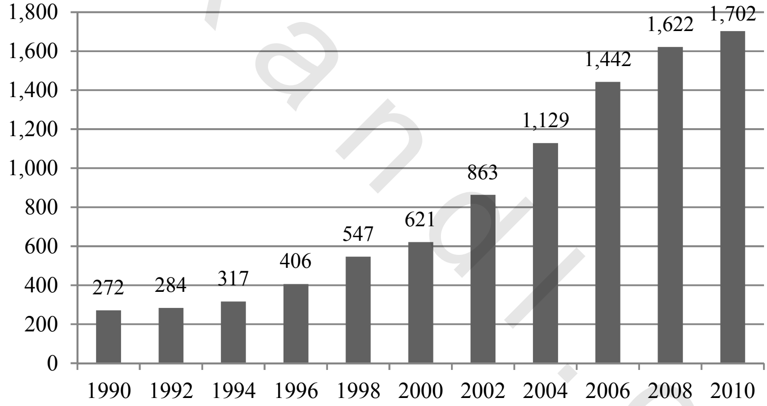
Non-conventional Water Resources

Seawater Desalination

With the deterioration of groundwater quality and the inability to meet the demand for high-quality water resources in various sectors – particularly the residential sector – the UAE government has invested in the desalination industry as a strategic option for the provision of fresh water. The desalination sector in the UAE has therefore become an important sector, significantly contributing to the development of the country.

Seawater desalination is, moreover, the primary source of fresh water in the UAE. Large desalination plants are located on the coasts of the Arabian Gulf and the Gulf of Oman. They are mostly thermal co-generation plants for the simultaneous production of electricity and water. There are some other plants located inland and operating using membrane technology (reverse osmosis). They are of low capacity and working on the production of fresh water that is often used for agricultural purposes, labor camps or industrial or oil activities in remote areas. The availability of energy, and transportation costs, are the two factors that will determine levels of desalination in the future.

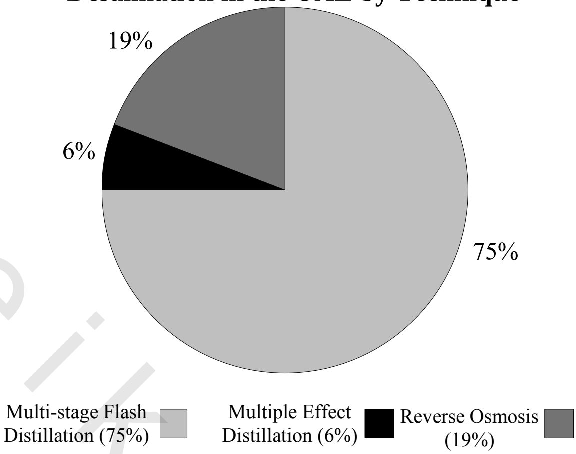
Figure 9.4
Development of Desalinated Water Production in the UAE, 1990–2010 (mcm/yr)



Source: Prepared by the researcher.

The first seawater desalination plant in Abu Dhabi began operation in 1960 – with a production capacity about 12,500 gallons per day. It was a multi-stage flash distillation (MSF) plant. The plant was shut down after a pipeline from Al-Ain city was extended to supply Abu Dhabi with groundwater. A second desalination plant was established in 1968 with a production capacity of 25,000. This was followed by three large plants with combined capacity of about two million imperial gallons per day (MIGD) in 1970.[13]

Figure 9.5
Desalination in the UAE by Technique



Source: Ministry of Environment and Water, op. cit.

Desalination capacity in the UAE has grown three-fold since 2000, due to increasing demand (Figure 9.4). The current capacity of the UAE's plants is about 1,700 mcm per year (Table 9.7), which ranks the UAE second in the world in terms of production, after Saudi Arabia. There are currently about 70 desalination plants in the UAE using thermal distillation and membranes. Thermal distillation technology includes multi-stage flash (MSF) and multiple effect distillation (MED), which are considered the most commonly used techniques due to their efficiency and the fact that they can be used in conjunction with power generation at the same plants. Use of membranes, however, is limited to the use of reverse osmosis (RO), as in Figure 9.5.

These techniques vary in terms of the volume of water needed to produce one cubic meter of desalinated water, as illustrated in Table 9.8. Water desalination using MSFis coupled with power generation to take advantage of the steam resulting from the distillation process, thereby increasing the efficiency of these plants and reducing costs. This technique is effective and reliable. Furthermore, it contributes to reducing capital costs. RO technology, in turn, is also important, as it contributes to the production of about 20 percent of the water in the UAE. It is expected that water produced using this technique will increase in the future, owing to the low cost of membranes, improved performance and low energy consumption.[14]

Table 9.7
Desalination in the UAE by Technique

Emirate	Plant Name	Production (1,000 m^3/day)	Technique	Production (mcm/yr)
Abu Dhabi	Old Al-Tuwaila-A1	146	MSF	118.3
	New Al-Tuwaila-A1	240	MED	58.9
	Al-Tuwaila-A2	232	MSF	77.7
	Al-Tuwaila-B1	318	MSF	107.4
	Al-Tuwaila-B2	105	MSF	25.0
	Al-Tuwaila extension-B2	314	MSF	0
	Umm Al-Nar East-A	86	MSF	0
	Umm Al-Nar East-B	105	MSF	26.4
	Umm Al-Nar West-1-6	109	MSF	31.1
	Umm Al-Nar West-7-8	105	MSF	4.3
	Umm Al-Nar West-9-10	32	MED	0
	Umm Al-Nar West-B	286	MSF	0
	Sas Al-Nakheel	95	MSF	137.5
	Al-Mahatta	68	MSF	0
	Al-Mirfa	104	MSF	47.9
	Al-Shuwaihat-1	459	MSF	150.0
	Qidfa', Fujairah	450	MSF/RO	132.5
Dubai	Jebel Ali-D	159	MSF	58
	Jebel Ali-E	114	MSF	42
	Jebel Ali-G	286	MSF	104
	Jebel Ali-K	273	MSF	100
	Jebel Ali-L	318	MSF	116
	Jebel Ali-M	477	MSF	174
	Jebel Ali	114	RO	42
Sharjah	Al-Layyah-1	147.7	MED	82
	Al-Layyah-2	81.8	RO	0
	Al-Saj'ah	28	RO	8.9
	Kalba-1	4.8	MED	1.68
	Kalba-2	9.1	RO	5.76
	Abu Musa Island	14.8	MED	0
	Al-Zubair	0.91	RO	1.29
	Sir Bu Nair	0.4	RO	0.2
Ras Al-Khaimah	Al-Breirat	5.5	RO	2
	Al-Hamraniyah	0.7	RO	0.25
	Rafaq	0.34	RO	0.12
	Ghalilah	13.6	RO	3.56
	Al-Nakheel	72.7	MED	23.7
Ajman		70.35	MED/RO	23.58
Fujairah	Qidfa'	18.18	MSF/RO	3.09
Total				**1,709**

Source: Mohamed Dawoud, "Future Growth in the Desalination Industry in Middle East Region," in D. Delgado and P. Moreno, *Desalination Research Progress* (New York: Nova Science Publishers, 2008), pp. 161–186.

Table 9.8

Comparison between Desalination Techniques Used in the UAE

Comparison	Thermal Techniques		Membrane Techniques (RO)	
	MSF	MED	Saline Water	Brackish Water
Brackish water needed to produce one cubic meter of fresh water (m^3)	10	7	2.5	1.5
Amount of high saline water (m^3)	3	2	1.5	0.5
Energy consumption (million joules/m^3)	186	162	24	29

Source: Environment Agency–Abu Dhabi, "Water Resources Management Strategy and Action Plans for the Emirate of Abu Dhabi," Abu Dhabi, 2010.

Sources of Energy Currently Used in Desalination

Desalination plants require large amounts of energy; in the form of heat to produce steam in the case of thermal plants, while RO plants depend on electricity for the production processes. Thermal plants require temperatures of 70–130°C, and consume between 25–200 kWh per cubic meter of water. RO plants, on the other hand, require 4–6 kWh per cubic meter of water when seawater is used (depending on the salinity of water). Brackish water desalination and wastewater treatment by reverse osmosis require only about 1 kWh per cubic meter. Currently, the energy required for co-generation in Abu Dhabi is satisfied by natural gas—either from the natural gas supply network of the emirate, or from the pipelines of the Dolphin Gas Project, which imports gas from Qatar. As for the Fujairah-1 plant, it operates on natural gas supplied from Oman—the completion of the Dolphin pipelines to Oman will ensure an increase in natural gas supplies to the plant. Since 2006, shortages in the supply of natural gas to these plants led to the supplementary use of fuel and oil. It is expected that demand for energy in the desalination sector will increase in line with the growing demand for fresh water in the UAE.

Potential Future Sources of Energy for Desalination

Electricity and water production plants consume vast quantities of oil and gas. This cannot continue indefinitely, owing to diminishing reserves and high oil prices. Therefore, it has become necessary to consider the viability of sustainable alternative energy sources.

Researchers have discussed several possibilities for alternative energy sources to supply current plants. However, alternatives bring their own problems. For example, the use of coal to power desalination plants would lead to extensive pollution—although Abu Dhabi has high atmospheric pressure, so the spread of contaminants is limited. Of course, renewable energy provides an alternative that is much less destructive to the environment. The UAE has taken two major steps in the use of solar and nuclear energy.

- Solar energy:the Abu Dhabi government has established the Abu Dhabi Future Energy Company (ADFEC, also known as "Masdar") with the main objective of investing in renewable energy alternatives that can be used in power generation and water desalination. The two renewable energy sources available in Abu Dhabi are solar and wind power. Solar energy potential in the Gulf region can exceed 1 kilowatt per square meter, and is available almost all year round.

  Researchers outside Masdar have studied the use of solar energy in desalination; however, the current technology does not provide the capacity or the safety required in Abu Dhabi's case. The results of recent steps towards the use of large fields for solar energy generation in the UAE, as well as global developments in this field, should be monitored carefully. The emirate of Abu Dhabi has initiated a pilot project that aims to create around 30 small solar desalination units with a production capacity of five cubic meters per unit per hour, with the aim of developing this system in remote areas of Abu Dhabi where there is no other source of water.[15]

  The use of solar energy for desalination has many advantages: it has less of an impact on the environment and global warming due to the absence of emissions; operating costs are lower than other methods; the returns on capital costs are better in the long term than other sources;

and capital costs will fall over time due to the development of the solar cell industry, in addition to the possibility of using solar collection mirrors which will greatly increase the efficiency of such systems.

Among the current challenges facing solar desalination is the high (current) capital cost compared with traditional methods. However, there are better prospects for long-term cost recovery when compared to traditional energy types. The second challenge is land use; but the development of the solar cell industry is gradually reducing the area of land required. Also, while the current efficiency of solar cells does not exceed 18 percent, studies indicate that some companies have developed cells with an efficiency of up to 33 percent (which are expected to enter the market soon). The third challenge is the need to store energy for use at night—a very costly element in the establishment of such plants.

- Nuclear energy:the UAE took a clear decision to evaluate the possibility of developing nuclear energy in its "Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy," published in April 2008. This strategy envisages semi-reliance on nuclear energy starting in 2017. This will require strict policy decisions to protect the environment. Nuclear energy may represent the best economic alternative to fossil fuels in electricity generation and desalination. However, the use of nuclear energy – especially following the Fukushima disaster in 2011 – raises some safety concerns among researchers and the public. Other questions are raised concerning the high capital and operating costs of such plants; the potential radioactive impact on workers and the areas surrounding such plants; and arrangements for the disposal of nuclear wastes. Nevertheless, these concerns should not lead to the option being overlooked, as it might be the only option available.

  Reports released by the International Atomic Energy Agency (IAEA) have shown that the use of nuclear energy in desalination is less expensive than that conventional fuels. Furthermore, the success of linking desalination units with nuclear energy plants has been demonstrated—it was first used in Kazakhstan (the former Soviet Union), where a nuclear energy plant was used for 27 years for the production of electricity (135 MW) and desalination (with a capacity

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of 80,000 m^3 per day). There are also many other countries that have recently begun using nuclear energy in desalination.[16] In Japan, 10 desalination plants were linked to nuclear power plants using pressurized light water reactors, each with a capacity of 1,000–3,000 m^3 per day. In this example, MSF units were initially used, which were later replaced with RO and MED units.

In India, two pressurized heavy water nuclear plants were built with a capacity of 170 MW_e each. They were linked to a pilot RO desalination plant with a capacity of 1,800 m^3 per day, and to a MSF plant with a capacity of 4,500 m^3 per day.

Similar projects are in their early stages in the Middle East; for example, Iran has designed a desalination plant with a capacity of 200,000 m^3 per day to be linked to the Bushehr reactor; Libya signed an agreement with France to build a nuclear desalination plant; and Qatar is seriously considering the construction of a nuclear power plant linked to a desalination plant with capacity of 1.3 mcm per day. Table 9.9 details selected projects linking desalination plants to nuclear power plants, as well as the desalination techniques used.

Table 9.9
Present and Proposed Nuclear Desalination Plants

Type of Reactor	Country	Desalination Technique	Status
Liquid metal fast reactor	Kazakhstan	MED, MSF	completed
Pressurized light-water reactor	Japan	MED, MSF, RO	completed
	Korea, Argentina	MED, RO	design phase
	Russia	MED, RO	design phase
Pressurized heavy-water reactor	India	MSF, RO	Delivery phase
	Canada	RO	design phase
	Pakistan	MED	under construction
Boiling light-water reactor	Japan	MSF	completed
Very high temperature reactor	South Africa	MED, MSF, RO	design phase
	China	MED	design phase

Source: Mohamed Darwish, Fatimah M. Al-Awadhi and Anwar O. Bin Amer, "Electricity Generation and Seawater Desalination Using Nuclear Energy in the State of Kuwait and the Gulf Countries" (Kuwait Foundation for the Advancement of Sciences, 2009).

