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Introduction

Agricultural and energy policies that are seemingly unrelated to water use, such as institutionalized support of biofuel production, can have major water-related impacts. For instance, expanding agriculture to meet countries' growing demand for biofuels could place extreme stress on global water resources. Clean and reliable water resources are necessary for nearly all social-industrial processes. Currently, agricultural production is the world's largest user of water.[1] However, agriculture is not the only sector straining global water supplies. Water demand continued to rise in nearly every component of global society over the last twenty years despite limited supplies, particularly in the world's expanding arid and semi-arid regions.[2]

Mounting evidence has prompted a nearly universal declaration of the existence of global water scarcity-coined the "global water crisis."

Utilizing biofuels has numerous positive results, such as reducing greenhouse gas ("GHG") emissions, improving countries' energy security, and providing economic opportunities in the world's impoverished rural areas. However, this renewable energy source also comes with a price. Biofuels compete with food crops for scarce arable land. For example, Europe's pledge to replace 5.75 percent of their fuels with biofuels by 2010 and the United States' proposal to substitute fifteen percent of U.S. gasoline use with biofuels by 2017 will place enormous demands on existing cropping systems. The U.S. plan alone would require 35 billion gallons of alternative fuel: the equivalent of 13.5 billion bushels of corn (using current technologies). The water-related consequences of large-scale biofuel production and the potential need for policy guidance in this area have yet to be fully explored.

This article has two major goals. The first is to establish that, in the context of the "global water crisis," water accounting is a useful tool with which to evaluate the international impacts of producing and trading biofuel stocks. The second idea to be conveyed is that the international community must move towards a more integrated understanding of the development of biofuels within the context of the global water crisis.

The Rise of Biofuels

Countries around the world are currently employing (or exploring) biofuels as cleaner, more secure alternatives to gasoline in meeting their transportation energy needs. Current biofuels technologies rely on converting crops that farmers have traditionally grown for feed purposes (i.e. corn, soybeans, sugar, and palm oil) into ethanol or biodiesel that could displace fossil fuels in motor vehicles, a significant source of carbon dioxide emissions.[3] Ethanol is produced from crops with high sugar content, such as wheat, beets, and sugar cane. These sugars are fermented into ethanol either by biologic or chemical means.[4] Biodiesel is made from oil crops such as rapeseed, soybeans, and jatropha; fuel derived from vegetable oils can be blended with oil-based diesel or used directly.[5]

Biofuels present a way to meet Kyoto Protocol commitments for GHG emission reductions, decrease air pollution for domestic reasons, and/or generate greater domestic energy security in non-oil producing countries.[6] Another reason for encouraging growth in the biofuels sector is to revitalize a deteriorating agricultural sector, both in developing and developed countries.[7] Some farmers see biofuels as the answer to often inaccessible and unpredictable global agricultural markets. For example, some individuals in South Africa believe that "the whole bioethanol revolution will save maize farmers" in this country.[8]

Beyond land and water constraints, concerns exist regarding increases in the production of biofuels. Developing countries will likely become the primary producers of biofuel feedstocks with developed countries as the primary consumers. A large group of international nongovernmental organizations ("NGOs") have expressed concern that increasing biofuel production may create a scenario reminiscent of earlier colonialism based on

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resource extraction and exploitation.[9] These groups recognize that there are likely short-term benefits to the agricultural sector in producing countries. Nonetheless, these NGOs worry that poorer countries will continue to be dependent on primary resource exports and may forgo opportunities to invest in increases in food production for their citizens. In contrast, biofuel expansion in developing countries is also viewed as a way to help reduce commodity dependency in these countries and support infrastructure development that will help with the distribution of crops.[10] In addition, there is concern about the implications of increasing monoculture farming practices for biodiversity in the surrounding ecosystems.

Obviously, there is much debate over these issues because specific threats and benefits for local communities are extremely difficult to predict with accuracy. As a result of these issues, some NGOs, Indigenous Peoples Organizations, farmer's movements, and individuals went as far as to publicly and formally oppose the use of biofuels to the Conference of the Parties of the Framework Convention on Climate Change.[11] Stating that "[b]iofuels are a disaster in the making," those opposing biofuels called for immediate suspension all subsidies and other support for trade.[12] However, whether or not such a North-South discord will exist within the biofuel trade regime may only be discovered through experience.

