Biofuels and Global Water Challenges[1]

INTRODUCTION

With increasing population, growing food requirements, industrialization and urbanization, the world is on the brink of an unprecedented water crisis. While the water crisis can partially be attributed to the uneven geographic distribution of water, the situation has been exacerbated by the absence of appropriate national and international policies that ensure sustainable use of water. Water is likely to be the most important strategic resource by the end of next decade and key to achieving economic development.

Yet, in the context of biofuel development, there has been very limited awareness and discussion of the water crisis. The current biofuel development strategy may aggravate the water crisis, and access to water could become a primary factor in the development of biofuel feedstock production.

In regions already under water stress, biofuel production may further decrease the freshwater availability for other development options and may limit the "right to water" both for ecosystem sustenance and for meeting peoples' basic needs. The indiscriminate promotion of biofuel development as a "cheap and green" energy option may interfere with optimal water allocation, and/or the pursuit of appropriate public water policies that will help address the water crisis.

Currently, biofuels are neither a sufficient replacement of petroleum, nor are they a dominant agricultural land use. In 2006, the world produced enough ethanol—accounting for almost 87.65 percent of total biofuels —to displace just over one percent of total petroleum based liquid fuel consumption.[2] Biofuel feedstocks account for only about 1 percent of the total area under crop and a similar percent of crop water use.[3]

But the production and use of biofuels is growing rapidly. There has been exponential growth in the biofuel sector since 2000. Between 2004 and 2005 alone, global ethanol production went up nearly 13 percent from 10.77 billion gallons to 12.15 billion gallons; between 2005 and 2006 there was a further increase of 11 percent to 13.49 billion gallons.[4]

Biodiesel production, accounting for a mere 5 percent of biofuel production in 2004, has also been expanding. In the United States, biodiesel production tripled from 25 million gallons in 2004 to 75 million gallons in to 2005. In 2006, the U.S produced 250 million gallons of biodiesel, a ten fold increase from 2004[5] By 2006, biodiesel accounted for 12.35 percent of the global biofuel production, 15.39 billion gallons.[6]

While the U.S., Brazil and European Union accounted for 75 percent of global biofuel production in 2006, it is spreading rapidly to other parts of the world.

The major factors that account for the explosive growth of the biofuel sector and widespread enthusiasm for the technology are: 1) the opportunity to reduce dependence on fossil fuels through renewable energy; 2) the search for energy independence or energy security in emerging economies and in countries such as U.S.; 3) its potential to reduce the net emissions of carbon dioxide into the atmosphere and help address global warming;[7] and 4) its potential to raise commodity prices, improve farmer income and increase rural employment opportunities.[8]

The two basic types of biofuels are ethanol (which replaces petrol and is made from corn, sugarcane, beets, wheat and other grains) and biodiesel (made from oil seeds, waste oil or treenuts). These biofuels are not strictly renewable in the same way

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solar, wind or tidal energy sources are, since their production depends on finite resources such as land and water.

Biofuel development has been increasingly portrayed as a strategic way to address many current social and ecological problems around the world. International financial institutions (IFIs) such as the World Bank and regional banks are promoting biofuel development as a sustainable development strategy for meeting the world's growing transportation fuel needs. Multinational agribusinesses and oil companies have identified it as an opportunity for doing "green" business. For energy-importing and growing economies like China or India, biofuel development seems to provide a means toward energy security and autonomy. Even some groups that question conventional patterns of growth and development on grounds of social and environmental justice are enthusiastic about biofuel development, which they hope will empower small farmers and local communities.

While biofuel feedstocks can be grown in a manner that enhances soil and water resources, most often the feedstocks are grown as industrially produced crops that have detrimental environmental consequences. The current biofuel development strategy, promoted both by IFIs and multinational corporations that increasingly control the production of biofuels (and that already control the storage, distribution and processing of the cash crops involved), focuses on intensive cultivation of monoculture cash crops such as sugarcane and corn. The environmental externalities associated with pesticide, fertilizer and water use for intensive monocultures is very high, resulting in polluted and (often) depleted water resources.

