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Water, Energy & Food Sustainability in the Middle East

The Sustainability Triangle

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Introduction and Scope

Adnan Badran, Elias Baydoun, and Sohail Murad

The importance of climate change and its impact on society in general is clear from the proceedings of the recent 21st Conference of the Parties of the UNFCCC (United Nations Framework Convention on Climate Change) in Paris and adopted by consensus on 12 December 2015.[1] The aim of the convention was as follows[2]:

(a) Holding the increase in the global average temperature to well below 2 °C above preindustrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above preindustrial levels, recognizing that this would significantly reduce the risks and impacts of climate change
(b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production
(c) Making finance flows consistent with a pathway toward low greenhouse gas emissions and climate-resilient development

Countries furthermore aim to reach "global peaking of greenhouse gas emissions as soon as possible."

While climate change is a problem that will challenge all countries, countries in the Middle East are especially vulnerable, because they are in a weak position to politically and economically cope with the expected damage to the environment

[1] "Framework Convention on Climate Change" (PDF). United Nations FCCC Int. United Nations. 12 December 2015. Retrieved 12 December 2015.

[2] "FCCC/CP/2015/L.9/Rev.1" (PDF). UNFCCC secretariat. Retrieved 12 December 2015.

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and the economic well-being of the region. This is primarily because many governments in the region are dysfunctional and are unlikely to undertake the long-term planning and complicated policies needed to cope with a changing world climate. Climate change has also resulted in major political upheavals in the area. In Syria, for example, the 5-year drought that began in 2006 resulted in drastically impoverishing farmers which led to their movement to urban areas, where no government support services were provided. This exodus led to unrest, social discontent, and tearing down the entire social and political fabric of the country – the consequences of this unrest are being felt all over the world, especially in neighboring countries and Europe. While climate change alone is not clearly responsible for the entire problem in, for example, Syria, it would be equally wrong to discount the role of climate change completely.

Most of the countries in the Middle East are essentially arid and receive very little rainfall (250–400 mm annually), and the expected drop from such limited amounts can be especially disastrous to domestic, agricultural, and industrial diversity.

Another problem facing countries in the region is the rise of sea level resulting from polar ice melts; for example, it is estimated that up to 30% of coastal areas could be submerged under water over the course of the twenty-first century in Middle East regions, such as the Nile Delta, the food basket of Egypt, where the sea level is expected to rise by half meter by 2025. The fertile Nile Delta provides around a third of the crops for Egypt's population of 80 million. "As a result, over half a million inhabitants may be displaced and approximately 70,000 jobs could be lost." Other estimates include serious threats to Alexandria, Egypt, of 4.1 million people and 40% of the country's industry. In addition, the Middle East is unlike other regions that are very susceptible to climate change in Asian and North American countries, where it imports almost half its food supplies. If food production in these areas is threatened, it could have additional impact on the Middle East.

According to the latest Intergovernmental Panel on Climate Change (IPCC),[3] higher temperatures (1–3 °C) are a likely outcome of climate change in the MENA region, and reduced precipitation will result in an addition of 80–100 million people in water-stressed areas. This will result in a decrease in agricultural yields, in rain-fed areas, coastal flooding, heat waves, and lower air quality, all further lowering the quality of life in the region.

There are, however, some encouraging signs. There continues to be increased awareness among decision makers in the Middle East region on the possible disastrous consequences of climate change, which likely is caused by the global increase in such awareness especially among the more enlightened leaders of the region. The awareness is also a result of more frequent droughts in the region and the worsening water supply shortage.

During the annual meeting of the Arab Academy of Sciences in Beirut in December 2015, as part of the final discussions, the urgent need of a book on the

[3]https://www.ipcc.ch/index.htm

consequences of climate change on the water, energy, and food triangle was discussed, as well as a comprehensive book that first describes the problem and then also provides possible solutions. This book is the end result of those discussions. The book is divided into three sections (although, as is often in science, the sections overlap). The first section is concerned with water. Water sustains life, environment, and development. Water crisis in terms of quantity and quality is a man-made disaster linked to the degradation of the life support ecosystem. The section on water includes chapters on the politics of water and the concept of virtual water, as well as water treatment and conservation strategies that are particularly applicable to Middle Eastern countries and are relevant for efficient agriculture. By 2050, it is estimated that half of the people on our planet will be living in water scarcity. Sustainable management of an integrated approach of water, land, and people for a sound ecosystem is needed. Sixty percent of renewable water resources in Arab countries originate from sources outside the region. Shared management of downstream with upstream riparian countries is imperative. The total Arab water resources is 371.8 billion m^3 distributed as follows: 41% Mashreq Arab States, 23.4% Maghreb Arab States, 31% Nile Arab States, and 4.6% Arab Peninsula (Gulf States).

Already one-third of the world population is living in water-scarce or water-short areas. Climate change will accelerate the figure to one-half; there are 13 Arab countries among the world's most water-scarce nations, and water availability in 8 Arab countries is less than 200 m^3/capita/year, less than half of the UN-designated water-severe country (UN severe water scarcity below 500 m^3/capita/year).

The Arab region houses 5% of the world population and occupies 10% of Earth space, with only 1% of world water resources. This is why the Arab region shares 50% of the world desalination capacity and is expected to double by 2020. Agriculture consumes 87% of available water resources, (the highest) as compared to 70% of the world average. The industrial sector consumes 7% and domestic use 6%.

It is a crisis of water management, fragmented institutions, inadequate policies and legal systems, lack of political will, and a widening gap between science and policy making at the national, regional, and global levels. Twelve percent of the world's population uses 85% of its fresh water. And water supply resources are being stretched to their limits. By 2050, an additional 3 billion people will be born mostly in countries already suffering from water shortage.