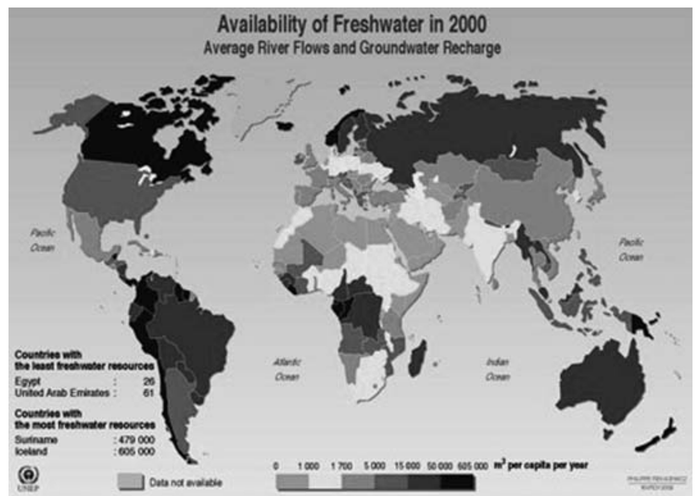
Global Water Crisis

Mounting evidence has prompted a nearly universal declaration of the existence of global water scarcity- coined the "global water crisis."[13] Such evidence includes the fact that more than two billion people are affected by water shortages in over forty countries.[14] The global water crisis is particularly evident when trends are examined with an eye toward the future, as water shortages experienced throughout the world often impose serious risks to long-term sustainability of linked socio-ecological water systems.[15] More specifically, several studies have concluded that the world's freshwater ecosystems have already been significantly degraded in form and function due to water overuse and contamination.[16] Further, a report initiated by the United Nations Environment Programme predicts that freshwater shortage will increase in severity in over two-thirds of the freshwater systems by 2020.[17]

At the root of the water crisis are inappropriate economic incentives for water use[18] and insufficient social institutions and legal frameworks for water management.[19] Whether scholars agree with the trend or not,[20] the global community is playing a significant role in the outcomes of local water scarcity issues. For example, international aid and development strategies have increasingly focused on addressing the critical nexus between global water scarcity and poverty, allocating funds for this problem at local levels, and further integrating global economic and political networks with water scarcity issues.[21] Additionally, the UN Millennium Development Goals challenge the world to decrease by one-half the proportion of people without access to potable water and sanitation by 2015.[22] However, "[w]ater is not only becoming scarce because of increased demand, but also because of higher pollution levels and habitat degradation."[23] Worldwide, only five percent of waste water is treated before entering the receiving fresh water bodies.[24] This has resulted in significant pollution levels in aquatic systems, especially surrounding mega-cities. For example, 200 million liters of raw sewage and twenty million liters of waste from Delhi are dumped into the Yamuna River every day.[25]

Water scarcity problems are also fundamentally due to geographic and temporal distribution, resulting in excess water in certain locations at a given time and too little water in other areas at a given time (see Figure 1). For example, many countries in sub-Saharan Africa or the Middle East must continually place water scarcity issues at the top of their policy agendas regardless of the existence of a current political crisis. In contrast, other regions struggle to cope with seasonal flooding and storage issues as well as groundwater intrusion.[26]

Figure 1: Global distribution of per capita freshwater resources



Source: World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life, World Resources Institute (WRI), Washington D.C., 2000.