However, a well planned biofuel development strategy has the potential to diversify agricultural cropping systems with environmentally beneficial crops, such as perennial grasses. According to an assessment of multifunctional agricultural systems (that involves joint production of standard commodities such as food and fiber crops as well as "ecological services" such as protection of biodiversity and water quality), potential socio-economic and environmental benefits increase as cultivation of perennial crops, an excellent source for cellulosic biofuels, increase.[9]

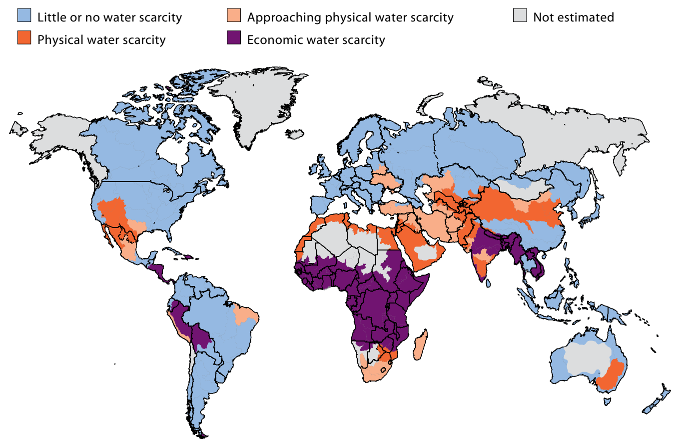
Thus multifunctional agricultural systems promise to address many problems associated with mono-cropped commodity agricultural systems. These problems are environmental (soil erosion, water quality deterioration), ecological (loss of plant and animal life diversity in the agricultural landscapes) and sociological (lack of economic opportunity leading to migration/agribusiness control of farms, decline in rural populations).

Proponents of biofuels development hope that it will especially address the rural economic crisis, largely through higher commodity prices paid to farmers and local ownership of biofuel facilities. But a biofuel sector built on the current agricultural model of production is unsustainable in the long run.

WHAT IS AT STAKE FOR WATER?

Over 1.2 billion people do not have access to safe drinking water, and almost 40 percent of humanity does not have access to water to meet their daily sanitation needs. According to international water policy experts, unless drastic changes are made in how we use and manage our water, there will not be enough water to meet the food, feed and fiber needs of humanity in the coming 50 years (See Map).[10]

WATER SCARCITY MAP[11]



Definitions and indicators

- Little or no water scarcity. Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.
- Physical water scarcity (water resources development is approaching or has exceeded sustainable limits). More than 75% of river flows are withdrawn for agriculture, industry, and domestic purposes (accounting for recycling of return flows). This definition—relating water availability to water demand—implies that dry areas are not necessarily water scarce.
- Approaching physical water scarcity. More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.
- Economic water scarcity (human, institutional, and financial capital limit access to water even though water in nature is available locally to meet human demands). Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Source: International Water Management Institute analysis done for the Comprehensive Assessment of Water Management in Agriculture using the Watersim model.

Courtesy *Water for food, water for life: A Comprehensive Assessment of Water Management in Agriculture* (International Water Management Institute).

The global water scarcity map shows regional variations for some countries like China, India, South Africa, Mexico and the U.S. Unlike countries such as Saudi Arabia and Israel, which have experienced physical water scarcity for a long time, many countries that are experiencing water scarcity today are major agricultural producers (e.g.: China, India). Ever increasing production of thirsty crops and livestock production have brought severe strains on water resources in many other parts of the world as well, including parts of North America and the European Union.

Although water scarcity is often described at the regional or national level, it is really an intensely local issue, often first experienced by subsistence farmers. In China, 550 of its largest 600 cities already face water shortages, and its cities and industry compete with farmers and rural areas for access to water.[12] Both China and India also have middle class populations as large as the entire United States population, and these middle classes aspire to a consumption style comparable to that of the

U.S. This further aggravates the water crisis. A case in point is Coca-Cola's operation in Plachimada, India, where an industry over-exploited the water resource and used it at the expense of the local community. Since establishing the factory in 2000, aquifers have been depleted and water quality has deteriorated. The local agriculture-based economy was destroyed, and many farmers had to abandon cultivation.[13]

Local water scarcity can be attributed to some extent to uneven geographical distribution of water or population pressure on the limited water available. Ironically, in response to persistent water shortages and growing water needs, many countries are pursueing even more massive projects.[14] Some recent examples include a proposal for the "interlinking of rivers" in India and the "South-to-North water diversion project" in China. Closer to home, there are the North American Super-Corridors under the "Security and Prosperity Partnership," with plans for water pipelines and bulk water transfers.[15]

But such water and land use policies, as well as investment policies (particularly those resulting in dammed or diverted rivers, polluted and over-used surface water, as well as depleted or contaminated groundwater resources) further contribute to the worsening of local water situation.