The second section is concerned with energy. Energy according to the IPCC Nov 2014 report; the world's electricity must be produced from zero carbon sources by 2050; otherwise, our planet faces irreversible damage. The report says renewables have to grow from 30% share of the power sector to 80% and all fossil fuel generation without carbon capture and storage (CCS) has to be phased out by 2100. Strategies to harvest it from abundant solar sources are suited to the Middle East, as it is situated in the desert sunbelt where sun is available over 90% of the year over vast areas in most countries of the region, as well as steps that can be undertaken for its efficient use as well as conservation. It includes producing hydrocarbon fuels from lingo-cellulose (agricultural waste is one such example). This is especially suited for many already oil-producing countries in the area since it eliminates the need for new infrastructure for ethanol-based fuels, for example. Two chapters focus on two important alternate energy sources that are especially important for the Middle East, viz., solar energy and wind energy. Morocco is an advanced country in utilizing renewable energy, sun and wind, in their energy mix. The Desert Tech Solar Project is aiming to export electricity by feeding it to the grid of Europe from the North Africa MENA region. Jordan although is moving slowly because of its governmental bureaucracy and insufficient grid capacity to accommodate renewables and is targeting to achieve 10–20% renewables in the energy mix by 2020. Emirates and Saudi Arabia have ambitious plans, in advancing renewables to reduce dependence on fossil fuel energy. Experts say that renewables have to grow to 80% share of the power sector by 2050.

Two final chapters focus on energy conservation strategies. The first focusses on the use of phase change materials (PCM) for both energy storage during non-peak and peak hours and other simple steps that can be taken to reduce energy usage. The second describes NetZero energy building that can either be designed or retrofitted to make them more efficient during renovations. Finally, to demonstrate the close connection between water and energy, a chapter is included on strategies to minimize energy use for water treatment technologies. This chapter serves as the link between the sections on water and energy. This chapter then leads to the last section on food.

This last section of the book addresses issues related to food. Included are chapters on food safety and security as they pertain to specific conditions in the Middle East. Because of the abundance of sea water in many Middle Eastern countries, one chapter focuses on agriculture based on saline (brackish) water as well as improving fresh water use efficiency. In addition, there is also a chapter on the diminishing arable land in the Middle East and how erosion can be minimized or reversed. There is also a chapter on the impact of food losses and waste on food security since losses constitute over 35% of food produced in the region. Finally, a chapter is included which discusses the technologies available for agriculture in water-challenged regions, especially those areas dependent largely on rain water for agriculture.

With climate change and managing scarce resources of water, food and water are inextricably linked. Therefore, food security for self-sufficiency could be achieved through right policies, improved agricultural and irrigation technologies with high-yield cultivars suitable for semiarid zones, and conservation of water through protected agricultural innovative practices to bring down the high use of water of 87% to the world average of 70%.

There is no doubt that the Climate change and Water – Energy – Food security Nexus in the Arab Middle East, is becoming more complex due to rapid population growth and growing demands by industrial and agricultural developments. Therefore, science becomes crucial in providing the basis for sound governance and a holistic approach enlightened policy linked to energy and water management for sound food security.

Contents

Part I
Water

Elias Baydoun

Climate Change and Water Science Policy in Management

Adnan Badran

Abstract Water sustains life, the environment and development. Human rights to water, as water is becoming a commodity threatens the poor. Global water crisis in term of quantity and quality is a man-made disaster linked to environmental imbalance and degradation of the life-support ecosystem. It is a crisis of water management, fragmented institutions, inadequate policies and legal systems, lack of political will, and a widening gap between science and policy making at the national, regional and global levels. Already one third of the world population is living in water-scarce or water-short areas. Climate change will accelerate the figure to one-half. 12% of the world's population uses 85% of its fresh water. And water supply resources are being stretched to their limits. By 2050 an additional three billion people will be born mostly in countries already suffering from water shortage.

According to the IPCC-Nov 2014 report, the world's electricity must be produced from zero carbon sources by 2050; otherwise, our planet faces irreversible damage. The report says renewables have to grow from 30% share of the power sector to 80%. And all fossil fuel generation without carbon capture and storage (CCS) has to be phased out by 2100.

Global warming is unequivocally linked to human interference in the ecosystem, causing glaciers to melt on the polar ice caps resulting in the rise of sea level flooding of agricultural coastal areas. The Nile delta, which is the food basket of Egypt housing 46 million people, may disappear. Coastal fresh water aquifers may be flooded by seeping seawater threatening food security of many large regions of the world.

With the advent of climate change, most of water stressed areas particularly in arid and semi-arid zones (Middle East and MENA regions) will face a rainfall decline of 20% and a temperature rise of 2–3 °C that would result in large losses of water resources, basic food, basic needs, and increased poverty.

Water science is a "must" in developing a unique water management scheme. It contributes to well-defined policies for efficiency, sound strategy and sustainable plans of action. There is unlimited potential with what science can do on our planet,

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where salt water and fresh water comprise 97.5% and 2.5% of planet waters, respectively. With 70% of waters tied in polar caps, only 30% is left in rivers, lakes and ground waters to humanity.

Food production accounts for 70% of water used in the world. Through the efficient use of water by renewables for desalination, recycling water for agriculture, using new cultivars under stress of low level of waters and brackish waters and genomes resistant to pests and droughts etc., have to intrigue scientists in our part of the world to find a lasting solution to the challenging problem.

Fundamental change in water policies and engaging science to develop a unique water management scheme is imperative. Currently, water policies are divorced from sound science. Demands should be managed by a new culture of efficiency, cutting losses, and protecting water from overuse and pollution.

There is no doubt that the Climate change and Water – Energy – Food security Nexus in the Arab Middle East, is becoming more complex due to rapid population growth and growing demands by industrial and agricultural developments. Therefore, science becomes crucial in providing the basis for sound governance and a holistic approach enlightened policy linked to energy and water management for sound food security. The potential of what modern science R&D can do is without limits.

Keywords Climate change • Water management • Global warming

Introduction

The improvement of water management techniques and technologies needed to cope with the projected increase in water scarcity will require new water science as well as extensive use of existing water science. Future water policies will have to be well informed by science if they are to be effective. Many existing water policies are not based on sound science and are aimed at goals other than ensuring that water is used efficiently, protected from qualitative degradation and maintained for future generations. The potential of science to contribute to the resolution of current and foreseeable water problems is virtually unlimited. There are numerous examples.