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Environmental Impacts of Desalination Plants

Like any other industry, desalination has some negative effects on the environment. Therefore, necessary precautions must be taken to mitigate these effects. Desalination plants contribute to global warming via their heavy consumption of fossil fuels, and resultant emissions. At present there is no accurate data concerning the amount of greenhouse gases (GHGs) associated with desalination in the UAE. The Abu Dhabi Water and Electricity Authority (ADWEA) estimated in 2006 that the total volume of GHGs emitted by desalination and power generation plants in the emirate of Abu Dhabi was about 13.5 million tons per year—of which approximately 99.5 percent was carbon dioxide. The government has made great efforts in order to make these emissions conform to international standards by increasing the efficiency of desalination plants and the use of natural gas to fuel such plants.[17] Moreover, the discharge of highly saline water into surrounding waters leads to negative physical, chemical and biological effects on the bio-marine environment.

Economic Aspects of Desalination

Desalination is expensive in terms of capital, operating and maintenance costs, as well as indirect costs such as the harmful impact on the environment, the consequences of the greenhouse effect, and the impact on marine organisms.

Table 9.10

Capital Costs and Energy Required to Produce One Cubic Meter of Desalinated Water

Element	Desalination Technique		
	RO	MED	MSF
Operating temperature (° C)	< 45	<70	<120
Average energy consumption (kWh /m³)	6	11	21
The cost of energy to produce a cubic meter ($/m³)	0.57	1.04	1.97
Capital cost ($/m³)	750	850	900

Source: Darwish, Al-Awadhi and Bin Amer, "Electricity Generation and Seawater Desalination Using Nuclear Energy in the State of Kuwait and the Gulf Countries," op. cit.

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Desalination costs are affected by many factors, including: the type of technique used; the production capacity of the plant; the nature of the water supply to the plant (temperature and salinity); geographic location; availability of raw materials; labor costs, etc. Moreover, the cost of the fuel used to operate these stations is one of the most important operational costs, as illustrated in Table 9.10. The table indicates that the cost of producing one cubic meter of desalinated water in the UAE is approximately AED 7.

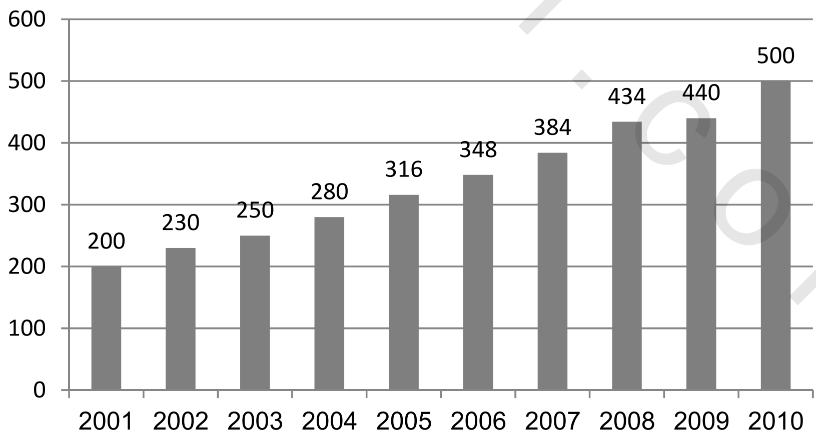
Treated Wastewater

Treated wastewater is a valuable and important resource in countries suffering from water scarcity—especially now that modern treatment systems are capable of producing safe drinking water in accordance with World Health Organization (WHO) criteria. This water can therefore be used directly or to recharge aquifers.

The UAE government has therefore exerted substantial effort in developing the treatment and reuse of wastewater. Since 1973, wastewater collected from a network of cities and residential areas in the UAE has been treated, and over this time the capacity of wastewater treatment plants in the UAE has greatly developed, as shown in Figure 9.6.

Figure 9.6

Treated Wastewater Production in the UAE (mcm), 2001–2010



Source: Ministry of Environment and Water, op. cit.

Today there are more than 60 treatment plants of various sizes in the UAE—32 stations in Abu Dhabi, 4 in Dubai, and 18 in the emirate of Sharjah, with the remainder distributed among the other emirates. Wastewater is collected from a network comprising about 10,000 kilometers of sewers. The total amount of treated wastewater in the state reached about 500 mcm/yr in 2010. Production of treated wastewater is expected to increase to reach 1,200 mcm by 2030—providing that the population continues to increase at the current rate. Table 9.11 shows projected treated wastewater production in the UAE (2010–2030) based on the assumptions that residential and government sectors will represent the main source of wastewater, that industrial wastewater will be treated within the industrial zone of production, and that the average per capita production of wastewater will be 200 liters per capita per day.

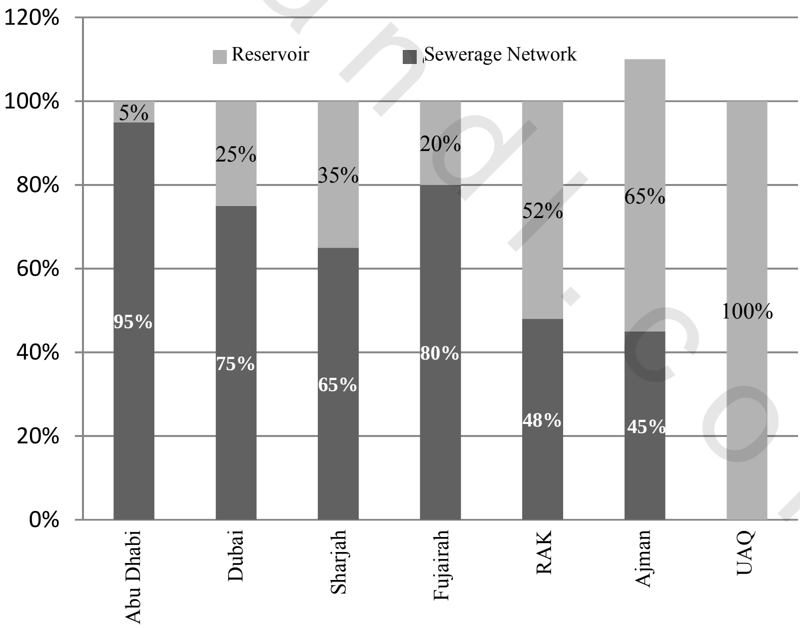
Table 9.11
Projected Production of Treated Wastewater in the UAE (mcm)

Emirate	Indicator	2010	2015	2020	2025	2030
Abu Dhabi	Population	1,664,950	1,996,595	2,394,328	2,871,293	3,443,271
	Quantity of wastewater	119	143	171	205	246
Dubai	Population	1,847,925	2,681,438	3,890,908	5,645,915	8,192,522
	Quantity of wastewater	132	191	277	403	584
Sharjah	Population	1,093,567	1,564,852	2,239,242	3,204,269	4,585,185
	Quantity of wastewater	78	112	160	228	327
Ajman	Population	264,229	347,963	458,233	603,447	794,675
	Quantity of wastewater	19	25	33	43	57
Fujairah	Population	160,350	208,340	270,755	351,850	457,256
	Quantity of wastewater	11	15	19	25	33
Ras Al-Khaimah	Population	248,067	298,488	359,210	320,210	520,125
	Quantity of wastewater	18	21	26	31	37
Umm Al-Quwain	Population	58,460	71,166	86,584	105,530	128,165
	Quantity of wastewater	4	5	6	8	9
UAE	**Population**	**5,440,744**	**7,516,186**	**10,412,112**	**14,462,088**	**20,138,280**
	Quantity of wastewater	**503**	**625**	**779**	**973**	**1,218**

Source: Ministry of Environment and Water, op. cit.

The UAE has achieved great progress in recent years in developing its wastewater collection and treatment system—by extending sewer networks and building assembly reservoirs. In some areas, assembly reservoirs are used (as shown in Figure 9.7). Advanced systems are used up to the third (tertiary) stage of treatment, which allows the reuse of water resulting from the treatment process on a wide scale, especially in landscape irrigation. The UAE constructed its first treatment plant (activated sludge) in 1973 to serve 30,000 inhabitants in Abu Dhabi, with an approximate capacity of 6,810 m^3 per day. Today, the total number of wastewater treatment plants exceeds 40, producing about 500 mcm of treated water. Total production is expected to eventually exceed 1.2 bcm per year.

Figure 9.7
Sewerage Network Services Coverage in the UAE



Source: Prepared by the researcher.

Most plants in the UAE use advanced treatment techniques, resulting in a high quality water.[18] Most of this water – up to 60 per cent of the total treated wastewater – is used to irrigate gardens, parks and some plantations or recreational areas. The rest is discharged into the Arabian Gulf or the desert. However, plans are being made to maximize the benefits of using this water, ensuring 100 percent utilization in the following areas:

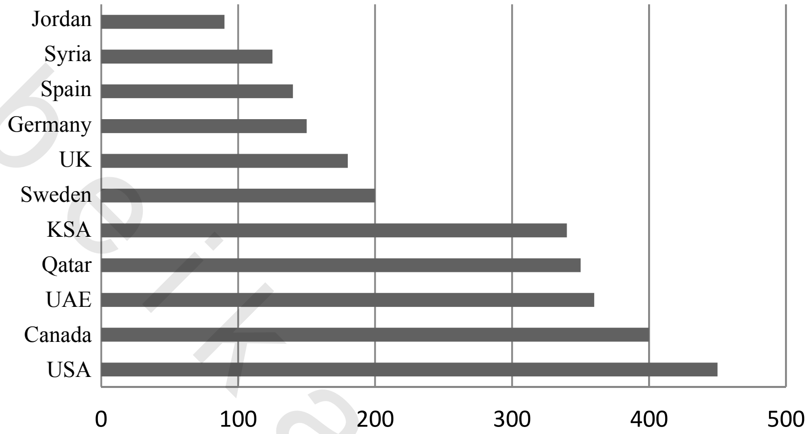
- Beautification: irrigating landscaped areas alongside main roads.
- Agriculture: to support food security—after making sure of the suitability and quality of water produced and its conformity with local and international standards.
- Central cooling: replacing large quantities of high-cost desalinated water currently used in the central cooling process.
- Recharging aquifers by exploiting the ability of the soil to further purify and treat water; then pumping this water and reusing it.[19] There is currently a project which aims to inject treated wastewater into Dubai's aquifer—this water would then be reused in irrigation.

Water Demand in the UAE

The average per capita daily consumption of water in the UAE is one of the highest in the world, as shown in Figure 9.8.[20] The UAE is the second largest producer of desalinated water globally, following Saudi Arabia. It uses most of its desalinated water to meet the demand for drinking water or urban consumption for domestic and industrial purposes. Part of it is also used to irrigate gardens in urban areas, agricultural areas as in Al Ain and some farms on the Dubai–Abu Dhabi border. Meanwhile, groundwater is used for agricultural irrigation, and reclaimed water is used in gardens and parks.

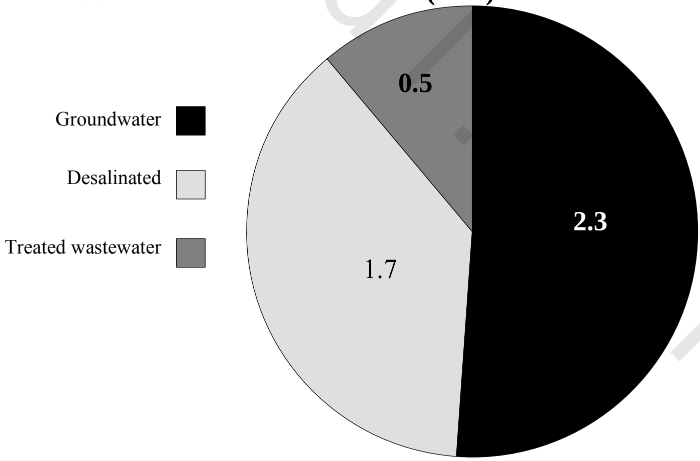
Total annual water consumption in the country is about 4.5 bcm, of which natural renewable and non-renewable (mainly groundwater) resources account for about 2.3 bcm or about 51 percent, comprising 150 mcm of renewable groundwater from both dams or rain runoff. Total non-natural renewable resources comprise 2.2 bcm, of which 1.7 bcm or 37 percent is desalinated water, and about 500 mcm or 12 percent is recycled sewage water (Figure 9.9).

Figure 9.8
Average Daily Per Capita Consumption of Water in the UAE vs. Other Countries (liters per capita per day)



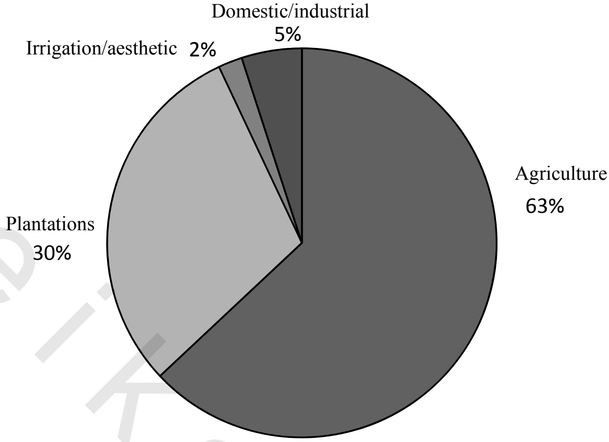
Source: Prepared by the researcher based on various sources.

Figure 9.9
Water Resources in the UAE (bcm)



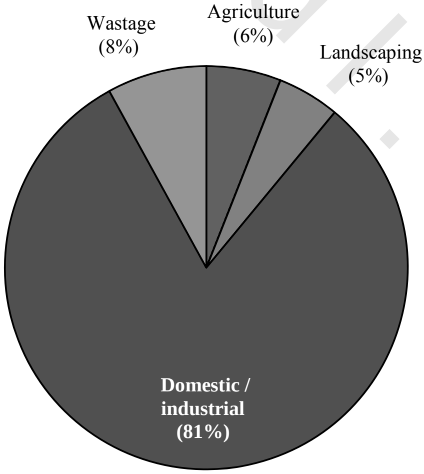
Source: Ministry of Environment and Water.