Public policies that support the development of biofuels should take into account the effect of the production and processing of biofuel crops on water availability to meet local, basic needs for water and food. Biofuels, because they currently depend on intensive mono-cultural crops, are unlikely to help resolve challenges in agriculture or development. Moreover, the development of biofuels in its current direction has significant and alarming implications for water use, particularly from socio-economic, environmental and human rights perspectives.

The most important concern regarding this pursuit of energy security through biofuel development is that it could aggravate water insecurity in many parts of the world. Energy security and water security are both essential and closely connected. While there are multiple sources for meeting our energy needs, there is only one way of ensuring our water security – by manageing it sustainably.

WATER USE IN BIOFUEL PRODUCTION

Biofuel production requires water inputs at two stages: in growing feedstock and for the production process in biofuel plants. If we focus only on water use in biofuel plants, biofuels might appear to have minimal impact on water, especially when compared to conventional oil/thermal energy production plants. However, the picture changes once we also consider water used per gallon of ethanol produced, (in feedstock production and in the processing plant) and the impact of feedstock production and processing on water quality. The water impacts that can be specifically attributed to feedstocks vary significantly based on whether it is: a) converting native vegetation; b) simply increasing current production practices/ shifting crops; or c) using existing native vegetation itself as feedstocks.[16] Globally biofuel crops account for about 1 percent of total crop water requirement.[17] Its share in irrigation water use is slightly higher, about 1.67 percent.[18]

This section will focuses primarily on the extent of water use in growing biofuel crops and externalities associated with this water use. It will also briefly review water use in biofuel plants using corn/maize and sugar as preliminary examples. (This study is constrained by the limited information available regarding water use both in feedstock production and in processing plants. Existing studies have focused mostly on net energy balance or net greenhouse effect. There are very few studies on the environmental impacts of water use in biofuel production.[19])

Water use in growing biofuel crops and in producing ethanol: Impacts on quantity and quality

The crop-water requirement in feedstock production and the effects associated with that water use vary depending on several factors. While the most important is irrigation, other factors include the crop in question, the evapo-transpiration at different stages of growth for a particular crop variety in a specific agro-climatic zone, the cultivation method, and the extent of fertilizer and pesticide use. Below are some available estimates for cumulative crop water requirement for corn (also called maize) and sugarcane, the two feedstock which together account for about 83.6 percent of world ethanol production in 2006.[20]

Corn/ Maize, an example from the U.S.

According to a report released by USDA in early March 2007, producers in the U.S. were expected to plant 90.5 million acres of corn, an all time high since 1944 and 12.1 million acres more than in 2006.[21] While part of this expansion is in response to an increase in export demand, much of it can be attributed to the expanding biofuel industry.

The United States is the largest producer of ethanol, accounting in 2006 for about 36 percent of global ethanol output, almost entirely with corn grown in the Midwest. For Iowa, in the heart of corn production in the U.S., the water use (associated with crop water requirement) for producing a gallon of ethanol has been calculated to be between 1081 and 1121 gallons of water.[22] However in fully irrigated agriculture, crop water use increases substantially.[23] For example for corn grown in Southwestern part of Nebraska, where it is irrigated, the average water use (associated with crop water requirement) for producing a gallon of ethanol has been estimated to be about 1568 gallons of water.[24]

A recent study by the International Water Management Institute (IWMI) compared average crop water requirements for major biofuel crops grown in selected countries.[25] Extrapolating from the data in this study, in China, where irrigated maize cultivation is a norm, average consumptive water use per gallon of maize-based ethanol is almost 1.5 times that in the United States. Concerned about national food security, China now plans to discontinue using maize and turn to non-food crops such as sweet sorghum and jathropha to produce ethanol and bio-diesel. [26]

Compared to feedstock production, water use in corn-based ethanol plants itself is negligible. For example, in Minnesota (the only state where ethanol's water consumption data is available) the water use efficiency in some of these plants has improved from about 5.8 gallons of water per gallon of ethanol produced in 1998 to 4.2 gallons of water per gallon of ethanol produced in 2005.[27] Thus crop water requirements for growing biofuel crops is a bigger concern than the water use in these modern plants. However the water used in biofuel processing plants is withdrawn from a smaller area, and can have localized impacts on water quality and quantity.