At the global level, the developments from nano-science can help in a variety of ways. Development of more effective ways of cloud seeding; development of nano-membranes for cleaning polluted water and improvements in diffusion technology which will lower the costs of desalination are important examples. Development of small-scale solar technology can improve energy generation and thus lower the costs of desalination. The importance of such a development can be illustrated by reference to the MENA region where solar energy falling on one square meter of surface annually is the BTU equivalent to one barrel of oil. Currently, the Arab region, with 5% of world population, produces 50% of desalinated water of the world (AFED 2010). Technology can help to extend the application of desalination and other water cleansing techniques to other areas throughout the world.

At the regional level, scientifically based management of shared water resources, whether surface or ground water, should be placed high on the agenda of countries with shared water basins. Effective bilateral and/or multilateral agreements should lead to stronger economic and political ties among countries with shared water-basins obviating the potential for conflict. The importance of dealing effectively with shared water is almost self-evident. This is particularly true in the MENA region where, "Of all renewable water resources…., two thirds originate from sources outside the region". (AFED 2010; El-Quosy 2009)

At the national level, science can contribute to the acquisition of knowledge about possible new water sources and about the application of techniques for using existing sources more efficiently. Thus, for example, agriculture accounts for 85% of water use in the Arab region as compared with a world average of 70%. On-farm irrigation efficiency remains at 35% so there is clearly room for improvement at the farm level (AFED 2010). Science can also contribute to the development of new crop strains that tolerate better both aridity and salinity. Rain-harvesting systems and efficiency improvements in science-based agricultural practices to achieve water savings should be emphasized. Other policy reforms leading to a new political economy of water management could focus on the acquisition of water "virtually" through imports of crops "from water-rich countries, while allocating scarce water resources to low-water consuming, high value crops that can generate foreign exchange". (AFED 2010, page 61).

In this way, food security may be achieved through a set of well-balanced trade and water management policies.

One potential new source of water is recycled wastewater. Wastewater generated by domestic and industrial sectors in the Arab region totals 10 km^3/year, of which 5.7 km^3 undergoes treatment. Of this volume of treated wastewater, only one third is reused. However, wastewater treatment plants currently handle waste loads that exceed their capacity limits. The untapped potential of wastewater should be the focus of appropriate policy interventions including national water management strategies for water reuse.

The focus of this chapter is on the importance of science in fashioning enlightened water policies to manage the intensifying global water scarcity. In the following section, the importance of water in sustaining life, the environment and economic development is discussed. Subsequently the decline of available water resources is characterized. The following sections focus on the importance of water science to fashioning solutions to the global water crisis; on the needs to build scientific competence and capacity and on issues related to making science based water policy. An important underlying theme that runs throughout the chapter is that the existing water scarcity in the arid and semi-arid Arab countries lies at the extreme edge of the global water scarcity picture. Moreover, it offers to other parts of the world, particularly those that are arid and semi arid, a picture of the future water situation likely to be visited upon them if the current situation is neglected.

Water Sustains Life, the Environment and Economic *Development*

Fresh water is tiny proportion of the water resources on earth, with salt water accounting for 97.5% of planetary waters and fresh water for only 2.5%. Seventy percent of the fresh water is tied up in polar caps, glacial ice and groundwater at inaccessible depths. This means that 30% of available freshwater or only 0.75% of total water supplies are available to humans for various uses (Shiklomanov 1997). Human water endowments, which are found in lakes, rivers and accessible ground, are but a tiny proportion of the total planetary water endowment. As documented by Vorosmarty et al. (2010) and others, water endowment is distributed unevenly around the globe in both spatial and temporal terms. This means that there are times and places where water is especially scarce as well as times and places where it is reasonably plentiful. This is shown in Fig. 1 where it can be seen that renewable fresh water is relatively scarce in the MENA and South Asia regions and relatively plentiful in the Americas, Australia and New Zealand. It is also important to recognize that there is significant variability within each region exhibited by water sparse and water rich locales.

The importance of water in sustaining life, the environment and development has been acknowledged in the Dublin-Rio water principles (Assaf 2010). In addition, Article 25 of United Nations Declaration of human rights 1948 (UN-Human-Development report 2006), that:

> Everyone has the right to a standard of living adequate for the health and well-being of himself and his family, including food, clothing, housing and medical care and necessary social services and the right to security.

Although water is not acknowledged explicitly, it is a crucially important part of the daily human diet and sustains life. It should be recognized that some efforts to manage water sustainably have unintended side effects that could have been predicted. A case in point is the treatment of water as a commodity, a practice that threatens the poor. Privatization of water resources has reduced the availability of fresh sanitary water. Two in three people survive on less that $2 a day and are simply unable to pay for water for simple washing, cooking and sanitation needs. One proposal for dealing with the problem is to create an escalating price system based on the quantities of water used. Under this system, costs to the poor are minimal since they use small amounts. This proved to be an effective social package policy related to poverty.

As resources are decreasing in quality and quantity, water policies promoted by developmental agencies with governments have concentrated on comprehensive integrated ecosystem of water management. Expanding demands for domestic, agricultural, and industrial water uses have made water a scarce resource in some countries in the Middle East where total water withdrawals exceed renewable water resources. In fact, most Arab countries are already below the water scarcity level (Plan Blue UNDP Database 2005–2009).

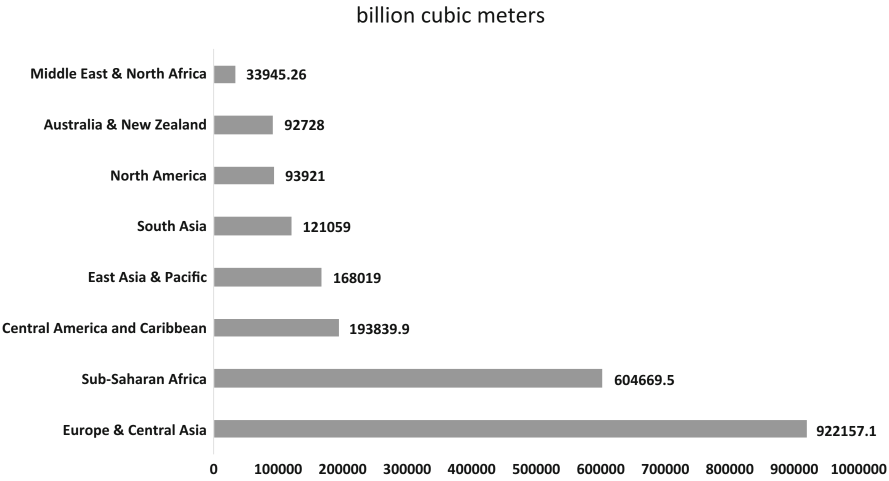

Fig. 1 Renewable internal freshwater resources per capita, by region 2014 (FAO 2016)

Therefore, science based water policies, strategies and management regimes are crucial if supplies, demands and allocations among stakeholders are provided in a balanced fashion that incorporates fairness and efficiency.

