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Water Security: Supplies, Resources, and Uncertainty

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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 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.

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–

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 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.

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]