Thus, the siting of these plants in water scarce regions and localities can affect the water available for other basic needs. As "Water use in Ethanol Plants," an IATP paper, warns: "the shortage of available water could become the Achilles heel of the ethanol boom if more efficient use of water isn't made a priority."

Depending on practices associated with growing corn, and the regulations regarding plant effluents, biofuel production can have varying impacts on water quality as well. For example, since corn is the most nitrogen intensive of major field crops, excess nitrates move down through the soil and leach into ground water, contaminating both soil and water sources. Nutrient leaching from farm land around the Mississippi River and its tributaries have contributed to high rates of algae growth in the Gulf of Mexico. This in turn has caused hypoxia (oxygen depletion) in the Gulf. Pesticide contamination and sediment erosion also impact the quality of water.

In October 2007, the National Academies of Sciences in the United States issued a report looking into the water implications of biofuel production in the United States. The report warns that "if projected increases in the use of corn for ethanol production occur, the harm to water quality could be considerable, and water supply problems at the regional and local levels could also arise."[28] It calls for policy interventions that will move away from current ethanol production practices that use corn as a feedstock, and suggests policy options to ensure that biofuels development in the U.S. adopts sustainable production strategies.

Sugarcane, an example from Brazil[29]

Brazil is the second largest producer of ethanol, accounting in 2006 for about 33.29 percent of global production. It is considered the only case where biofuel use has reached competitiveness with fossil fuel/petroleum. Here, ethanol production is primarily sugarcane based. The country has two distinct sugarcane producing regions: the Center South region (accounting for 85 percent of national production) and the North/Northeast region accounting for the remaining sugarcane production. In northeastern Brazil, where drought is common, sugarcane cultivation is at least partially irrigated. Even in the central and southeastern regions, where rainfall characteristics are very well defined, dry spells can affect water availability for agriculture and other uses in some years.[30] The center-south state of Sao Paolo in the Paraná River Basin is the largest producer of sugarcane based ethanol, accounting for about 60 percent of Brazilian ethanol production.

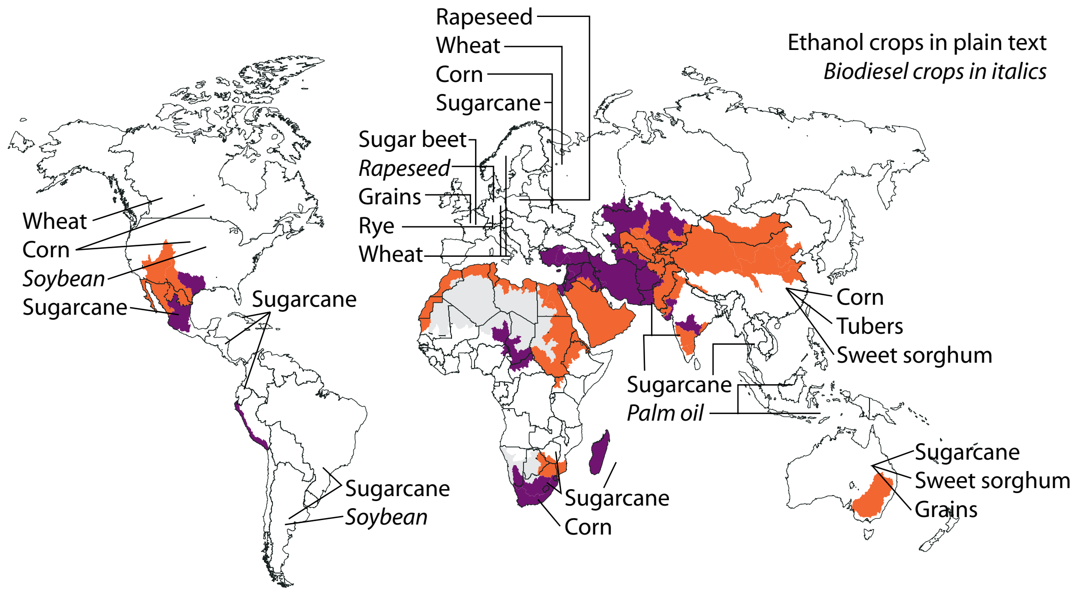
But sugarcane is a water intensive crop, and its cultivation can have a direct impact on the quality and quantity of water available for other uses in the area. According to the Food and Agriculture Organization (FAO), depending on climatic conditions, the maximum crop water requirements of sugarcane vary from 1500 mm to 2500 mm evenly distributed over the growing season.[31]