Fresh Water Resources Are Becoming Less Available

The UN & UNESCO classify rich-water countries as those who secure 8000 m^3 per capita per year. The World average is estimated to be 6000 m^3 per capita per year. Water scarce countries are defined as those with annual allocations below 1000 m^3 per capita while allocations of below 500 m^3 per capita per year constitute severe water scarcity. Annual per capita endowments of renewable water resources are shown for the 25 most populous countries in the world in Fig. 2. Global per capita renewable fresh water resources are declining at significant rates. Rayne and Forest (2013) reported “substantial reductions of global per capita stock of 54% between 1962 and 2011. There was a decrease of 75% in sub-Saharan Africa, 71% in the Middle East & North Africa (MENA), 64% in South Asia, 61% in Latin America and the Caribbean, 52% in East Asia & the Pacific, and 41% in North America”. At current rates of depletion, global per capita renewable internal fresh water resources are projected to decline from levels observed for 1962 by 65% by 2020. Thirteen Arab countries are among the 19 most water scarce nations in the world (Jagannathan et al. 2009). Per capita water availability of eight of those countries is below 200 m^3, less than half of the level that the UN defines as severe scarcity. Per capita annual renewable freshwater resources for the MENA region are expected to decline from 1962 values by 80% in the year 2020.

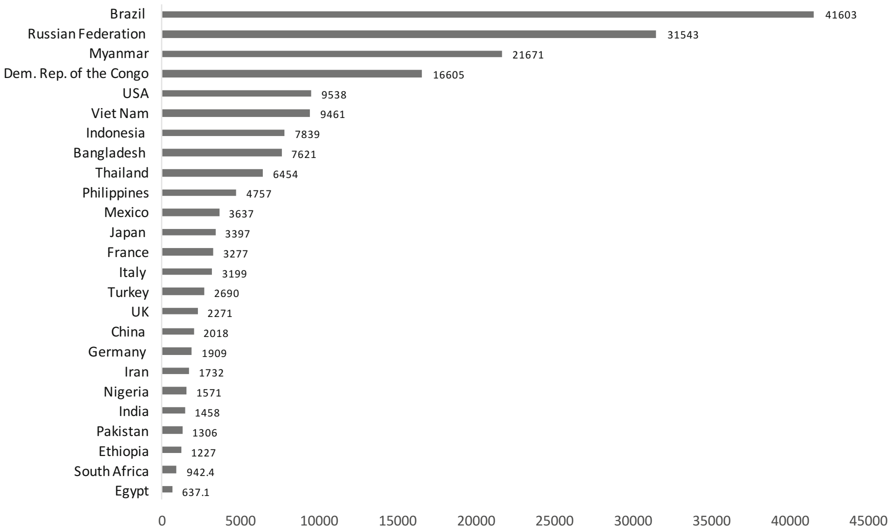

Fig. 2 Total renewable water resources per capita for the 25 most populous countries in 2014 (in 1000 m^3 per person per year) (FAO 2016)

The reasons for this decline are many and the importance of each varies by region. Population growth, which has occurred in all regions, is an obvious reason. Declines in the availability of the water resources also account for diminishing per capita availability. The world-wide trend of declining water quality means that there is less water available for consumptive uses. Declining water quality reduces available supplies just as surely as drought. Lower per capita endowments also result over time when non-renewable resources of water are persistently utilized as long-term supplies. Fossil ground water and quantities of water that are over drafted from renewable aquifers are the most obvious examples of non-renewable supplies. Persistent withdrawal of such supplies depletes them to the point where demand pressures (that were previously supplied by non-renewable sources) fall on renewable sources that are physically substitutable. A final explanation is climate change, which has occurred in the past and is expected to occur in the future. This means that for some regions water is less available than it was historically.

The picture that emerges, then, is one of intensifying scarcity. The fundamental cause of the intensifying scarcity is bound up in the fact that demands for water are growing at the same time that available supplies of water of appropriate quality are shrinking. Some of that scarcity is self-inflicted owing to the absence of effective water policies and management regimes. Some of that scarcity can be avoided by employing existing science in the making of policy and in the fashioning of improved techniques and technologies, which will permit water to be used both more efficiently and more extensively than it has been in the past. Commitments to programs of research and development will also be required since science is needed as a basis for the public policies and innovative technologies necessary to confront and manage the emerging global water crisis.

The Need for Science and More

There is little argument that science will need to be at the foundation of the policies needed to address the intensifying water scarcity. Nevertheless, while existing science and science to be developed in the future will be crucial, science by itself will not be sufficient to resolve global and regional water problems. Other needed elements will include the process of adapting scientific findings for use in managing water resources and building the necessary institutional linkages to facilitate the use of science in the making of policy.

Science As shown in Fig. 3 world-wide spending on research and development has grown from $522.5 million in 1996 to $1.275 trillion in 2009. Most of the growth was accounted for by OECD countries. Additionally, total spending on R&D as a percent of Gross Domestic Product ranged from 1.2% (Spain) to 3.37% (Sweden) as shown in Fig. 4. That figure also shows that the private sector contributes more than the public sector for the countries listed.

These figures mask several important facts about the investment in scientific research related to water. First, water is not large or even constant percentage of the research budgets of any of the nations considered. Moreover, it is not unreasonable to assert that water research budgets have not grown in parallel to the total R&D budgets over the period in question. Thus, for example, in the United States public spending on water research in real terms (adjusted for inflation) was at the same level in 2000 as it had been in the late 1970s and did not grow in parallel with the substantial growth of general R&D over the same period (National Research Council 2004).