Figure 9.10
Usage of Groundwater by Sector



Source: Ministry of Environment and Water, op. cit.

Figure 9.11
Use of Desalinated Water by Sector



Source: Ministry of Environment and Water, op. cit.

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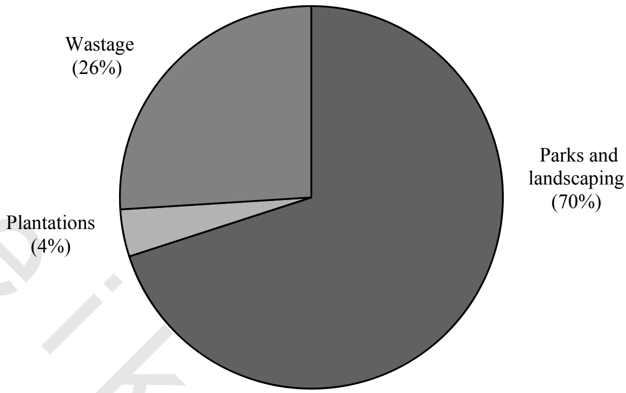
Figure 9.12
Use of Reclaimed Wastewater per Sector in Abu Dhabi



Source: Ministry of Environment and Water, op. cit.

Groundwater

Most groundwater is used for irrigation purposes, whether in the agricultural or plantation sectors or for civil horticulture. The agricultural sector consumes about 1.5 bcm (equivalent to 63 percent of total groundwater usage in the country). The plantation sector consumes about 690 mcm, (equivalent to 30 percent), while about 120 mcm (5 percent) of fresh and desalinated groundwater is used in domestic and industrial purposes, and about 50 mcm (two percent) for the irrigation of landscaping activities in urban areas, as shown in Figure 9.10.

Desalinated Water

Most desalinated water is used for drinking and domestic use, as well as in the industrial and commercial sectors. The total production of desalinated water is about 1.7 bcm, of which around 1.35 bcm is used in urban areas for domestic, industrial and commercial uses – including irrigation of home gardens – while about 90 mcm is used for agricultural purposes on farms, and 80 mcm for ornamental horticulture, gardens and parks. About 180 mcm is lost (leaked) though the distribution network (five percent) and distribution sub-network (18–20 percent). Figure 9.11 demonstrates the usage of desalinated water by sector.

Reclaimed Wastewater

Reclaimed wastewater production totals about 500 mcm, of which about 60 percent is used for decoration, gardens and parks. The Abu Dhabi government is currently conducting a study to reduce the amount of water being pumped into the environment, estimated at 350 thousand cubic meters per day, so that 100 percent of the reclaimed wastewater is utilized by the end of 2012. Figure 9.12 shows illustrates the use of reclaimed wastewater in Abu Dhabi.

Water Consumption by Sector

Agriculture

Irrigation is the largest source of water consumption in the UAE. It can be divided into three main areas: agriculture; plantations; and gardens, parks and roadside green belts. Currently the bulk of the demand for irrigation for agriculture and plantations is met by groundwater supplies, while the needs of gardens and parks are met through reclaimed wastewater, desalinated water, and occasionally groundwater.

The process of distributing water for irrigation purposes is expected to witness a change in terms of its sources and priorities as a result of the increasing demand from the non-agricultural sector, the growing population, and ongoing urban and industrial development. There is already an increase in the demand for water as a result of the expansion of the agricultural sector and the growing number of parks, gardens and artificial landscaping activities. The main objectives of agricultural irrigation are: food production and increasing self-sufficiency; the elimination of poverty; improving environmental conditions and systems; and protecting the environment and its natural resources.

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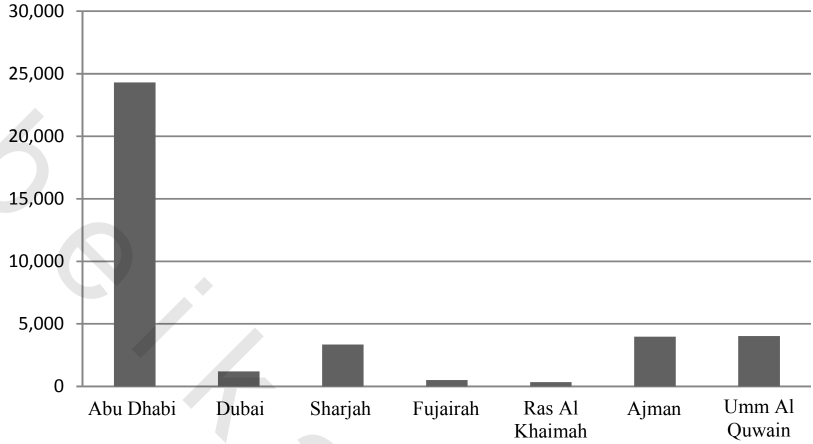
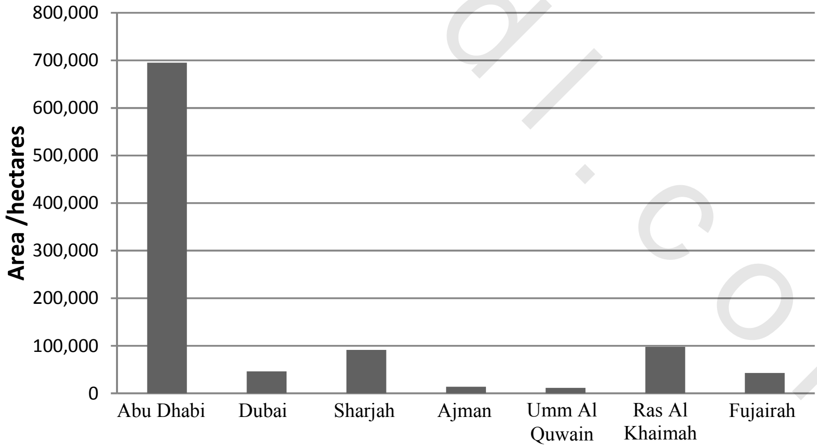
Figure 9.13
Number of Farms by Emirate



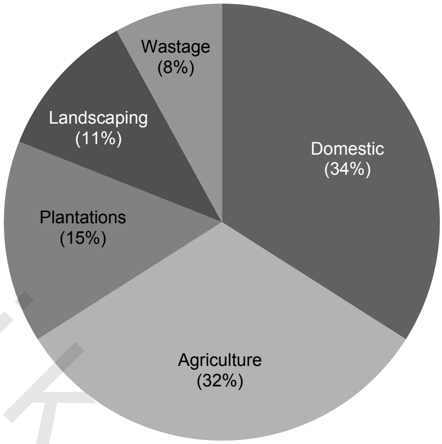
Source: Prepared by the researcher.

Figure 9.14
Farmed Area in the UAE by Emirate



Source: Ministry of Environment and Water, op. cit.

Figure 9.15
Water Consumption Rates by Sector



Source: Ministry of Environment and Water, op. cit.

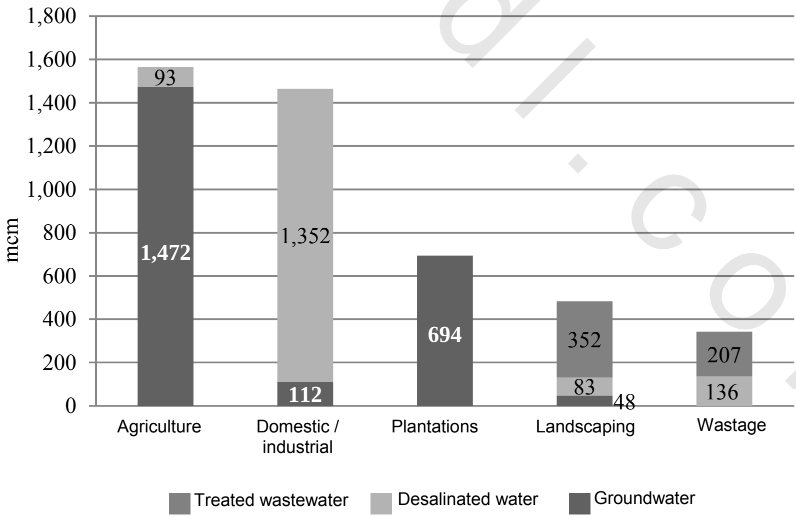
The culture and heritage of the UAE are linked to its land and water. The country has a long tradition of agriculture in the oases, where some crops have been grown for 5,000 years. Following the establishment of the UAE in 1971, the government sought to support small traditional farms and extend them by thousands of hectares using groundwater. As a result the number of farms in the country has reached 37,710, spread over the different emirates, in Abu Dhabi alone there are around 24,300 farms, as shown in Figure 9.13, with a total cultivated area of around 800 hectares, as shown in Figure 9.14, according to 2010 statistics.

The agricultural sector is the largest consumer of water in the country, accounting for 1.56 bcm or 34 percent of total water resources. About 95 percent of its needs are met by groundwater, as shown in Figure 9.15. The quantity of desalinated water used in the agricultural sector is about 90 mcm per year. In an initiative launched by the UAE government to rationalize water use in the agricultural sector and increase efficiency, an agricultural policy has been developed by which the cultivation of Rhodes grass *(Chloris gayana)* has been limited after it was determined to be the crop with the highest water consumption. Modern equipment and technologies have also been introduced to the sector such as greenhouses and modern irrigation methods. Studies indicate the possibility of maximizing the use of irrigation water, whereby 80 kilograms of tomatoes can be produced per cubic meter of water, compared to six kilograms using traditional methods.

Plantations

There are about 300 plantations in the UAE comprising bushes, shrubs and small trees, with a total area of 210,000 hectares (ha). These plantations consume about 694 mcm of water per year, 15 percent of the total water resources of the country, and mostly in the form of saline groundwater. There has been a decline of up to 40 percent in water consumption of the plantation sector since 2003 due to a reduction in the area of these plantations—such as *U Aldebssa* in the Western Region of Abu Dhabi. However, on the eastern side of the emirate the plantations' demand for water has increased by 1.5 percent, and the government has sought to increase their area, enhancing efficiency and improve irrigation methods.

Figure 9.16
Water Resource use by Sector and Source



Source: Ministry of Environment and Water, op. cit.

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Ornamental Plants and Gardens

The UAE government has focused on improving the living conditions of individuals. To that end, it has expanded ornamental horticulture, public gardens and parks, and recreational facilities such as golf courses and sports arenas. There are currently over 100 gardens and parks in the country, as well as numerous entertainment venues and road side plantations, which also fall under this sector. This sector consumes about 490 mcm of water, most of which comprises reclaimed wastewater.

In order to rationalize water consumption in this sector, the government has adopted a policy to reduce green spaces, while also employing modern irrigation systems. This may reduce water consumption significantly—by up to 60 percent.

Domestic, Industrial and Commercial Sector

There has been a major construction boom in the United Arab Emirates over the past forty years, accompanied by a significant increase in population. The domestic, industrial and commercial sector consumes some 1.4 bcm of water annually, or 34 percent of the total water resources of the nation. Desalinated water provides 1.26 bcm (90 percent) while the remainder is met by groundwater. In light of the country's commitment to support the supply of freshwater resources, water consumption has increased gradually and steadily alongside the increase in population, urban growth and industrial expansion.

Estimated water consumption in urban areas (including domestic and industrial, commercial and government facilities) is about 750 liters per person per day, which is one of the highest rates in the world. Estimated water consumption in the domestic sector alone is about 364 liters per person per day. Studies conducted by the Regulation and Supervision Bureau (RSB) and the Environment Agency – Abu Dhabi (EAD), have shown that daily per capita consumption of water varies depending on the standard of living and the emirate, ranging from 200 liters per capita per day in Sharjah to more than 550 liters in Abu Dhabi, with an average of 360 liters per capita per day at the state level. Figure 9.16 shows total water resource use in the country.

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Future Demand for Water Resources

The process of calculating future demand for water is complex and multi-dimensional. There are many factors that must be taken into account when making such calculations, which sometimes requires the use of complex mathematical models and the development of various scenarios and assumptions. There are also sector-specific factors that affect future demand.

The most important factors in the domestic sector are: projected rate of population growth; per capita consumption of water (liter per capita per day); the impact of outreach programs and rationalization to change patterns of per capita consumption; effectiveness of water policies and pricing; urban growth; availability of transmission and distribution networks; and personal income level.

Factors affecting the agricultural and plantation sectors are: potential expansion of cultivated areas; crops and types of plants, and their associated water needs; current and future methods of irrigation; effective sector-specific water policies; weather conditions (temperature, humidity, wind, evaporation and other factors); government approaches to rationalizing the use of aquifers and the availability of alternative water sources.

Domestic Water Demand Growth

To calculate projected growth in domestic demand for desalinated water, the Ministry of Environment and Water, in cooperation with other national stakeholders, devised the following scenarios:

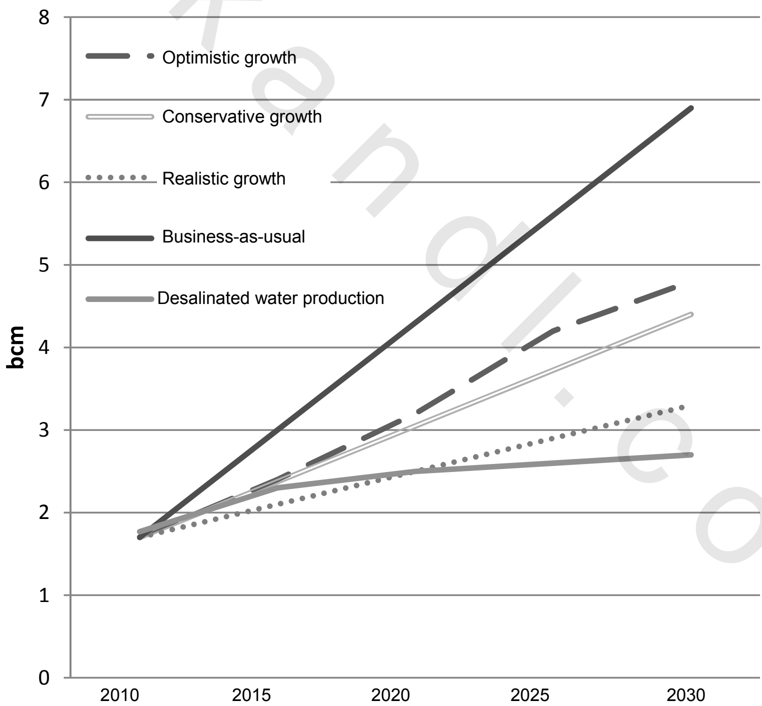
- Optimistic growth: this assumes a domestic sector growth rate of ten percent until 2020, and a rate of 1.5 percent thereafter. This scenario assumes demand growth in the commercial and industrial sectors of thirteen percent annually until 2015, ten percent until year 2020, and 6.9 percent until 2030.