The crop water requirement of sugarcane grown in Brazil is estimated to be about 8-12 mm per ton.[32] Using the productivity data from UNICA brochure/ Pamphlet, we find that for sugarcane grown in the center South region of Brazil, the water use (associated with crop water requirement) for producing a gallon of ethanol ranges between 927 and 1391 gallons of water.[33]

Water use in the ethanol/sugar plants itself is comparatively less than plant production. Much of the water use efficiency improvement is focused on water use in the plant. For example, in Sao Paolo the water use efficiency in sugarcane-based ethanol plants has improved from about 56 gallons of water per gallon of ethanol produced in 1997 to 21 gallons of water per gallon of ethanol produced in 2005.[34] Much of this water/ waste water is reused/ circulated in the plant itself. As in the case of corn in the U.S., sugarcane in Brazil is produced in a mono-cultural cropping system. Water impacts associated with such sugarcane production include contamination of surface waters and ground water by agrochemicals and fertilizers.

Several studies have identified Brazilian sugarcane cultivation and processing as a source of water pollution. For example in the case of the Ipojuca River, in Northeastern Brazil, water impacts associated with the sugarcane industry include nitrate leaching and acidification, increased turbidity, and oxygen imbalance.[35] Another source of soil and water contamination in this sector is from ferti-gation, commonly practiced in Sao Paulo. Ferti-gation (or ferti-irrigation) is a disposal mechanism for vinasse, a major effluent of sugarcane-based ethanol industry. Vinasse is highly polluting and its decomposition requires high levels of oxygen. If disposed in large volumes in surface waters, it reduces the dissolved oxygen levels in water, and damages aquatic life. However, sugarcane processing plants in Brazil (which process ethanol as well) distribute vinasse in the sugarcane fields (which are often owned by them). According to the sugar industry union, it helps meet the needs for nutrient enrichment and water replacement of the soil. However, vinasse application increases the acidity of soil and water in these areas, and it also contributes to nutrient run off from farms. Sediment contamination associated with soil erosion from the sugar-cane fields is another water quality concern in Brazil. In São Paulo, soil erosion in sugarcane fields is estimated to be as high as 30 tonnes of soil per hectare per year.[36]

While impacts on water quality and quantity associated with sugarcane production in Brazil are well documented, they are often glossed over. One rationale for this is Brazil's abundance of surface and groundwater resources. In addition it also has one of the lowest water use to water supplies ratios in the world. However, regional experiences of water scarcity and pollution are plenty. In fact, in the early 1990s an IDRC publication warned that "São Paulo is facing a difficult environmental future unless careful management of its water resources and appropriate environmental policies are implemented."[37] With the expansion of the biofuel industry, the situation may need urgent attention.



Water-scarce basins in 2000 and 2050 — Water-scarce basins in 2050 but not in 2000

Source: International Water Management Institute analysis done for the Comprehensive Assessment of Water Management in Agriculture using the Watersim model.

Water quality and quantity impacts associated with sugarcane production and processing are also high for other sugarcane based ethanol producing countries such as India and South Africa. Increased sugarcane cultivation in these countries puts further pressure on the already scarce water resources available for meeting other basic needs. Yet India, which currently accounts for close to 5 percent of global ethanol production, plans to increase its ethanol production by 50 percent by the end of the decade. Aware of the constraints, India too has been exploring the potential of some of its dry-land crops (such as Jathropha and Karanja) for its bio-diesel production. These biofuel crops have high water use efficiency, but their development is still at a nascent stage. Ethanol feedstocks that are under pilot phase in India include casava and sweet sorghum (latter has a crop water requirement four times lower than that of sugarcane, the current feedstock).[38]

BIOFUEL PRODUCTION AND WATER USE: FUTURE IMPLICATIONS

While this paper has been constrained by a lack of data (especially with reference to biofuel plants), it is evident from the available information that the water quality and quantity impact of fossil fuel dependent, conventional feedstock production is not sustainable even at the current scale for many regions. As the above two examples on corn- and sugarcane- based ethanol production suggest, if most of the feedstock requirement for the biofuel sector is met through intensive cultivation of monoculture cash crops, the externalities associated with pesticide, fertilizer and water use itself can be very high.