A second important fact about investment in R&D generally and water research specifically is that there is a great deal of variation between countries and regions. Badran (2005) provided a comprehensive review on the state of science in the Arab region. He concluded that the region exhibited poor performance in science and technology. This was attributed to political turmoil, low quality education, and an inadequate R&D infrastructure. In short, the region has failed to deliver high quality science and failed to build capacity in R&D (Badran 2013). This has resulted in low rates of innovation and a below average evolution to a knowledge based economy compared to the rest of the world. The results are summarized in Figs. 5 and 6, which indicate that the scientific research personnel per million inhabitants varies but is generally low in the Arab States. Only Africa has fewer scientists per million inhabitants. Figure 7 shows that in the Arab region only 0.2% of GDP is directed to R&D and most of that is public sector or governments.

This measure of research capacity contrasts with the general levels of water availability and the effectiveness of water management in the region. With the

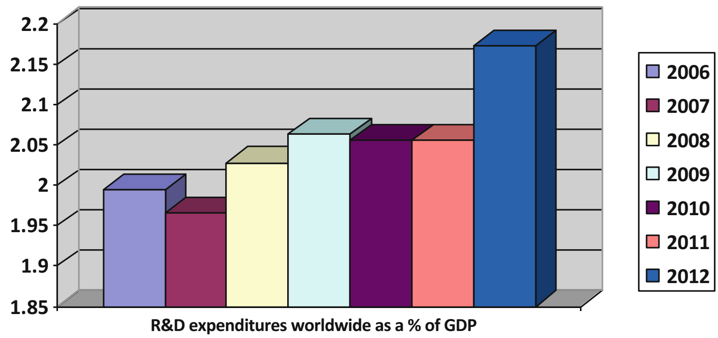

Fig. 3 R&D expenditures worldwide 2006–2012 as % of GDP (*United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics*. ***License:Open***)

Country	Spending on R&D(% GDP)	The contribution of private sector (% GDP)	The contribution of public sector (% GDP)
Sweden	3.37	2.79	0.94
Japan	3.39	2.62	0.77
Finland	3.37	2.46	0.91
USA	2.61	1.84	0.77
Germany	2.53	1.77	0.76
France	2.09	1.34	0.75
Eu (27 countries)	1.84	1.11	0.73
China	1.42	1.01	0.41
Italy	1.9	0.54	0.55
Spain	1.20	0.67	0.53

Fig. 4 Expenditure on R&D: The contribution of private sectors vs. public sector (*United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics*. ***License: Open***)

exception of Sudan and Iraq, all Arab countries are water-poor. In agriculture, there is an effort to utilize technology for saving water in irrigation but the effort needs expansion. Also, the bio saline center for agriculture in Abu Dhabi is developing sustainable crop production by using saline water (Badran and Zoubi 2010) and this effort also needs to be built upon. In another area, research-based universities in the MENA region have started to give priority to research focused at the nexus of water and energy for a sustainable model of technical knowledge and a system linking technology with policy. Badran (2011) has found a strong connection between human rights, levels of R&D and rates of innovation. Indicators have shown a strong correlation between human rights as a contributor to effective science and technology among Islamic (OIC) and Arab countries. Globally, the World Bank

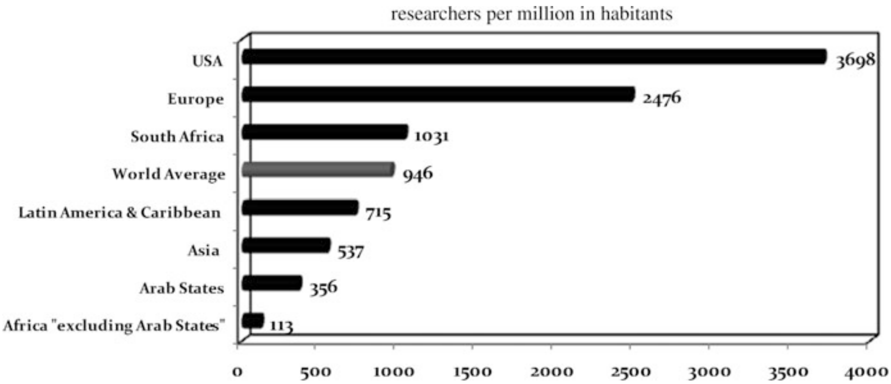

Fig. 5 Researchers in the Arab region as compared to other regions of the world (*Source: UNESCO Institute for Statistics 2012*. ***License: Open***)

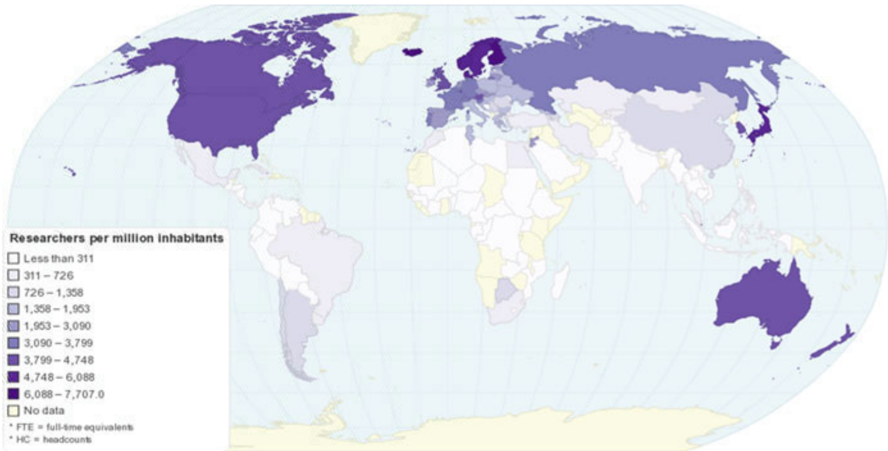

Fig. 6 Researchers Per Million Inhabitants, 2010 (*Source: UNESCO Institute for Statistics 2012*. ***License: Open***)

found effective performance of water research in various sectors such as agriculture, but concluded that very little of this was being conducted in the Arab region (World Bank 2008). In another report, the Bank concluded that when compared with other regions water science was at a low level in the Arab region (World Bank 2007). Demand for water research is not yet an integral part of water policy in many countries in the region. There are, however, a few bright and promising spots such as the Masdar Institute in Abu Dhabi, Kaust in Saudi Arabia and the Science and Technology Foundation in Qatar.