- Conservative growth: this assumes a population growth rate of eight percent until 2020, and then 1.5 percent thereafter until year 2030. Annual demand growth in the commercial and industrial sectors is estimated at thirteen percent until 2015, then eight percent until 2020, and 6.9 percent until 2030.

- Realistic growth: this assumes a population growth rate of nine percent until 2015, then 3.5 percent until 2020, and 2.5 percent thereafter until 2030. Demand growth in the commercial and industrial sectors is estimated at nine percent per annum to 2015, and three percent to 2030.
- Business-as-usual: this scenario assumes current growth rates remain as they are until 2030, when the country's population is expected to reach 20 million people.

Figure 9.17

Projections of Domestic Demand for Desalinated Water



Source: Ministry of Environment and Water, op. cit.

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A numerical model has been used to represent the domestic sector demand in the period 2010–2030. Figure 9.17 shows the results of the calculations, which indicate that demand from the domestic sector will reach 4.8 bcm per annum according to the optimistic growth scenario; 4.4 bcm in the conservative projection; 3.3 bcm in the realistic projection; and 6.9 bcm in the business-as-usual projection. The results indicate that there will be a gap between water demand and available resources in the absence of the following:

- Demand management in the domestic sector to rationalize consumption through the use of water-saving tools and the application of modern standards and specifications in the distribution and transmission networks, reducing wastage caused by network leakage.
- Government measures to establish laws and legislation to reduce water wastage, including by the use of incentives.
- Changes in water pricing policies by the establishment of varying water tariffs according to consumption (varied tariff system).
- Reduction in the amount of desalinated water used in agriculture, and substitution by other sources such as reclaimed wastewater or a mixture including groundwater.
- Investment to build new desalination plants or increase the production capacity of existing plants.

Demand Growth in the Agricultural Sector

Cultivated land in the UAE has increased significantly during the period 1971–2011. Crops differ from emirate to emirate, with vegetables grown in the Northern emirates, fodder and palm trees in Abu Dhabi, and fruit in the eastern region. The agricultural sector accounts for about 90 percent of the groundwater consumed in the UAE, as well as about 20 percent of desalinated water. It is expected that the demand for water from this sector will rise from 4.5 bcm in 2010 to more than 7.5 bcm by 2030 (Figure 9.18).

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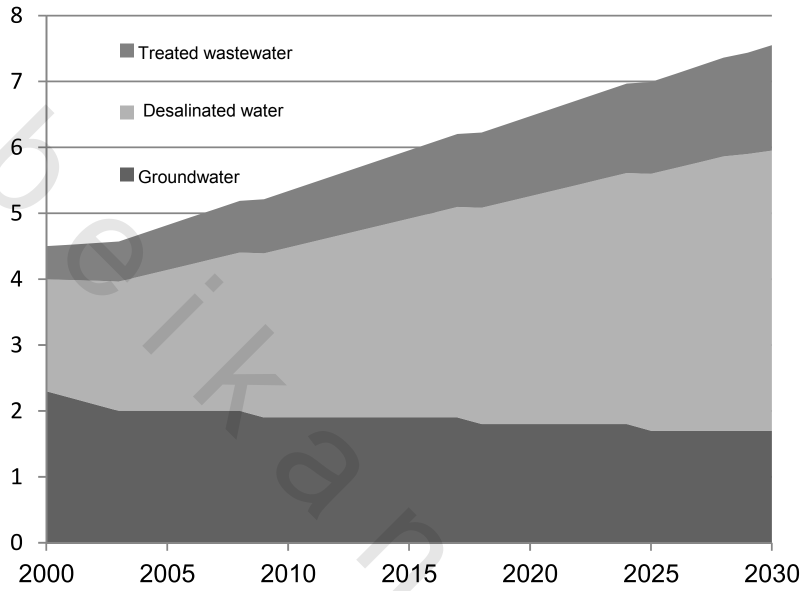
Figure 9.18
Projected Demand to 2030 (bcm)



Source: Ministry of environment and water, op. cit.

A Legislative and Institutional Framework for the Management of UAE Water Resources

The UAE has devoted much effort to the organization of the water sector and has developed legal, legislative, regulatory and institutional frameworks to support the implementation of appropriate policies and administrative decisions with which to efficiently manage this vital resource. Through these efforts, undertaken over forty years, steps have been taken to identify a competent authority, as well as the roles and responsibilities of various institutions in the country. A framework has also been developed through which management concepts and sustainable development of water resources can be developed and integrated.

Regulation of Groundwater Usage

At the federal level, the Ministry of Environment and Water has played a key role in maintaining groundwater resources and in developing public policies, national standards, and a strategic plan for groundwater, coordinating these activities among the different Emirates. Then comes the role of local authorities in the implementation of controls and legislation regulating groundwater uses, granting permits for well-drilling and other activities.

There has been extensive depletion of groundwater reserves due to increasing demand from the 1960s onwards, the revival of the agricultural sector, plantation projects and landscaping, the creation of parks and gardens, and a deterioration in the quality of groundwater aquifers. The UAE has therefore established standards and legislative frameworks to organize the process of well-drilling, and each emirate has issued a law regulating this process. Most of these laws are similar in terms of content, and all aim to achieve a number of objectives, namely: identification of those responsible for organizing well-drilling and the granting of drilling licenses; reduction of overdrawing and indiscriminate drilling; preserving groundwater quantity and quantity; determining uses of, and control measures for groundwater.

Regulation of Desalinated Water Usage

At the federal level, the Ministry of Energy is responsible for desalination policy and strategic planning, as well as the development of national standards in this area and the coordination of activities between the different emirates.

There is no separate federal law governing desalinated water, but it is addressed in general in Federal Law No. (24) of 1999, which sets standards for pumping and discharge of water to and from the sea. Also, Decree No. (37) of 2009 concerning the establishment of a supreme council for electricity and water chaired by the Minister of Energy, tasks the council with the coordination of desalinated water production activities—an important step in coordinating roles among the bodies responsible for the production, distribution, control and regulation of desalinated water.

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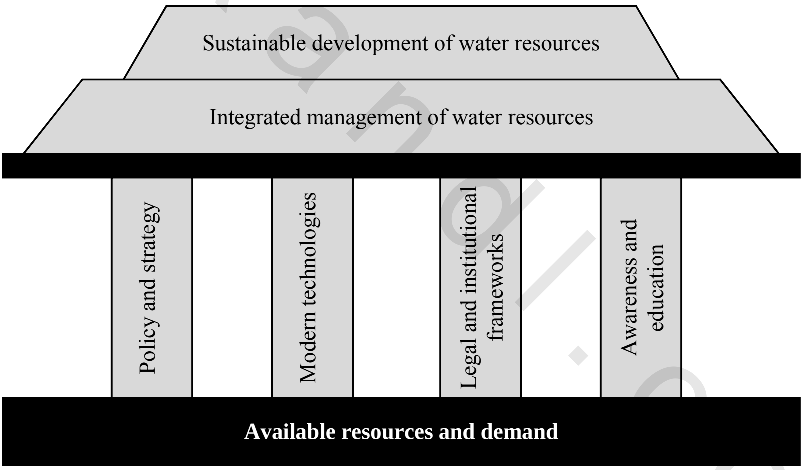
Regulation of Wastewater Treatment and Usage

The General Secretariat of UAE Municipalities was responsible for sewage follow-up and treatment until 2009, when the Ministry of Environment and Water assumed responsibility. Federal Law No. (24) of 1999 contains three articles concerned with wastewater treatment and usage: Articles 35, 37 and 38. The regulatory and legislative frameworks also cover the reuse of wastewater in Abu Dhabi, which issued Law No. (21) of 2008 allowing Abu Dhabi Sewerage Services to sell reclaimed wastewater to developers and the private sector whereas previously reclaimed water could only be sold to the municipalities.

Figure 9.19
Work Plan for Integrated Water Management in the UAE



Source: prepared by the researcher.

Towards Integrated Management and Sustainable Development of Water Resources in the UAE

In order to achieve integrated management and sustainable development of scarce water resources in the UAE, the government is undertaking a variety of measures in the following four main areas in order to achieve water security:

- Developing public policy that reflects the government's vision to achieve sustainable development of water resources, as well as a strategic plan for specific goals and standards to measure performance levels. This will be followed by a schedule of programs and projects to achieve the desired objectives. To ensure success, there is a follow-up and evaluation process comprising performance indicators and tools.
- Reviewing legislative and legal frameworks, as well as the institutional and regulatory framework for the management of water resources in the state, in order to identify any omissions or inconsistencies in terms of reference, and to develop the necessary programs to avoid such inconsistencies.
- Raising awareness and education through the development of educational programs for all water-consuming sectors. These programs are designed based on the 'message' to be delivered, as well as on the specific target groups, their scientific and cultural background, and language.
- Developing and adopting modern technologies in order to rationalize water usage in all water-consuming sectors, as well as raising the efficiency of water production and reducing its cost.

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10

Food Security in the UAE

Eckart Woertz

The United Arab Emirates is "food secure"; its supermarkets display food from around the globe and the buffets in its hotels are overflowing. Business travelers often complain about gaining weight while traveling in the emirates. Most of this food is not produced in the UAE, but imported—food security does not require food self-sufficiency. The UAE has a high per capita income and can afford to finance food imports. Income inequality is high – as anecdotal evidence in the face of a dearth of statistics would suggest – but no one needs to go to bed hungry, as long as wages are paid.

The global food crisis of 2008 unhinged this sense of security. Rising food prices alone were manageable for an oil- and cash-rich country like the UAE, but trade restrictions by food exporters such as Argentina, Russia, India and Vietnam were disconcerting and raised memories of vulnerability to food import disruption.

The UAE reacted with three different measures: price controls, a build-up of strategic storage, and the announcement of agro-investments abroad, many in countries that are food insecure, such as Sudan or Pakistan. This article explores the motivation for these policy steps and discusses their viability. It argues that price controls are untenable in the long run if not accompanied by some form of subsidy. Strategic storage would benefit from international or regional cooperation in order to pool capacities and avoid unnecessary and expensive storage. Finally, it suggests reasons as to why such a large gap exists between the announcement of agro-investments and their actual implementation. Major obstacles have included insufficient infrastructure, difficult framework conditions, and political backlashes in target countries on the one hand, and lack of capacities in the UAE and complicated financing in the wake of the global financial crisis on the other.

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The strengthening of international food markets and regulations will be more important for UAE food security than the search for exclusive bilateral access to food production from food insecure countries, which will likely prove elusive in a crisis. There are many areas of food security that deserve greater attention and can be tackled on a national level. Unhealthy diets cause diseases like obesity and diabetes, water management can be improved and food accessibility for vulnerable segments of the population can be maintained by tackling violations of labor laws. Finally, economic diversification not only has the potential for job creation, but will affect food imports options in the long run.

Mistrust in Markets: The Global Food Crisis 2008 and the UAE's Reaction

Price Controls

In the wake of the Arab Spring, governments across the Middle East have used welfare payments to preempt public discontent.[1] The provision of affordable services, utilities and public sector jobs is important for political legitimacy. In the rentier states of the Gulf they constitute a *quid pro quo* for lack of political participation. The UAE's subsidy regime is less extensive than that of Egypt, Iran or Saudi Arabia. It focuses on fuels and the provision of electricity and water at cheap rates for UAE and GCC nationals. The UAE does not have formal food subsidies in place as in Saudi Arabia, which supports prices for various staple foods and livestock fodder like barley, adjusting them flexibly depending on world market conditions.[2] The UAE has also not had to resort to *ad hoc* measures like those taken in Kuwait, where the government announced the free distribution of staple foods to locals over a 14-month period as part of a general subsidy package.

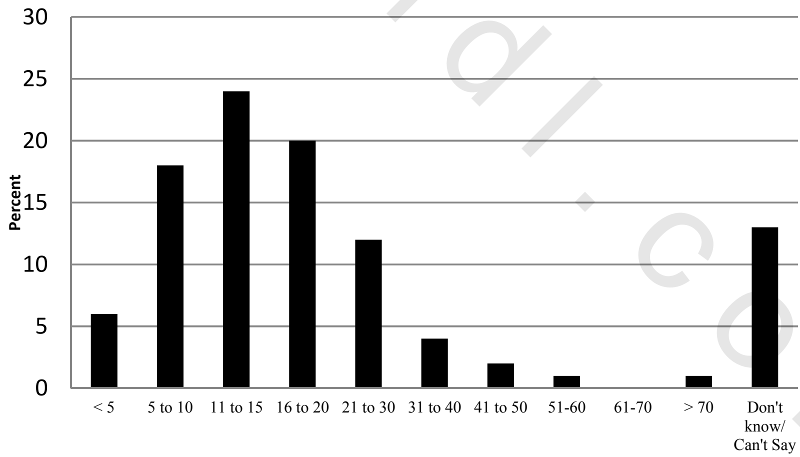
Like Qatar, the UAE has raised public sector wages and implemented price controls. Pay hikes started at 35 percent and reached 100 percent for employees of the federal judicial authority, the ministry of health and teachers at the ministry of education.[3] At least 80 percent of the national population is employed by the public sector and these measures have primarily improved their purchasing power. The largely expatriate workforce in the private sector did not immediately benefit.