Virtual Water: Rethinking a Resource

Virtual Water Accounting

Global trade in agricultural and other commodities influences how water is consumed among countries; however, international commodity trade has an under-recognized role in redistributing global water resources. This is especially true for trade in crops, which often require large quantities of water to grow. The volume of water that farmers use to grow a crop, which is not physically embodied in the final product, is dubbed the crop's "virtual water" content.[27]

Table 1 demonstrates how virtual water accounting has been developed as a useful empirical tool for quantifying the flows of water between countries as well as explaining the social, economic, and environmental consequences of the trends. This virtual tool can even be used to identify valuable policy levers; for instance, specific crop trading practices that would put undue burden (or provide relief) in instances of water scarcity. Virtual water accounting emphasizes the important role of social and political institutions—in addition to the relative availability of water resources—in determining how water is used and distributed around the world.[28]

Table 1: Global Virtual Water Flows Between Nations By Product (Adapted from Hoekstra and Hung 2005)

Product	% Global Virtual Water Flow
Wheat	30.2
Soybean	17.1
Rice	15.4
Maize	8.9
Raw Sugar	7.2

Virtual Water Content and Trade

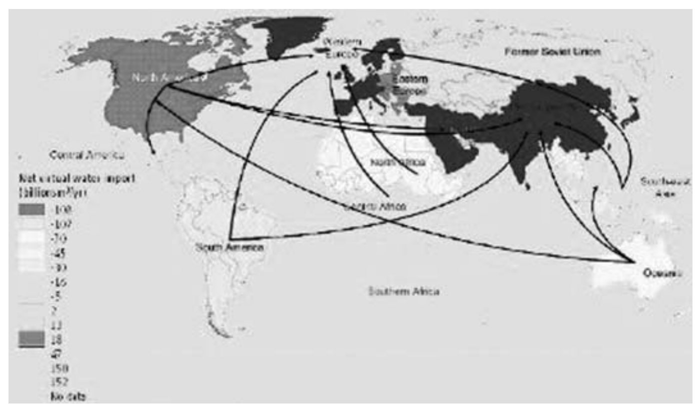
Relying on irrigated crops to produce biofuels would significantly strain global water resources. The global average virtual water content of wheat, sugar cane, and rapeseed is 1300, 175 and 1600 m3/ton, respectively.[29] These crops are generally grown under rain-fed conditions, but expanding production may push crops into more marginal areas that require irrigation. Depending on system configuration, the processing is less water-intensive but can cause major pollution loads on aquatic systems, and hence an environmental burden shift to producing countries.[30]

International trade in biofuels or in their ingredients will cause additional virtual water flows, above and beyond existing crop trade and its impact on global water resources as trade volumes increase. For example, if South Africa increases biofuel exports it will increase its net virtual water trade deficit. However, just as water is differentially distributed around the globe, so is the capacity for countries to increase their production of biofuels. For instance, the United States and Brazil are currently the world's leading ethanol producers. Brazil represents 50 percent of global ethanol exports, exporting primarily to the United States and India.[31] The United States and Brazil are also major consumers, but their level of trade in ethanol is small relative to ethanol production levels.[32] Interestingly, trade in cane sugar and maize has not risen along with the ethanol boom. Most likely this results from subsidies in developed countries favoring domestic ethanol production. On the other hand, biodiesel represents an emerging new force in oilseeds trade. For example, a spike in palm oil exports from Malaysia and Indonesia to the European Union is most likely attributed to biodiesel demand.

It is forecasted that the commitment of the EU to a 30 percent increase in biofuel use by 2025 will require imports of biofuel feedstock from other countries. Even without considering the needs of other countries, virtual water flows lead one to believe that there possibly might be a shortage of available, arable land to meet the demand created by this target unless significant changes in crop selection and cultivation are instituted. Implementing such changes would require political and technical exchanges, such as subsidization policy changes and technology transfers. Such exchanges have thus far been avoided in the international arena. Innovations have lead to potential decreases in water competition. For example, the use of jatropha, a plant able to grow quite easily in arid regions, has the potential to significantly reduce the volume of water resources needed to sustain biofuel production.[33] Regardless, water availability will likely still be a problem.