The biomass needed to produce one liter of biofuel (under currently available conversion techniques) evaporates between 1,000 and 3,500 liters of water, at a global average, according to the "Comprehensive Assessment of Water Management in Agriculture."[39] According to the IWMI study on biofuels, if current patterns were to continue, by 2030 the biofuel sector will account for three times the current area under biofuel production, and 5 percent of the irrigated water use.[40]

Energy hungry, but natural resource-constrained, nations need to be particularly cognizant of the water limits of biofuel development as a route to energy security. Water scarce countries such as China and India (which will face even more acute water scarcity as their economies develop further and lifestyle changes take place among large numbers of elites), or other energy deficit countries, need to research the constraints placed by natural resources, not only nationally but also internationally, and explore options within these limits.

Purely from a water quantity perspective, it is important to grow crops with minimal water input (e.g., supplementary irrigation, rather than intensive irrigation), especially in regions where water is already under threat. However, even low water input crops can have an impact on local water availability if they are raised on large tracts of land.

Reliance on biofuels to meet local needs might seem to make more sense where the resources needed are plentiful. But caution is required even in these cases, since the co-existence of a number of basic natural resources (such as land, water, biota) are required for crop development. If one such resource is already under tremendous pressure from other competing uses such as food production or ecosystem sustenance (such as biodiversity hotspots in Brazil or Borneo Island), plentiful availability may not be adequate to ensure planned development in a sustainable manner.

The current pursuit of first generation biofuels (grain/ starch/ seed based biofuel production) that ignore environmental and social justice concerns may help some nations in meeting part of their energy needs or addressing trade imbalances. However, the promotion of export-oriented biofuel production that relies on large-scale adoption of intensive monoculture practices is almost certain to deplete and degrade available water resources. In order to reduce the impact biofuel development has on water quality and quantity, it would be necessary to reduce fossil fuel based production of feedstock, and ensure that it emphasizes sustainable agricultural practices locally.

It is in this context that research on cellulosic feedstock (grass, wood waste) may offer a water wise option for feedstock production to meet local energy needs. However, pursuit of cellulosic based biofuel production needs to be undertaken with utmost care to ensure that energy security is being met sustainably, and that it benefits farming communities. For example, some of the pilot projects currently under development for cellulosic ethanol use include eucalyptus trees, a fast growing species known to have caused aquifer depletion in several countries. Nevertheless, cellulosic based biofuel production has the potential to be locally based and be part of a multifunctional agricultural system that could make biofuel energy a sustainable option to pursue.

CONCLUSION

Energy security and water security are closely connected. The current and planned expansion of biofuels lacks this understanding. In fact, biofuels might aggravate the water crisis in some regions that are already under stress. In addition policy incentives and regulations have to be set in place to ensure that: 1) multifunctional agricultural systems are promoted and that they function as the primary source for biofuels feedstock; 2) water conservation practices are encouraged and 3); water efficiency improvement plans and effluent treatment plan are integral to biofuels processing facilities.

It is not enough, of course, to evaluate only biofuel development from the perspective of the impending water crisis. Though the water crisis is experienced locally, global policies and global initiatives have a tremendous influence on local water availability. Thus, it is necessary to pursue global and multilateral policies and rules that ensure investment and trade agreements do not impinge on the right and responsibility of nations to fulfill the needs of its people and its environment.

An integrated water/energy policy will need to look outside the box to generate creative solutions to water and energy problems that is informed, sustainable, just and democratic.

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Maps on pp. 2 and 5 courtesy International Water Management Institute, and Earthscan "Water for food, Water for life: A Comprehensive Assessment of Water Management in Agriculture." Edited by David Molden. <http://www.iwmi.cgiar.org/Assessment/>