The share of food in the general Consumer Price Index (CPI) in the UAE is relatively low at 14.3 percent, compared to 26 percent in Saudi Arabia and 18 percent in Qatar.[4] Yet the UAE CPI is outdated and the International Monetary Fund (IMF), banks and international think tanks have questioned official inflation estimates in the past.[5] Lack of reliable data hampers policy formulation, and a much needed reform of the CPI is currently being undertaken by the Ministry of Economy.

Lower income groups are particularly affected by food inflation, as they spend a relatively high share of their disposable income on food. According to a survey by Bayt.com and YouGov Siraj in 2007, people in the UAE generally spent between 10 and 20 percent of their disposable household income on food. This is similar to levels in developed countries and considerably lower than in developing countries, where this ratio can reach 40 percent or more; but there were also quite a few people in the UAE who spent up to 30 and 40 percent of their disposable income on food (see Figure 10.1).

Figure 10.1

Percentage of Disposable Income spent on Food in UAE, 2007



Source: Bayt.com/YouGov Siraj, "Research Results, Rents, Transports and Costs," October 2007 (http://img.b8cdn.com/images/uploads/article_docs/ rents_bayt_en.pdf_ 20090609081905.pdf).

With over 3,000 interviewees in the UAE the Bayt/YouGov Siraj survey had a considerable sample size. Of the respondents, 26 percent had an income below $1,001. This does not leave room for great differentiation between poorer segments of the population; the relative difference between $200 and $800 is more substantial than between $3,000 and $4,000. As the survey was conducted online, there might have been a considerable sample bias, since poorer, blue-collar workers often have limited internet access. Bias is also reflected in the relatively low sample size of 31 percent of Asians overall, even though they constitute a majority of the population of the UAE. In sum the survey revealed that a large part of the UAE population spends a relatively small share of their income on food, similar to developed countries. However, the survey also contained a group of people who needed more than 30 percent of their incomes to buy food. They made up only eight percent of the sample – possibly due also to underrepresentation – while their relative size might be higher in reality.

Obviously, pay hikes in the public sector have not directly addressed the situation of the lowest paid. Yet, UAE authorities have also been concerned about food price hikes. They implemented price controls for up to 700 commodities ahead of the inflation-prone Ramadan season in 2011.[6] This created a problem, in that the UAE does not have a system of consumption subsidies like Saudi Arabia. Once world market prices exceed a level at which a profit can be made within the confines of the price ceilings, traders will incur losses. Either they will stop offering the respective items and a black market with higher prices will develop, or controlled staple foods will need to be cross-subsidized with other sales. Retailers in fact started to complain about the situation and some stopped offering those goods for which prescript sales prices were below profitable levels.[7] The UAE would need to introduce food subsidies like other countries in the region, if it wanted to keep food prices in certain boundaries. In an environment of growing global food prices, price controls alone are not viable in the long run.

Strategic Storage

Global stocks-to-use ratios for grains and oilseeds were at historic lows in 2008. At 14 percent they were even one percent lower than during the world food crisis of 1973/74; even though the price increases were smaller in relative terms than during the 1970s.[8] Utilization of crops had outpaced production in the preceding years and created a draw on existing stocks. The causes have been widely debated. On the demand side, biofuels, population growth and the growing meat intake of diets in emerging markets weighed in. On the supply side, productivity growth in developed markets petered out. Switches in agricultural policies in the European Union and the United States from price support of commodities to monetary support of farmers reduced production and the need for storage to stabilize prices. To make matters worse, agro-exporters like Argentina, Russia and Vietnam implemented export restrictions out of concern for their own food security and China – traditionally a large stockpiler for strategic reasons – did not make its reserves internationally available as it had done earlier in the 2000s, when it acted as a supplier of last resort. Instead, it taxed grain and rice exports as well. Ultimately only the US and Thailand remained in the rice market as exporters.[9]

Once beaten twice shy, the Gulf countries have identified an increase of strategic storage as an important ingredient of managing food import dependence. Oman had the most extensive system in place before the food crisis. At that time it covered 3–4 months of staple food needs.[10] Storage was increased to one year for rice, six months for edible oils, milk and sugar, and to 3–5 months for wheat.[11] The handling capacities at the ports of Sohar and Salalah were extended as part of the expansion of storage facilities.[12]

In Saudi Arabia, Deputy Minister of Agriculture Abdullah Al-Obaid announced the build-up of strategic storage for rice and wheat for 3–6 months of consumption in April 2009.[13] In 2011, Minister of Agriculture Fahd Balghunaim increased that level and declared that a 12-month storage for wheat should be achieved by 2014.[14] This is similar to the level of the Third Five-year Plan (1980–85), when Saudi Arabia increased targeted capacity to 12 months, up from the prevailing six months that were stipulated in the plans of the 1970s.[15] The fact that storage was so much lower before the current food crisis in 2008 illustrates the relative neglect of strategic storage during the period of low global food prices. Like Oman, Saudi Arabia has also expanded port handling facilities in Jeddah, Yanbu, King Abdul Aziz Port/Dammam and Jubail.

The UAE decided to build up a strategic food reserve as well in order to reduce exposure to market volatility. Then the issue somewhat

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disappeared from the headlines, possibly because global food prices corrected sharply in the second half of 2008 and reduced the sense of urgency. Only by 2010, food prices crept upwards again and the federal Ministry of Economy announced that it had given the green light to an implementation plan for storage facilities following a feasibility study.[16] In 2012, it seemed that the first steps of implementation were considered, with the private sector playing an important role in the storage administration.[17] The long lead time and the fact that no further details like the storage amount were provided, suggests that the topic is regarded as less important in the UAE than in Oman or Saudi Arabia. In 2007, the Abu Dhabi Food Control Authority was given the task of attending to issues of food safety and domestic agriculture in the largest emirate. However, the UAE does not have a prominent, centralized planning agency for food security issues like the Qatar National Food Security Program (QNFSP) or a coordinating body like the King Abdullah Initiative for Saudi Agricultural Investment Abroad (KAISAIA). Possibly the federal structure of the UAE makes decision-making and consensus building more difficult. At the same time, emirate-level institutions curtail the authority of federal institutions.

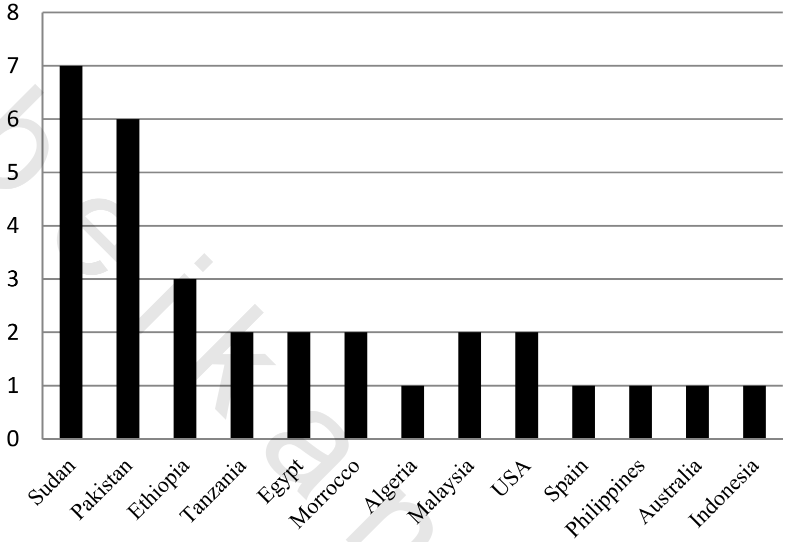
Foreign Agro-Investments

Like other GCC countries the UAE has announced foreign agro-investments to gain privileged bilateral access to food production. Established food exporters like the US or Australia have not ranked very prominently; Sudan and Pakistan have been the most favorable investment destinations, followed by Ethiopia (see Figure 10.2). These countries might be geographically close and offer logistical advantages, but they are food insecure. They were the top three recipients of food aid from the World Food Program (WFP) in 2010.[18] Pakistan also suffers from a physical water shortage and has high inequality of land ownership.

Not surprisingly, so-called “land-grab” investments are highly controversial. Advocacy groups argue that they compromise local food security and the customary land rights of small-scale farmers and pastoralists, while benefits in the form of jobs, compensation and business opportunities are limited. The World Bank has deplored the abysmally low job creation of capital intensive large-scale investments.[19]

Figure 10.2

Agro-projects and MOUs Announced in the UAE, 2008–2011



Source: "Food Crisis and the Global Land Grab" (www.farmlandgrab.org).

The UAE and other Gulf countries have faced resistance to their agricultural projects. In Sudan there have been violent protests against the Merowe dam, which is co-funded by Gulf development funds like the Abu Dhabi Fund for Development (ADFD) and has led to the resettlement of 40,000 people. Similar displacements are expected after the ongoing heightening of the Roseires dam.[20] In Ethiopia the government resettles local populations, often by force, in order to make land available to foreign investors which it hopes will help to spur an agriculture-led industrialization. Among prominent investors is the Saudi Star company of Saudi billionaire Mohammed Al-Amoudi (whose farm was attacked by gunmen in 2012, resulting in the death of several workers).[21] When the UAE negotiated possible agro-projects in Pakistan it tried to guarantee "a blanket exemption" from export restrictions that Pakistan had implemented out of concern for its domestic food security. Pakistan was only ready to grant such privileges in specifically proposed agricultural free zones.[22] In Baluchistan in western Pakistan, the regional government blocked direct deals between UAE private investors and Pakistani landowners after farmers protested. The central government stipulated in the aftermath that outside investors must enter sharecropping arrangements with local farmers on a 50:50 basis. At the same time, Pakistan is interested in foreign investments and increased the amount of farmland open to foreign investors to three million hectares.[23] It also offered Gulf countries a security force of 100,000 men to protect farm assets. This is a strong hint at the intricate socio-economic conflicts that such large land transactions would involve.[24] The Saudi Minister of Industry and Commerce, Ali Reza, conveyed to US diplomats in a WikiLeaks cable that an agricultural project in Pakistan was not pursued, "because the Saudi Government and its companies did not believe they could manage the security issues involved."[25]

These examples show the considerable ambiguity of foreign agro-investments. Gulf countries argue that a win–win situation is possible, with Gulf countries supplying the capital and target countries the land and labor. There is indeed a strong need for investments in agriculture. Irrigation infrastructure in the Sudanese Gezira scheme or the Punjab in Pakistan need to be rehabilitated. To be successful any agricultural investment not only needs to bring the local population on board, but also needs to be part of a broader process of development planning by respective national institutions. Corruption and a lack of governance in target countries are often obstacles in this regard. This was one reason why the plans of Gulf countries to develop Sudan as an Arab bread-basket in the 1970s failed.[26] On the other hand, local technocrats in Sudan have complained about an occasional approach by Gulf investors to reduce transaction costs by gaining privileged access to individual politicians and bypassing national institutions of development planning.[27]

So far, agro-investments by the UAE and other Gulf countries have lagged far behind announcements. The media perception that Gulf countries were already producing food abroad on a large-scale to cover their food needs is inaccurate.[28] The political backlash, lack of infrastructure and governance in target countries, and reduced availability of finance in the wake of the global financial crisis have been reasons for the implementation gap. In Pakistan, the World Bank did not find signs of a single implemented project.[29] In Sudan, about 100 kilometers south of Khartoum, the Zayed al-Khair project of the UAE based Al-Anhar Group has existed for over ten years, but less than 10 percent of a total acreage of 40,000 feddans are actually planted. In the rain-fed area around Gedaref the UAE's Al-Zafra Group recently left a project after only one season of cultivation. A large project that the ADFD announced has not been started at all yet.[30]

The UAE's sizable food imports continue to come primarily from established agro-exporters like Canada, Australia or Brazil, and less so from developing countries. Pakistan and India play an important role for supply of basmati rice, but do so without Gulf agro-investments. As long as markets stay open Gulf countries are food secure, because foreign farmers want to make money. Helping them to do so might be better achieved through trade agreements and contract farming. The fully owned plantation model that Gulf countries mostly aspire to in developing countries is less suitable.[31]

UAE Domestic Agriculture: Cherished and Unsustainable

Agriculture is regarded as an important tribute to ancestral land, traditions and food security in the UAE, yet it is unsustainable in its current form. For Sheikh Zayed bin Sultan Al Nahyan, the founder of the UAE, the free distribution of water and the promotion of agriculture via subsidies were important sources of legitimacy.[32] The UAE has granted land and subsidies to nationals to help them set up farms as part of its generous welfare system. Actual operation of the farms is mostly in the hands of expatriate labor. Often the farms have the character of weekend leisure gardens with attached agricultural production units rather than fully fledged commercial operations. Subsidized purchasing prices apply to dates, and in Abu Dhabi also to green fodder. Only vegetable production is market-based.

Water scarcity is the biggest challenge for UAE agriculture and the reason for its lack of sustainability. The United Nations Food and Agriculture Organization (FAO) advised in 1973 against a "massive effort to expand agriculture" for this reason.[33] Yet, the 1970s saw the build-up of essential infrastructure, and the 1980s the implementation of projects and marketing operations.[34] The cultivated area more than tripled between

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1994 and 2003, and irrigated areas increased from 67,000 hectares (ha) to 226,600 ha over the same period.[35]

The government has tried to forge production growth through pilot farms and research stations. A five-year plan in 1968 emphasized agricultural development and a number of research stations were set up to develop locally adapted crops.[36] Extensive research was undertaken in the second half of the 1970s; in 1983, the government set up a model farm.[37] The International Center for Biosaline Agriculture in Dubai was established in 1992 and supports research on desert hardy and salt tolerant crops as well. However, dissemination of such crops and other research results has been limited and water consumption in agriculture remains inefficient.