Taylor et al. (2008) identified constraints on the ability of science to influence policy in water management in the MENA region as follows:

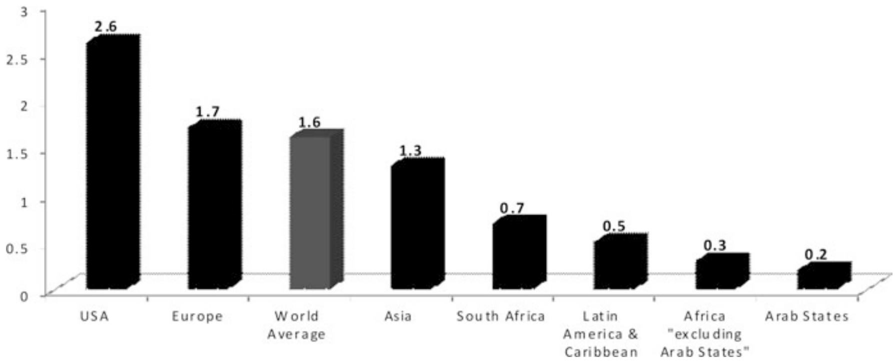

Fig. 7 Gross expenditure on research and development (GERD) as % of Gross Domestic Product (GDP) (*Source: UNESCO Institute for Statistics 2012. **License: Open***)

- "The unavailability of a critical mass of competent researchers in the region.
- The management and leadership of research organizations are ineffective.
- The linkages between research and policy communities are not established.
- Career opportunities in the region for researchers may not be compelling enough to retain them.
- Limited connectivity to international research communities hampers professional growth, learning, and exposure to new ideas, all of which are vital to the success of careers in research.
- Many organizations in the region lack an internal research agenda that is "owned" by the organization itself. Many research organizations feel obliged to follow donors' agendas, which are not necessarily aligned with community or national needs. Consequently, researchers may feel "sub-contracted" to pursue the agenda of others, leading to frustration and a sense of disempowerment.
- Organizations whose primary goal is to influence policy will often resort to recruiting well-connected and reputable researchers in order to increase policy makers' confidence in their research. However, reputation in the Arab region seems to be closely associated with seniority rather than performance in terms of relevant, high quality research. The importance of seniority appears to make it difficult for young researchers to attract funding or support for their own research ideas."

Building Scientific Capacity and Infrastructure

In regions where science needs to be more available to support water policy-making, the scientific community needs to identify research priorities. The research itself should be conducted in an integrated and interdisciplinary fashion, which will allow scientists to find solutions to complex problems arising from an increasingly dynamic environment. The international water research community should be involved in strong partnerships that are appropriate and feasible. Simultaneously efforts should be made to improve and expand the educational opportunities for young scientists with interests in hydrology and related water disciplines. An interdisciplinary approach should be part of the educational and training effort. It no longer suffices for water research to be done exclusively by agricultural schools or civil engineering departments, as has been the case in the past. Rather water science needs to be viewed for both educational and research purposes as an integrated and interdisciplinary field of endeavor.

In Germany, there are 500 institutes conducting research on water and related fields. The resulting fragmentation of the research structure can be attributed to the heterogeneous funding system for universities and research institutions. To combat this, a "water science alliance" was formed in 2009 with the aim of joining and strengthening existing competences in water research and creating a framework for complex research in water sciences over the foreseeable future. The alliance is a tool for bringing together and interlinking leading groups and institutions in "thematic clusters" to conduct research leading to concrete solutions to water problems. The alliance will bring synergy and added-value by integrating different disciplines (Teutsch and Krueger 2010). This is one model that has great promise in reducing fragmentation and creating integrated programs of water research.

In Australia, South East Queensland (SEQ) has faced intensive pressures on its water resources, which may be compounded by climate change. An alliance for scientific research on water was established as a partnership between the Queensland Provincial government, the Commonwealth Scientific and Industrial Research Organization (CSIRO), and the University of Queensland and Griffith University. The resulting partnership was to tackle problems of uncertainty and development of a strategic plan for managing the water resources of SEQ. It was supported with a $50 million appropriation over a period of five years (Clayden et al. 2010). Specific elements of the task include:

- Ensuring the reliability and safety of recycled water.
- Identifying needed infrastructure and developing needed technology for recycling waste water and storm water.
- Building scientific knowledge into the procedures for planning and management of water supply systems.
- Developing methods for increasing public confidence in water supplies of the future.

Integrated water management analyses have shown that coordinated development of water, land and related resources cannot be solved by structural measures alone, but require linkages of knowledge with action for sustainable development. Institutional and organization structures that effectively link scientific knowledge to decision-making contribute to problem solving and innovation for integrated urban water systems.

There is also a need for business-based models for technology transfer. These can be established by research managers in the form of incubators and science business parks. Funding mechanisms that are mostly governmental tend to be inadequate and not sustainable. Although external funding has contributed importantly to meet water research challenges, the emerging research agendas were not based on national needs, but rather on the donors' agenda. High quality research requires a national science and research agenda, political endorsement, outstanding research managers, as well as sustainable funding and linkage between research and policy (Laarmani and Salih 2010). Ultimately, water decision makers must employ the results of carefully targeted research and development in establishing water policy or the most important water challenges are unlikely to be addressed.

Bridging Science and Policy

Interactive knowledge sharing in the development of policy for the sustainable management of water resources is sometimes hampered by stakeholders who oppose certain policies on political or ideological grounds (Howari 2008). Solid scientific knowledge can provide the basis for a credible common ground among stakeholders and lead to effective science-based water policies. The key element in linking science to policy is governmental requirement that research be used in the formulation of policy (Carden 2009). Taylor et al. (2008) found in a survey that building institutional relationships between independent or private research organizations and policy-making bodies is difficult to sustain.

A UNESCO International conference held in 1977 on multiple uses of water and integrated water management is seen by many as the genesis of integrated water management. Many countries including the United States, South Africa, Australia and the United Kingdom have adopted integrated watershed management as the fundamental approach to water policy. Powerful environmental movements in North America and Europe in 1980 were confronted with existing governmental policies that have concentrated exclusively on economic growth, with no equity and sustainability.

Global efforts that resulted in the development of the Dublin-Rio water principles for a holistic approach for integrated water management (Assaf 2010) gave further voice to the notion of integrated watershed management.

- 1st principle: Fresh water is both of finite quantity and essential to sustain life, development and environment. Fresh water is needed to maintain all forms of life and for socio-economic human development.
- 2nd principle: Management should include participation of stakeholders, users and policy-makers.
- 3rd principle: Women should be purposefully involved in the making of water policy and in water management. Women in rural areas spend most of their time looking for water and carrying it over long distances.
- 4th principle: Water has an economic value and should be considered as a commodity.

The last principle, which leads to the pricing of water, is not popular unless the poor are secured and consumers understand the value of water, so as not to pollute it or waste it. Still in many countries, water is perceived as a public good. After all, research for water policy should be conceived of within the framework provided by the notion of integrated watershed management.

The concepts of green water, blue water and virtual water also need to inform the research-policy interface. Green water is the soil moisture within two meters depth which is made available for absorption by the root system of the plants. Additionally, it contributes to water vapor in the atmosphere through direct evaporation or transpiration from plants. To conserve green water, soil ploughing particularly for rain fed summer crops and fallowing is practiced. Also, the use of plastic culture to conserve soil moisture has been found effective as a water-management technique. Engineered crops that utilize less water and sometimes are subject to moisture stress, is another way to conserve green water. The management and manipulation of green water is a highly promising area for water research and development.

Blue water is found in rivers, lakes, aquifers. It includes transboundary waters, whether surface waters or aquifer waters. Globally, blue water is becoming fully appropriated. This means that research should be directed at means for economizing on blue water but also at economical ways of using green water. Protecting blue water from pollution and from diversions that are not renewable are other ways to conserve blue water.

Virtual water is water embodied in foodstuffs and other commodities which can be imported. It permits water short countries to acquire water from water-rich countries and utilize internal supplies to grow high valued crops that will generate foreign exchange. The figures below show the quantities of virtual water that are embodied in wheat, rice and red meat.

Jordan's Water Situation: A Case Study

In Jordan, there is a strict policy on national (as opposed to transboundary) water aquifers. Hydrological studies and geological surveys have been done to provide the basic data needed to manage ground water. No new licenses are offered for drilling water wells, with few exceptions for university campuses and hospitals. All wells are controlled and supervised by the water national authority, where meters are installed and monitored very closely. The amount of water pumped out from the underground is measured and actions are taken accordingly.

The landscape of water resources in Jordan is as follows:

1. **Rainfall distribution of water in Jordan**
   - 8200 million m^3 annual rainfall, 80% loss to evaporation.
   - 1640 million m^3 annually left: (Haddadin 2011)
     - 510 million m^3 blue water – surface.
     - 200 million-m^3 ground water blue water - aquifers.
     - 860 million-m^3 soil moisture green water-soil moisture.
     - 70 million m^3 reclaimed water recycled water.

2. Jordanian share from transboundary annually (Blue water):
   - 80 million m^3 Yarmouk transboundary basin (original 296 million m^3) according to Johnston plan of distracting between Syria. Israel and Jordan.
   - 60 million m^3 Tiberias.
   - 68 million m^3 Syrian-Jordan underground basins.
   - 100 million m^3 Saudi –Jordan basin underground (Disi).

   Total: 1948 million m^3 annually (314 m^3\capita\year), which puts Jordan according to UN classification as a severely water scarce country. Virtual water is hard to calculate since there are both imports of meat, grains, fruits and vegetables as well as exports of fresh produce.

1 kg wheat	**Needs 1000 liters of water**
1 kg rice	**Needs 1400 liters of water**
1 kg red meat	**Needs 13000 liters of water**

Research aimed at developing technologies and techniques for exploiting green water, conserving blue water and identifying economical opportunities to acquire virtual water is needed.

Finally, demand management policies, which emphasize on rationing or economizing on water have not been fully utilized though many of them have a strong basis in science. Any research that can increase the public acceptability of demand management policies will be helpful.

Scientists and Policy-Making Scientists in the labs and the field believe that their mandate is to create knowledge and disseminate it through publication in peer-reviewed journals – that is it. Other professionals should take the task of bridging the scientific findings with policy and decision-making. Therefore, the missing link in politics is to bridge science output with policy. Carden (2009) suggested the creation of knowledge brokers, such as Intergovernmental Organizations (IGO's) or Nongovernmental Organizations (NGO's). The National Water Research Center of Egypt is a consortium and is an ideal mechanism. The Royal Water Commission in Jordan and the Higher Council for Water and Climate in Morocco are other examples.

Policy-science interaction (PSI) in the water sector aims to bridge the science-policy gap with different types of knowledge brokering instruments (KBI) at national and regional levels. KBI aims to increase the quality of science-policy interactions by positioning the public to learn about the complexity of the issue, and by understanding the impact of driving forces affecting their future.

The major challenge to sustainability is how to use science to overcome uncertainty in basic issues of agenda **21** related to environment and development (Earth summit Rio 1992). These are complex issues and cannot be addressed except through alliances and interdisciplinary, holistic approaches of physical, life sciences (hydrology, ecology, agriculture-human food and health... etc) and social sciences (policy, social sciences, economics, human development etc.). An approach of this type will lead to a physical-social earth agenda for the use of natural resources linked with managerial skills responsive to stakeholders.

Escalating pressure on less than 1% of the world's total supply of water is made more difficult to manage because of population increase and is exacerbated by climate change and degradation of water quality. In addition, research activity is fragmented and poorly linked to policy and management needs (jimwallace@easynet.co.uk). The UNESCO and WMO set up the HELP (hydrology for the environment, life and policy) initiative to deliver social, economic and environmental benefits through the sustainable use of water by deploying hydrological science, which is an interdisciplinary science to achieve integrated catchment area. The objective here is to form a global network to bring together hydrologists, water resource managers, and policy and legal experts to address water issues defined by local stakeholders (www.unesco.org\water\ihp\help). Twenty-five basins were established from different climatic, social and economic regions around the world. These basins will serve as "outdoor labs". The main outcome is to integrate hydrological, social-economic and legal research responsive to related water-policy. HELP has created a platform for dialogue between physical and social scientists, water resource managers and policy makers.