Self-sufficiency in food production was a "matter of principle" for Sheikh Zayed, according to an official portrayal.[38] This goal was never achieved. Only fruits, vegetables, fish and eggs had relatively high ratios of self-sufficiency in 2008 (see Table 10.1). However, some of these numbers appear inflated given the recent upward revision of population figures and the cosmopolitan display of fruits and vegetables from all over the world in UAE supermarkets.[39]

Table 10.1

Self-Sufficiency Ratios UAE (%, 2008)

Cereals (total)	1
Potatoes	10
Pulses	10
Vegetables	38
Fruits	66
Meat (total)	21
Red Meat	12
Poultry	23
Fish	72
Eggs	51
Milk and Dairy Products	17

Source: Arab Organization for Agricultural Development, *Arab Agricultural Statistics Yearbook*, vol. 29, 2009 (http://www.aoad.org/ Statistical_Yearly_ Book_Vol_29.pdf).

Water has not only been lacking, its use has been disorganized and inefficient. Extensive water usage for afforestation, parks and leisure

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gardens has diverted it away from food production. The work of agricultural research centers has had no centralized coordination. Overlapping institutional responsibilities and the federal structure of the UAE have complicated decision-making. Coordination was limited between the federal Ministry of Agriculture, the departments of agriculture in Abu Dhabi and Al-Ain and the municipalities in other emirates that were in charge of distributing land.[40]

In 2003, three-quarters of the UAE's 255,000 cultivated hectares were used for permanent crops—mostly date palms, followed by fodder and vegetables.[41] The UAE does not have the kind of large-scale subsidized wheat production that Saudi Arabia has decided to phase out by 2016. However, it does have a substantial livestock sector. Over two million animals have high feedstock needs. Currently Rhodes grass accounts for 60 percent of water use in agriculture. It is targeted for a phase out in order to preserve water resources. Green fodder will need to be increasingly imported.[42]

UAE agriculture is at times identified as an important pillar of food security. The opposite is true: its contribution to food supplies is only a fraction of total consumption, at the same time it is compromising water security because it is the country's largest water consumer. There is not enough water around for the maintenance of current agriculture, not to mention its expansion. Considerable leverage on a national level exists, however, in a number of overlooked policy fields that are crucial for a broad based concept of food security. They will be discussed in the following section.

UAE Food and Water Security: Some Policy Suggestions

International Markets: If You Can't Beat Them, Join Them

Gulf countries express a fundamental mistrust of global food markets when they increase strategic storage and try to gain privileged bilateral access to food production. This mistrust is informed by the export restrictions placed on food exporters in 2008, but also by earlier experiences of geopolitical supply disruptions. During World War I and II, food supplies were fragile and depended on political alliances. During the 1970s, food trade was politicized and the US contemplated grain embargos against Arab countries in retaliation to their oil boycott.[43] Still, with all justified caution, it must be stressed that global food markets have served the Gulf countries well, even during crises. Their replacement by some bilateral autarky would be unrealistic; therefore, the challenge is to make them more reliable and predictable through enhanced international cooperation.

The World Trade Organization (WTO) allows food export restrictions at times of crisis, as Saudi Arabia's former WTO chief negotiator Fawaz al-Alami has pointed out when arguing against Gulf agro-investments. Because of their lack of reliability, he recommended the build-up of strategic storage instead.[44] Gulf countries are implementing such programs now as outlined above. Yet, they do so on a national level, without international or even regional coordination. The International Food Policy Research Institute (IFPRI) has pointed out that the additional demand of a rapid expansion of national storage might cause the very problem it seeks to address: tight global food markets and rising prices. Instead, IFPRI has suggested an international food reserve to avoid unnecessary and expensive storage.[45] Such a reserve has been debated in development circles since the 1950s. States have been reluctant to give up sovereignty in this matter and there are issues of practicality. Yet, there is a strong case for increased international cooperation of some form. The Middle East actually offers a case study. The Allied Middle East Supply Center in Cairo avoided excessive storage during World War II by pooling reserves all over the region.[46] Similar arguments for regional cooperation today have been made.[47]

Hence, the UAE and other Gulf countries may consider increasing cooperation in the Middle East and pushing their case more prominently in international organizations like the WTO or the FAO. To do so they would need to beef up their capacity to communicate on an institutional level. Gulf bureaucracies are sometimes top heavy, driven by single personalities and lack qualified human resources with discretionary power on an intermediate level. As financial speculation in agricultural commodities has contributed to increased volatility and overshooting of prices,[48] reforms to the financial architecture would be in Gulf countries' best interests. Again, they could align themselves with initiatives on the international level. As major financers of global imbalances, their voice

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certainly carries weight. Another recently emerging strategy is Abu Dhabi's plan to establish a food-trading house to gain a foothold in a market that is so far dominated by a few large trading houses like ADM, Bunge, Cargill and Dreyfus.

Water and Food Security

The UAE has the highest water consumption per capita in the world—even higher than in the United States or Canada, and about double that of most European countries. For a water-scarce country, this is both flabbergasting and unsustainable. The vast majority of water is consumed by agriculture and its irrigation needs. The concept of food self-sufficiency collides with water security, which is an indispensable part of food security. Renewable water reserves are abstracted many times over replenishment rates. Non-renewable fossil groundwater is mined at alarming rates. At current consumption rates, groundwater resources will be depleted within 20–40 years.[49] The only alternative would then be desalinated water, which is prohibitively expensive for agricultural use. The first desalination plant of the UAE was installed in Abu Dhabi in 1976 and capacity has been expanding ever since. Cities now rely on it almost exclusively. If desalination plants failed due to an oil spill or sabotage, cities would run dry within two days. For this reason, Abu Dhabi has started to build up a strategic water reserve in suitable geological formations.[50] Currently desalinated water is predominantly used for residential purposes, landscaping and home gardens. Yet 11 percent of desalinated water production is directed to agriculture, according to the Abu Dhabi Water Resources Master Plan, which suggests the actual figure might possibly be far higher.[51] This allocation of desalinated water is economically wasteful and ecologically questionable.

There is an urgent need in the UAE to reduce water consumption. Water tariffs need to reflect the actual costs of making water available. Subsidies should be cut radically. In as far as cheap or free water is regarded as indispensable for political legitimacy, it could be substituted by transfer payments. The important thing is to bring consumption down; to this end, agriculture needs to be reduced and redirected towards more value-added and less water-dependent products. The substantive livestock industry produces feces that constitute an additional threat to groundwater

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quality and must be pushed back. The same is true for Rhodes grass cultivation, which consumes about 60 percent of agricultural water use. Water saving technologies like greenhouses, drip irrigation and drought tolerant crops should be disseminated more widely.

Unhealthy Diets and Obesity

Food security requires access to healthy and nutritious food for all people at all times. In that sense it is threatened in the UAE by an abundance of calories, not a lack thereof. Unhealthy diets, excessive intake of calories and lack of physical exercise have caused an obesity and diabetes epidemic in the UAE. Obesity rates have trebled since 1980 and remain at 34 percent. Globally, the UAE and Saudi Arabia are among the top five countries affected by diabetes, with prevalence rates of around 13 percent.[52] The dietary change towards greater portions of meat and dairy products, processed foods and sugar that is now taking place in emerging markets like China and India had already started in the Gulf region in the 1970s.

Obesity and diabetes severely curtail the well being of a person and his or her ability to work. They cause an incalculable risk to national wealth. The gravest effects often only show after a patient has suffered for decades from the condition. Pushing them back is an urgent policy requirement. Awareness campaigns and promotion of physical exercise in schools and communities can help, but in the end there is no way around more robust legal measures, which can be contentious among food industry representatives. Like similarly affected OECD countries the UAE will need to consider measures like taxation of fast food, and better product information that allows consumers to make informed choices.

Scarcity amidst Plenty? Food Accessibility of the Blue-Collar Workforce

Asian blue-collar workers constitute a substantial section of the population in the Gulf. In the UAE, Qatar and Kuwait they outnumber locals and expatriates from other continents.[53] Blue-collar workers have suffered most from food inflation as they spend a relatively high share of their income on food. At times, non-payment of wages have further aggravated their situation and a number of wildcat strikes have occurred in the UAE and other Gulf states.

Often there is a tendency in the Gulf countries to portray migrant workers as a security risk. The Bahraini Minister of Labor went so far as to call Asian labor migration “a danger worse than the atomic bomb or an Israeli attack” in 2008.[54] Obviously, such statements do not do justice to the economic contribution of expatriate laborers and their legitimate grievances.

Social peace and food security are important in safeguarding stability. During the food crisis of 2008 UAE officials were particularly concerned about the price of rice, the main staple food of the Asian worker community.[55] The importance of mediating institutions was acknowledged by enhancing the role of the labor courts to address violations of labor laws. In cooperation with Indian counterparts the UAE has also tried to remedy problems with the recruitment process in expatriates’ home countries. A reliance on ruthless agencies often results in high indebtedness among expatriate laborers before they even arrive in the UAE. Still more can be done. Transparency and the powers of the labor courts could be increased, while disadvantageous aspects of the sponsorship system – like the widespread practice of confiscating the passports of blue-collar workers during their contract period – could be abolished.

Ever since Nobel laureate Amartya Sen’s seminal research about historical famines in India and Ethiopia, we have tended to view food insecurity as a political and social construct, not just as a technical challenge of agricultural productivity and food distribution.[56] On a macro-level the UAE is food secure and, indeed, people consume too many calories. The country is far removed from famine scenarios. Yet on a micro-level, parts of the blue-collar workforce can face a lack of entitlements and food accessibility. It is of vital importance that the state empowers institutions able to address such issues, especially in the case of an economic or political crisis when such entitlement shortages could become more widespread.

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Economic Diversification

The ability to finance food imports from water-rich countries is the condition *sine qua non* of UAE food security. Because the UAE has ample oil revenues, it is food secure. Economic diversification not only can reduce one-sided exposure of the economy and provide jobs for the young population, it is also important in financing food imports in the long-term, if oil production and revenues decline.

Table 10.2

Oil and Gas Dependence of GCC Economies in 2010 (%)

	Saudi Arabia	UAE	Kuwait	Qatar	Oman	Bahrain
Hydrocarbon / GDP	52	34	52	57	54	25
Hydrocarbons / Gov. revenues	90	76	81	55*	85	80*
Hydrocarbons / Exports	86*	35*	95	90	66	76*

Source: International Monetary Fund (IMF), Chapter IV Consultation, Staff Reports (2011: Kuwait, Saudi Arabia, UAE; 2010: Qatar, Oman; 2007: Bahrain). GDP figures from IMF, "Gulf Cooperation Council Countries (GCC): Enhancing Economic Outcomes in an Uncertain Global Economy," (Washington DC, 2011).

Notes: Figures are rounded estimates. (*) Figures for hydrocarbon exports of Saudi Arabia and UAE include refined products. Investment income of state-owned hydrocarbon companies in Qatar is subsumed under non-hydrocarbon revenues and the investment income of state-owned companies in general. The latter's share in government revenues was one quarter in 2010. Bahrain's numbers for the hydrocarbon shares of government revenues and exports are from 2007.

Oil revenues in the Gulf countries constituted on average 46 percent of gross domestic product (GDP) in 2010 and around three-quarters of government revenues and total exports (see Table 10.2). Diversification in the UAE is relatively advanced compared with Kuwait or Saudi Arabia, as new sectors have emerged in the fields of services, tourism, trade and logistics. However, a thriving re-export trade via Dubai also tends to overstate the degree of diversification, as such exports do not really reflect production and economic capacities within the country.

Generally, the oil dependence of the economies of the Gulf has declined since the 1970s because of successful diversification, but it has inched up again in the 2000s as a result of rising oil prices.[57] In the long-run, renewable energies could be of particular importance in overcoming a one-sided reliance on hydrocarbon revenues. The UAE has already undertaken steps to foster this sector with the establishment of Masdar and the self-set goal to produce seven percent of its energy needs from renewable sources by 2020 (which it has pushed back to 2030, however).[58]

Thus, economic diversification increases food import options and their sustainability in the long run. By creating jobs outside the capital-intensive hydrocarbon sector it also has the potential to enhance food accessibility and enable a more broad-based participation in economic development.

The Lack of Statistics

Any food security planning requires information. Yet, statistics in the UAE are often deficient and need to be improved. The consumer price index (CPI) is outdated and most likely does not accurately reflect consumer baskets. A revision has been planned for a long time, but has not been realized yet. An accurate population count is essential to gauge the amount of food needed, yet until recently there has been great confusion about the real numbers. The UAE massively revised its population figures upward from 4.1 million in 2005 to 8.26 million in the second quarter of 2010.[59] This was due in part to the fact that the economic boom of the UAE attracted many new migrant workers, but another major factor for the revision was the correction of flawed older data. There is clearly an urgent need to improve data quality in the UAE overall, centralize responsibilities and start to produce more industry-specific data.

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Conclusion

International agro-investments have been a widely publicized reaction of the UAE and other Gulf countries to the global food crisis of 2008. Yet, to improve food security other policy fields are more important and the UAE has a considerable number of national levers at its disposal to influence them in its favor. International storage solutions and other forms of multilateral engagement could make global food markets more reliable and predictable. Water security is an indispensable part of food security; ironically, it could be increased by reducing water-guzzling agriculture. The high prevalence of obesity and diabetes are caused by unhealthy diets and constitute a different and possibly unexpected threat to food security. Again, the UAE has the possibility to address these issues with national policies. This is also true for policies of economic diversification and steps to address labor grievances. The former influences food import options in the long run, the latter safeguards the food accessibility of vulnerable segments of the population. After all, food security is usually a problem of food accessibility, not so much of food availability, as Amartya Sen has shown. Food accessibility the UAE can influence nationally, for food availability it will continue to rely on international supplies. The case for international cooperation is strong: like others count on oil exports, the UAE counts on its food supplies.

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CONTRIBUTORS

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Chapter 4

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has been estimated to be roughly 100 liters per day, while for agriculture, industry and hydro-electric energy generation it is between five and twenty times this amount. According to this indicator, 1,700 cubic meters of renewable water per person per year represents the threshold between scarcity and abundance of water. Countries with an annual share of water per person which falls below this level are categorized as “water stressed.” If the level drops to below 1,000 cubic meters per person per year, countries are classified as being below the “water poverty line.” If the rate is below 500 cubic meters per capita (or the so-called “acute water poverty line”), water will become the main obstacle to development and may lead to severe effects on standard of living, and the condition of personal health and the environment. See: M. Falkenmark, “The Massive Water Scarcity now Threatening Africa: Why isn't it being Addressed?” *Ambio* no. 18, 1989, pp. 112–118. Researchers used to combine desalinated water – and sometimes treated water – together with imported water in annual figures.