Conclusion

Analyses of science-links-policy in water management in the MENA region show that water research is not part of the water policy-making. There is an absence of cutting-edge scientific research, and linkage of knowledge to policy is not well developed. There is a lack of national science and technology policy and coordination. Agendas may be dictated by donor agencies and water policy is influenced by politics of interest groups more than by science-based discourse. Capacity building in training scientists to excel in water research is needed. This requires a national agenda that includes water research priorities, political commitment, sound research management, sustainable funding, manpower plan to attract outstanding scientists and to send outstanding graduates abroad on scholarship in distinguished institutions for Ph.D and postgraduate studies to develop the critical mass in water research nationally.

Conferences and other interactions between scientists, planners, communicators, managers and public officers, should bring water science to the policy making process for water management.

Stakeholders should be engaged in water policy-making and they should utilize knowledge in overcoming differences. Universities and research centers should develop water science research groups to tackle priorities of the water sector. This will develop an interdisciplinary approach that will pool resources and develop the critical mass of the know-how and attract funding for joint proposals related to the water national agenda.

National water agendas should not be subjected to the whims of outsiders but international scientific cooperation with world-class research institutions should be encouraged and maintained. Scholars should produce tangible scientific results that are perceived by the government as credible. Research must be placed at the center of water policy and governments should implement sustainable water policies to rationalize demand to ensure efficient use. The government's role should be shifted from being an exclusive provider to being an effective regulator and planner.

A report from the economist intelligence unit published recently on challenges to meet water supply in 2030, emphasized that shortage and stress will yield scientific innovations. The report (2012) cited a few promising technologies:

– Lower-cost water desalination: carbon nano-tubes with membranes to radial deionization for removing salts from water.
– Better wastewater reuse: R&D is cutting energy now by 30–45%**.**
– Managing aquifers recharge: storing surplus water

Finally, with the right political will and consumer backing, water stress will force technology development and innovation in all phases of the water cycle.

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The Triangle: Energy, Water & Food Nexus for Sustainable Security in the Arab Middle East

Peter Rogers

Abstract This chapter examines water security in the broader relationships governing the Food-Water-Energy-Climate Nexus. It particularly stresses the role of the great global transmissions of the nineteenth and twentieth centuries in presenting intractable barriers to returning to less complicated eras of resource conflicts. These transitions are manifest in total and urban populations' growth and shift to urbanization; radical shifts in the nutrition demanded by the new economic and social developments; the radical changes in land use and chemicals in agriculture; a rapid shift in emphasis on renewable energy resources and reduced reliance on fossil fuels; and finally the great challenge of climate change. All of these transitions have major implications for water security both globally, and regionally. Globally this is well articulated by DuBois (The case for "energy-smart food for people and climate". Food and Agriculture Organization of the United Nations, World Food Day-Oct 16, 2015):

> Our agrifood systems currently consume 30 percent of the world's available energy—with more than 70 percent occurring beyond the farm gate, and produce about 20 percent of the world's greenhouse gas emissions. More than one third of the food we produce is lost or wasted, and with it about 38 percent of the energy consumed in the agrifood chain.

To this we can add that the greatest loss of water in the overall national water balances is that of the water used to grow the food that is wasted.

While the water security situation for the Arab Middle East Region is generally considered bleak, the paper is fairly optimistic that, at least water resource use, until 2050 will be still manageable if the eleven "technical fixes," outlined in the paper are pursued. These technical fixes are not to be construed as purely engineering the water supply, but fixes to many of the economic and social barriers to a more secure water future. They cover major national policy choices such as international trade in virtual water, traditional water engineering of traditional and non-traditional sources, improving efficiency in use via agronomic research, improvement of post harvest food and value chains, and softer options

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such as trading among users, pricing, rationalizing property rights and legal protection for third parties.

Keywords Agrifood • Water security • Food security

Origins of the Concept of an Energy, Water, and Food Nexus

While the concept of the energy, water and food Nexus has been discussed for about a decade, only recently has there been a plethora of reports by major agencies, institutions, and academics. So much is now available that it is impossible to analyze all of them and arrive at a coherent picture of the whole. For example, Allouche et al. (2014) are skeptical that there is anything new in the reframing of water security and climate change in this way, and that it may not provide new and innovative solutions to water, food, and energy problems. Even the title of their report (Nexus Nirvana or Nexus Nullity) expresses a lack of confidence in the usefulness of the concept. However, Unver and Pluschke (2015) perhaps reflecting FAO's institutional biases, see the Nexus as "not only relevant, but also potentially preferable to the more traditional approaches." This is probably the most widely held view of the concept.

The World Bank has been a major contributor to the literature of the Nexus generally, but also of its analysis of the Middle East and North African (MENA) region (Hallegatte et al. (2012), Ray et al. (2015) for examination of the concepts, and Verner and Breisinger (2013) for specific country analyses). The Arab Forum for Environment and Development (AFED) was an early contributor to the debate over the Nexus (see Tolba and Saab 2009) as was the Arab Organization for Agriculture and Development (AOAD 2012). The FAO has also been a major participant in the discussion, as for example, through its Swedish FAO Committee (2014). The various bilateral agencies have been very active in promoting the concepts and potential remedies. For example the USDA's contribution stressing the Nexus, was released as late as December 1, 2015 to the Paris COP 21 (USDA 2015). The International Food Policy Institute (IFPRI) has made several country specific studies in the MENA region (Breisinger et al. 2010, 2012).

Academicians have weighed in recently with many journal articles; as for example, in the September 2015 special issue, volume 31 of the *International Journal of Water Resources Development (IJWRD)* devoted to the Water-Food-Energy-climate nexus (see Allan et al., 2015). This issue should be of great interest, and required reading, for regional resources managers and policymakers. The journal *Water* has also published several papers this year (see Endo et al., 2015).

There are two lengthy political commentaries Waterbury (2013) and Greenwood (2014) focusing on climate change, and political economy and governance of the Arab nations. Each focuses on the role of the components of the Nexus, not the Nexus itself. Both conclude that the water, food, and energy problems are extremely serious, but with Waterbury saying more depressingly "Despite the apparent urgency of the challenges facing the Arab region as a result of climate