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Chapter 5

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Sustainable Development (Earth Summit) in South Africa in September 2002, which provided for "providing the basic requirements for a person such as clean water and sanitation." This was followed by a document issued by the Committee on Economic, Social and Cultural Rights (UN High Commissioner for Human Rights) in November 2002, entitled "Human Rights to Water." On July 26, 2010, the General Assembly of the United Nations issued Resolution No. 10967 with the consent of 122 countries (41 countries abstained) and unopposed, and that access to clean water and improved sanitation is considered a human right. For more details on "Human rights to water" as a sub-indicator of economic indicator of water security, see Malcolm Langford, "The United Nations Concept of Water as a Human Right: A New Paradigm for Old Problem," *Water Resources Development*, vol. 21, no. 2 (June 2005); Jason Morrison and Peter Schulte, "The Human Right to Water: Emerging Corporate Practice and Stakeholder Expectations," United Nations Global Compact, November 2010; Peter Gleick, "The Human Right to Water," *Water Policy*, vol. 1, no. 5 (1999): pp. 487–503; "The Human Right to Water and Sanitation – Translating Theory into Practice," 2009; (http://www.gtz.de/de/dokumente/gtz2009-human-right-to-water-and-sanitation.pdf).

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crop production." Allen stressed that "Virtual Water Theory" can contribute to solving water scarcity problem in the Middle East countries, as countries suffering from water scarcity could replace crop cultivation that requires much use of water, with importing water from countries with plenty of water. In this way, the importing countries accrue revenues by trade in "virtual water". It should be noted that recent studies have demonstrated precise calculations of virtual water in all kinds of food commodities such as meat, fruit and vegetables. Although "virtual water" theory may seem economically rational, there are political and strategic considerations that prevent the region's countries from relying too much on grain imports from abroad, as these countries often feel that grain production by themselves is an important issue strategically. For more details on "Virtual Water", see: J.A. Allan, "Virtual Water: A Long-term Solution for Water-short Middle Eastern Economies?" Proceedings of the 1997 Leeds Conference, Leeds, UK, The British Association, 1997; J.A. Allan, "Water Security in the Middle East and the Mediterranean," paper presented to the Conference *Security and the Environment in the Mediterranean in the 20th Century*, London, September 8–10, 2001; J.A. Allan, "Virtual Water Eliminates Water War?: A Case Study from the Middle East," in A.Y. Hoekstra (ed.), *Virtual Water Trade* (Amsterdam: IHE Delft, 2003), pp. 137–145.

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Chapter 6

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Chapter 8

1. In this paper, “Arab Gulf states” are the GCC countries, namely Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE.

2. Food security has a macro and a micro dimension. The macro-level dimension largely depends on the food import dependency relative to a country’s ability to finance those imports at any point in time (availability of food). The micro-level dimension refers to households’ access to healthy and nutritious food.

3. According to FAOSTAT, wheat and rice together account for 39%, 44%, and 40% of total energy intake in Saudi Arabia, UAE, and Kuwait, respectively.

4. Saudi Arabia’s share of cereals is 52% of the country’s food consumption accounting for over three quarters of GCC total cereal consumption

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despite constituting around two thirds of the GCC total population, in 2007. Overall, Saudi Arabia imports two thirds of GCC total food imports. Economist Intelligence Unit, "The GCC to 2020," 2009.

5. However, in Saudi Arabia there is a very particular preference for barley, followed by wheat. In Bahrain, Kuwait, and Qatar there is a relatively higher demand for animal produce compared to cereals.

6. Various Authors, "Food Security," *Special Issue: Food Security in the Arab World*, vol. 3, supplement 1, Springer, February 2011.

7. Despite the drastic cereal yield improvement in the past three decades due to mechanization and an increasingly input-intensive production pattern, with latest yields being around five times those of the early 1980s, poor soil quality and scanty water resources are an insurmountable obstacle to cereal production in the region.

8. With the exception of Saudi Arabia, the GCC region imports all of its cereal demand, which averages less than 90% when Saudi Arabia's wheat production is included. However, the Saudi decision to put an end to the subsidized production of wheat by 2016, although totally sensible, will eventually lead to a higher cereal import dependence of the region. Maize and rice are already totally imported.

9. In 2010, the GCC population was about 41.5 million and expected to reach 53.4 million by 2020 (Economist Intelligence Unit, op. cit.). Around 63% of the GCC total population is Saudi. Almost 70% of the Saudi population is less than 30 years old, while the share in Bahrain, Kuwait, Qatar, and UAE is estimated to be 54%, 48%, 50%, and 44%, respectively.

10. Urbanization rates in Kuwait, Oman, Saudi Arabia, and UAE are 98%, 72%, 82%, and 78%, respectively. The overall GCC average is around 86%.

11. Obesity rates in the region have continuously increased with Saudi Arabia being the country with the highest obesity rate in the world

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at 35.6% (when Pacific islands are not considered) followed by the United States (33.9%). Four GCC countries (UAE, Bahrain, and Kuwait in addition to Saudi Arabia) are ranked in the top ten (WHO BMI Database accessed on March 20, 2012). This also reflects on diabetes rates that are among the highest in their income groups.

12. Consumer price statistics and price monitoring systems in the GCC are still insufficient and do not allow a proper analysis of price trends and their impact on various income groups.

13. This means that for any 1% point increase in world food prices, domestic prices tend to increase by at least 0.2%. However, with the exception of the UAE, the price transmission is asymmetric and highly downward-sticky: a decline in world food prices does not transmit into domestic food markets as much as an increase does. These transmission patterns are also due to a number of country-specific factors, such as exchange rate regimes, inefficiency of subsidy systems, levels of competition among importers and wholesalers, supply chain characteristics, infrastructure, etc. Food price transmission typically takes about one year to show its effects on domestic markets. However, in most of the GCC countries it takes on average about seven months (World Bank, "Regional Economic Update: MENA Facing Challenges and Opportunities," Middle East and North Africa Region, 2011; E. Ianchovichina, J. Loening, and C. Wood, "How Vulnerable are Arab Countries to Global Food Price Shocks?" World Bank, 2012.

14. See, for example: UN Food and Agriculture Organization (FAO), "Safeguarding Food Security in Volatile Global Markets," 2011; and World Bank, "Managing Food Price Risks and Instability in an Environment of Market Liberalization," Agriculture and Rural Development Department, Report No. 32727-GLB, 2005.

15. Fertilizer prices have also been quite volatile and remained at higher levels, with February 2012 prices being 2.59 times 2005 average prices (Word Bank, "Commodity Markets Review," March 2012).

16. Low elasticities also imply that small shocks to production can have large price impacts. According to the FAPRI database, demand and supply elasticities for wheat in the Middle East region are -0.15 and 0.09, respectively, compared to -0.16 and 0.24 for Mexico, -0.39 and 0.41 for Argentina, and -0.34 and 0.29 for Eastern Europe. Saudi demand elasticity for rice is set at 0.1 vis-à-vis 0.46 for Mexico, 0.11 for Argentina, 0.38 for the EU. Saudi demand elasticity for barley is estimated at -0.19, vis-à-vis -0.24 for Mexico, -0.17 for Argentina, -0.35 for Eastern Europe (www.fapri.iastate.edu/tolls/elasticity.aspx).

17. World Bank, "Global Economic Prospects 2009," Washington, DC, 2009.

18. For example, in the 2010 budget, Saudi Arabia allocated $12.3 billion to the agriculture and water sectors vis-à-vis $10.4 billion of private investment on agricultural projects (NCB Capital, "GCC Agriculture: Bridging the Food Gap," Economic Research, March 2010).

19. About 40% of the GCC population is made up of expats, with the UAE, Qatar, and Kuwait ranging between 69% and 85%, while Oman, Saudi Arabia and Bahrain range in the 28–39% share (International Labor Organization [ILO], "International Labor Migration and Employment in the Arab Region," Thematic Paper, Beirut, 2009; and EIU, op. cit.). Three quarters of the UAE labor force is estimated to be made up of Asian expats. The share of Arab labor in the Gulf has declined from a peak of 72 percent of all inward migration in the beginning of the 1970s to an estimated 23% in 2005 (ILO, op. cit.). Qatar, Saudi Arabia and Kuwait tend to employ the highest number of non-national Arab workers (between 30% and 40% of the total foreign workforce) among the GCC countries, whereas in

the United Arab Emirates and in Oman the share of Arabs among non-national workers is below 10%.

20. Various Authors, 2011, op. cit.

21. There is a clear relationship between population growth and increased demand for cereals for human consumption, on the one hand, and between rising income and growing demand for feedstock, on the other.

22. Highest of the four GDP growth rates from the Millennium Ecosystem Assessment GDP scenarios, and the rate used in the baseline. Low variant of UN population forecasts (http://esa.un.org/unpp/index.asp). For further methodological details, please see: Gerald C. Nelson, Mark W. Rosegrant, Amanda Palazzo, Ian Gray, Christina Ingersoll, Richard Robertson, SimlaTokgoz, Tingju Zhu, Timothy B. Sulser, Claudia Ringler, Siwa Msangi, and Liangzhi You, "Food Security, Farming and Climate Change until 2050: Scenarios, Results and Policy Options," IFPRI Research Monograph no. 172 2010.

23. Usually, international agencies do not have reliable data on changes in cereal stocks and estimate these as a residual of production, consumption and trade estimates. Major exporters' stocks-to-disappearance ratio measures the share of stocks held by the top five exporters on their total consumption plus exports.

24. For example, in 1972–1973, a reduction in world wheat production of less than 2% at a time when stocks were very low, caused the grain price to more than double (B. Wright, "International Grain Reserves: And Other Instruments to Address Volatility in Grain Markets," FAO Working Paper, 2009; and S. Wiggins, S. Keats, and Julia Compton, "What Caused the Food Price Spike of 2007/08? Lessons for World Cereals Markets," Overseas Development Institute, London, UK, 2010).

25. Over the period 2009–2011, 12–13% of world grains production was exported. Wheat recorded the highest ratio among grains hovering around

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20%, while rice has the lowest ratio with only about 7% (US Department of Agriculture [USDA], "World Agricultural Supply and Demand Estimates," WASDE 503, February 2012). This entails that small shifts in supply or demand can lead to large shifts in prices. Rice is particularly affected by market volatility as it is also characterized by a highly segmented market along different types and qualities.

26. Saudi Arabia is also the world's largest importer of barley (averaging 7–8 million metric tons) that is used as feedstock for its large domestic livestock industry.

27. Cereal supply on international markets is concentrated in six main exporters, namely Argentina, Australia, Canada, EU, Russia, and USA. The world's largest exporters (i.e. USA, for wheat, and Thailand and Vietnam, for rice) are underrepresented in the GCC region's trade exchanges. Russia and Central Asia have been large suppliers of the region for a short period but alleged lower quality grains and the 2010 Russian export ban led to supply disruptions and a quick shift in the geography of suppliers.

28. Although supply risk usually arises from poor logistics such as few import entry points and limited unloading capacity, the GCC region is potentially affected by this type of risk because of the supply disruptions experienced in some key exporters in the recent past.

29. The wheat stock levels at the Grain Silos and Flour Mills Organization (GSFMO) silos have been estimated at around two million mt, equal to about 9–10 months of domestic demand, which is one of the highest known levels (USDA, op. cit.). Within the Arab region, Egypt is reportedly the largest holder. According to available estimates, China, India and USA hold around half of the world's wheat reserves (USDA, op. cit.).

30. These reserves often serve as both operational and strategic storages.

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31. UN Food and Agriculture Organization (FAO) and World Bank, "The Grain Chain, MENA Region," 2012. Here there is an assumption of constant unit costs which should be considered a good approximation in regions like the Arab Gulf where humidity is low, modern infrastructure is available, and are integrated in the global markets. The overall cost summing up port logistics, storage, inland transport, and management (which in turn includes product loss, cost of capital, and overheads) are on average $42 per mt of wheat, equal to around one eightieth of the current price of wheat on international markets (D. Larson, J. Lampietti, C. Gouel, C. Cafiero, and J. Roberts, "Food Security Storage in the Middle East and North Africa," World Bank, 2012). To this one needs to add transport costs which in the case of the Arab region is set on average at $35.5 per mt (FAO and World Bank, op. cit.). Therefore the total cost which includes transport, logistics, storage, and management sum up to around $77.5 per mt or around one quarter of the wheat price of one metric ton. In Saudi Arabia, all these operations are carried out by the Grain Silos and Flour Mills Organization (GSFMO). In Oman, Qatar, and Bahrain a milling company controls most of the supply chain in each of those countries. The company often has both private and public shareholders.

32. Jordan reports the lowest storage costs in the region ($1.7) while Tunisia the highest ($3.5).

33. To this cost one needs to add the market cost of wheat, which is currently around $270–300/mt (US wheat), thereby resulting in a purchase of about $700 million and therefore in an overall cost of around $750 million. In terms of opportunity cost, low interest rates resulting from the global financial crisis reduce the relative price of storage and global economic uncertainty encourages the purchase of real commodities (J.A. Frankel, "The Effect of Monetary Policy on Real Commodity Prices," in John Y. Campbell (ed.), *Asset Prices and Monetary Policy*, NBER Working Paper 12713, 2008).

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34. Martin and Anderson emphasize the reversibility of trade openness, as evidenced by collective action problems posed by recent episodes of export restrictions (W. Martin and K. Anderson, "Export Restrictions and Price Insulation during Commodity Price Booms," *American Journal of Agricultural Economics*, vol. 94, no. 1, 2012, pp. 422–427). Storage–trade complementarity and the right mix of these policies have therefore been increasingly studied and found to provide a powerful stabilization tool while tapping also into efficiency gains (S.S. Makki, L.G. Tweeten, and M.J. Miranda, "Storage–Trade Interactions under Uncertainty: Implications for Food Security," *Journal of Policy Modeling*, vol. 23, no. 2, 2001, pp. 127–140; C. Gouel, and S. Jean, "Optimal Food Price Stabilization in a Small Open Developing Country," World Bank, 2012). Hence. strengthening WTO rules on export control would be an important pillar of a global multi-pronged strategy.

35. M. Torero and J. von Braun, "Alternative Mechanisms to Reduce Food Price Volatility and Price Spikes," IFPRI, Washington DC. 2009.

36. Since Saudi Arabia is part of the G20, it should become an active member of such discussions, bringing up in that forum the interests of the other GCC members and of the wider Arab region, given that many of the challenges and stakes are common to all.

37. Some regional economic groups have already responded to the price hikes by establishing or strengthening their regional responses. For instance, in West Africa, ECOWAS has launched a program promoting regional value chains for rice and maize. The East Africa Community is developing a regional food security strategy. ASEAN has recently reformed the ASEAN Emergency Rice Reserve (AERR) and established the East Asian Emergency Rice Reserve which has expanded its regional stocks and strengthened its governance framework.

38. When a replenishment rate is to be chosen, logistics costs need to be taken into account, as there is an inverse relationship between the latter and the cost of replenishment. In addition, a high rate needs to factor in the risk of purchasing reserves exactly when international markets are tight and spikes have emerged. Conversely, a low rate tends to smooth the cost curve over a longer time period. All else being equal, a large stock size would typically allow a lower replenishment rate (for an in-depth discussion, please see: Larson, et al., op. cit.).

39. For instance, given that national wheat prices do not systematically co-move as reported in Figure 0.6, prices can exceed the ceiling in one country but not in another. This kind of situation would need to be clearly regulated.

40. The closest example to this organizational and governance framework is that of a central bank whose independence and arm-length relationship with governments is crucial for implementing a successful monetary policy. However, independence is normally a serious challenge since food security is a highly politically-charged topic.

41. More specifically, when comparing Saudi Arabia's average vessel turnaround time with that of Bahrain or Qatar, it shows 3–4 times higher turnaround time. (FAO and World Bank, 2012, op. cit.).

42. Given the ownership structure of grain reserves in the GCC countries (see note no. 31), the risk of crowding out seems relatively lower.

43. This is one more reason that supports the idea of holding a storage hub at the main entry ports of the GCC countries so as to save logistic-related costs.

44. C. Breisinger, O. Ecker, J. Funes, and B. Yu, "Food as the Basis for Development and Security: A Strategy for Yemen," IFPRI Discussion Paper 01036, 2010.

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45. The Chicago Board of Trade uses a system that examines price and volume data to determine an "accepted" price range based on their distribution. The prices that make up 70% of the trade are normally considered the "value area" and prices about two standard deviations away from the mode are deemed as outside the range bound (Agricultural Market Information System [AMIS], "Enhancing Market Transparency," Rome, 2011). However, the economic literature has been divided on whether a clear commitment to a pre-announced price band can be really effective in limiting the risk of hoarding and speculations (See D.M.G. Newbery and J.E. Stiglitz, *The Theory of Commodity Price Stabilization* [Oxford: Clarendon Press, 1981] in favor of this position; and B. Wright, "International Grain Reserves: And Other Instruments to Address Volatility in Grain Markets," FAO Working Paper, 2009; and J.C. Williams, and B. Wright, *Storage and Commodity Markets* [Cambridge: Cambridge University Press, 1991], showing that price bands actually tend to increase price volatility and speculations). According to the latter, if speculators sense that the price is dangerously getting closer to the price band limit and stocks are insufficient to maintain the targeted price band, they will rush to buy the necessary amount of extra stocks that will shoot price up beyond the set band. This contributes to explain the rationale that commodity price cycles tend to exhibit long flat bottoms punctuated by occasional sharp peaks.

46. Some cereal producers, such as Quaker Oats, also lock in the price of corn and oats using forward contract with growers. Anheuser Busch and Dole, two large beverage companies, use such a contract to lock in the price of grains and fruits used to make their beverages.

47. The former is an agreement to receive a commodity on a pre-determined date at an agreed upon price with a standardized delivery period, contract size, and quality; the latter is a contract that gives the client the right to buy a commodity future contract at a negotiated price and time. Options are therefore a kind of insurance mechanism

against the occurrence of future price rises. The right to call the option costs a price premium.

48. Practical case studies come from Malawi and Mexico, which employed a hedging strategy for food security. Malawi is self-sufficient in maize, but in years of poor growing conditions and a shortfall in domestic production the Government of Malawi must fill the gap by imports. The government needed not only to hedge the financial cost, but also to ensure the delivery of physical maize. In September 2005, Malawi bought a physical call option to purchase 60,000 mt of maize at the September price of physical maize for delivery from November 2005 to February 2006. The option premium was \$25.5/mt. In December, when maize shortage became apparent and since maize and transportation prices had increased, the Government exercised the option. Compared to buying at December prices for immediate delivery, the Government of Malawi made significant savings of around \$25–\$65/mt and delivery took place smoothly. If prices had decreased between September and December, the Government of Malawi would not have exercised the option and the cost would have been limited to the option premium (World Bank, "Risk Management & the Global Food Crisis," Agriculture & Rural Development, 2008).

49. World Bank, UN Food and Agriculture Organization (FAO), and International Fund for Agricultural Development (IFAD), "Improving Food Security in Arab Countries," 2009.

50. Discretionary hedging means hedging when the price is thought to be favorable, while non-discretionary hedging means purchasing hedges at regular intervals irrespective of price.

51. Financial derivatives are risky as they can often lead to losses. Human resource capacity is therefore a particularly binding constraint because it is crucial to rely on a team of professionals able to forecast future commodity prices based on the available information on the markets. As a telling example, Southwest Airlines stayed one of the very few

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profitable airlines during the 2008 crisis because they rightly forecasted oil prices, unlike Continental which had large losses because they purchased fuel futures at a time when prices dropped precipitously.

52. The possibility that spot and futures prices will not move together is called basis risk and the appropriate hedging strategy will depend on this factor. The basis risk is due to factors such as cost of freight, handling, and storage as well as local supply and demand factors. In the GCC region, the cost of these factors should be rather stable, which should ensure low or at least predictable basis risk. However, the issue of basis risk would need to be further investigated in the specific case of food commodities in the GCC countries.

53. Huber, Sweeney and Smyth (2004). B. Huber, E. Sweeney and A. Smyth, "Purchasing Consortia and Electronic Markets: A Procurement Direction in Integrated Supply Chain Management," *Electronic Markets*, vol. 14, no. 4, 2004 pp. 284–294.

54. International Food Policy Research Institute (IFPRI), "A Meta Analysis of Rates of Return to Agricultural R&D," Washington DC, 2002.

55. World Bank. "Agricultural Innovation Systems, an Investment Sourcebook," 2012.

56. Public expenditure on agriculture in GCC countries in 2007 varied from 0.1% of GDP in Bahrain, 0.2% in Kuwait and Oman, to 0% in the UAE (the UAE government spent 0.6% of its total expenditure on agriculture). Governments' expenditure on agriculture may vary across a wide range of activities that may not include R&D components. A recent example in Saudi Arabia is a case in point, while not necessarily applicable to other GCC countries. The Saudi government announced in 2012 the total of 0.09% of its total expenditure committed to the agricultural sector to support creation of new wheat storage and building mills in addition to the support of its

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existing local and foreign projects. The announcement on this budget did not, however, have any indication of intended investments in research and innovation (saudi-agriculture.com).

57. Anderson, op. cit.

58. A. Djeflat A, “Absorptive Capacity and Innovation Demand as driving Engines for Emerging Innovation Systems (EIS): Evidence from GCC and Maghreb Countries,” 2010.

59. A micro survey of innovative firms was undertaken in Abu Dhabi, where it has been found that innovation at the firm level predominately occurs in services rather than innovation in goods, which shows the firms’ reluctance to invest in high-risk R&D (Anderson, op. cit.).

60. World Bank, op. cit., 2012.

61. INCONET-GCC (www.inconet-gcc.eu).

62. Summary of E-consultation of West and North Africa (WANA) Region, by Mohammad Majdalawi for the Global Forum on Agricultural Research (GFAR), GCC participants: Bahrain, Kuwait, Oman and UAE.

63. GCC Patent Office website (http://www.gccpo.org/)

64. UN Industrial Development Organization (UNIDO), “Strategies for Regional Innovation System,” 2003.

65. D.A. Wolfe, “Program on Globalization and Regional Innovation Systems,” Program on Globalization and Regional Innovation Systems, Centre for International Studies, University of Toronto, 2005.

66. World Bank, op. cit., 2012..

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67. A comparison between the GCC and Australia may be sensible as they both have similar aggregate GDP, as well as climatic conditions and challenges.

68. This ratio measures R&D investment in agriculture relative to the size of agricultural GDP.

69. Mullen, et al. "R&D: A Good Investment for Australian Agriculture." Based on presentation to the 51st Annual Conference of AARES, Queenstown, February 13–16, 2007; latest figures available from 2005.

70. GCC countries with available R&D spending are Kuwait, Oman, Qatar and Saudi Arabia.

71. World Bank, op. cit., 2012.

72. Two top priority areas for the region's R&D will be: (i) solar-energy-induced water desalination and wastewater recycling; and (ii) R&D capacity building and application in Sudan that will in turn benefit the GCC region given its huge production potential and trade links (current maize yields are around 1.2 mt/ha that could be increased to about 7 mt/ha with proper technology adoption and extension services).

73. World Bank, op. cit., 2012.

74. Rainfall is very erratic and cannot be counted upon for activities such as agriculture.

75. The 'water footprint' is a measure of the appropriation of freshwater resources as it assesses the water volumes consumed, evaporated or incorporated into a product or polluted. The internal and external water footprint brings into play the issue of virtual water, which assesses the water embedded in a product which is exported or imported. Thus, the sum of the domestic water footprint and the virtual water imported minus the virtual water exported provide the water balance of a nation or region (M.M. Mekonnen and A.Y.

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Hoekstra, "National Water Footprint Accounts: Production and Consumption; Vol. 1: Main Report," Research Report Series No. 50, UNESCO-IHE, University of Twente, The Netherlands, 2011; and World Water Council, "E-Conference Synthesis: Virtual Water Trade: Conscious Choices," March 2004).

76. The high footprint for GCC is due to domestic use (even higher than the United States) while for most other countries it is the industry which is higher, meaning that GCC countries need to seriously curb their domestic water use imbalance.

77. In arid regions, when crop fields are watered either through rainfall or through irrigation, part of the water is absorbed by the plant, while the remainder is mostly lost through evaporation into the atmosphere, leaving a small amount of water locked inside the end-product. Yet, the quantity of water that was involved in its production was large, up to 1,500 cubic meters in the case of one mt of wheat. This is the concept of virtual water, which allows to establish a link between water, food and trade (M. Krieth, "Water Inputs in California Food Production," Water Education Foundation, 1991).

78. It has been argued that the flow of virtual water into the Arab region – mostly in the form of grain imports – is equivalent to the annual flow of the Nile (J.A. Allan, "Virtual Water: The Water, Food and Trade Nexus: Useful Concept or Misleading Metaphor?" *Water International*, vol. 28, no. 1, 2003). Since Saudi Arabia imports around 7.5 million mt of barley yearly that is used as feedstock (mainly from Ukraine), it is saving around 9.1 bcm of water, which is about half of the current agricultural water demand. However, in 2007, the country still used 3.2 bcm of water to grow 2.4 million mt of wheat.

79. M.M. Mekonnen and A.Y. Hoekstra, "The Green, Blue and Grey Water Footprint of Crops and Derived Products," *Hydrology and Earth System Sciences* no. 15, 2011, pp. 1577–1600.

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80. D. Renault, “Value of Virtual Water in Food: Principles and Virtues,” paper presented at the UNESCO-IHE Workshop on Virtual Water Trade, December 12–13, 2002, Delft, The Netherlands.

81. D. Zimmer and D. Renault, “Virtual Water in Food Production and Global Trade: Review of Methodological Issues and Preliminary Results,” World Water Council and FAO, Rome, 2011.

82. Ibid.

83. D. Renault, 2002, op. cit.

84. Kajenthira, et al. analyze waste water reuse in Saudi Arabia by incorporating energy use into the water equation (A. Kajenthira, A. Siddiqi, and L. Diaz Anadon. “A New Case for Promoting Wastewater Reuse in Saudi Arabia: Bringing Energy into the Water Equation,” *Journal of Environmental Management*, no. 102, 2012, pp. 184–192).

85. Ibid.

86. K.W. Easter and Y. Liu, “Cost Recovery and Water Pricing for Irrigation and Drainage Projects,” Agriculture and Rural Development Discussion Paper 26, The World Bank, Washington, DC, 2005.

87. United Nations Food and Agriculture Organization (FAO), FAOSTAT, 2012 (http://faostat.fao.org/default.aspx).

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Water and Food Security in the Arabian Gulf

Growing populations and economies have led to an increase in water demand around the globe. However, there are large variations in the amounts of water available to nations and regions, and growing concern surrounding the uncertainty associated with these supplies, due in large part to natural and human impacts on the water cycle.

Despite its high financial and resource costs, and the associated security risks, many see desalination as the only viable means of ensuring security of supply in the region.

Global food security also faces an uncertain future. The Arabian Gulf region suffers from a substantial food gap, as all the countries of the region are net food importers. The increase in the region's population, rising income levels, and harsh weather conditions that prevent the increase of local food production, have resulted in a vast increase in the region's food imports.

The ECSSR 17th Annual Conference, *Water and Food Security in the Arabian Gulf*, held at the Center on March 26–27, 2012 in Abu Dhabi, and the resultant papers contained in this volume, provide a detailed investigation of the food and water security challenges facing the region. They explore water and food resource management strategies and policies in the Gulf states, the global geopolitics of water security, future demand trends in the Arabian Gulf region, and the particular challenges faced by the UAE in ensuring a reliable supply of food and water in the coming decades.

ISBN 978-9948-14-622-3

9 789948 146223

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