As shown in Table 1, four of the five crops most responsible for the global flow of virtual water are also used in the production of ethanol and biodiesel. Also, global trade in wheat alone is responsible for 30 percent of global virtual water flows.[34] If the trade in these commodities is to greatly increase in the future to meet the growing demand for biofuels it seems more than reasonable to propose an assessment of how this will impact the water resources in producing and consuming countries. Additionally, there is the need to address these concerns in the policy frameworks which will undoubtedly arise around the trade regimes. New biofuel crops may add themselves to the list of "top five" virtual water crops, and those crops that are currently responsible for most of the world's virtual water trade will continue to grow in importance. If the global community agrees that: (1) there is a global water crisis; (2) it is possible to calculate the virtual water flows of agricultural crops; and (3) there is the desire to maximize our ability as a global community to produce low-carbon emissions fuels, then such measuring of virtual water flows is imperative.

Figure 2: Net virtual water imports around the world (Source: UNESCO 2006)



Regional virtual water balances and net interregional water flows related to trade in agricultural projects. Period 1997-2001.

The Role Virtual Water Can Play in InterNational Biofuels Policy

As trade in biofuels increases, virtual water metrics should be used to improve global water governance. Achieving integration in governance systems at the global level is a daunting task, but one that is necessary to ensure sustainable and equitable futures as the global community move toward the use and development of alternative energy sources. Innovative perspectives to this problem are needed and it would positively serve the global community think creatively about the types of governing institutions and policies that would be capable of addressing linked water scarcity problems to causes and solutions. Thus far, policy proposals have addressed virtual water balances and biofuels trade in isolation. Considering these issues simultaneously could lead to three types of policy proposals: (1) domestic regulation; (2) international regulation; and (3) self-regulation within the industry.

Domestic Regulation

A straightforward solution to tackling water-related concerns in biofuel production is regulation at the domestic level. For example, countries may be able to limit irrigation licenses depending on water availability or to set regulative priorities for food over biofuel production when necessary. This strategy will depend in part on a government's ability to collaborate with often powerful agricultural lobbies. Moreover, in many cases the capacity of a single nation-state to handle water issues is limited when water crosses national frontiers. For example, more than thirty percent of all states meet thirty percent or more of their domestic water needs from sources in neighboring countries.[35] Therefore, international agreements are likely needed in many cases in order to achieve sustainable solutions.

International Regulation

International regulation means either modification of current international regimes, especially global trade rules, or developing a specific international water regime able to address biofuel trade. In the former case, an obvious option is to integrate biofuel trading into existing international trade regimes in an attempt to harmonize its regulation with other agricultural and energy-related commodities. Biofuels must first be formally classified within General Agreement on Tariffs and Trade ("GATT") framework; however, the lack of commodity classification of biofuels may be significant barrier in incorporating of biofuels into the GATT.[36]

Additionally, current trade regimes such as the GATT only consider standards which refer to the traded products themselves, without standards regulating the production process. For example, imports of bottled water can be rejected if the quality of the bottled water implies health threats. There is no way to ban imported bottle water from ground water aquifers that are threatened in terms of water over-use. Modifying current trade rules to internationalize such environmental and social costs related to water use for biofuel production could improve the sustainability of some water systems being used for biofuel production. However, suggesting such modifications are easier than implementing them. Parties to trade agreements must become aware of the importance of integrating environmental concerns into trade agreements.

The development of standards and numerical criteria will also play a key role in determining not only where within the GATT biofuels are placed, but how water-related criteria are able to be applied and how subsidy schedules will need to be adjusted within and between countries. This is an area where basic and applied research can significantly improve the global community's ability to address the global trade of biofuels from a virtual water perspective because the potential trade flows will be more predictable once standards allow classification.[37]

Ensuring that trade in biofuels proceeds in a way that maximizes benefits for those who need them most is critical. The World Food Programme, a UN organization dedicated to ensuring food security worldwide, has recognized the potential that trade in agricultural commodities can have for these communities. Their support of trade as a tool for development is not without reservations, as the achievement of key goals is critical if trade regimes are to benefit a greater number of countries than currently. As expressed in a 2002 WFP report:

> While there are potential gains from freer trade in farm products, the actual progress made in the ongoing negotiations has been limited so far, and the benefits remain modest. If further liberalization focuses too narrowly on a removal of OECD subsidies, the lion's share of gains will accrue to developed country consumers and taxpayers. More important for developing countries are: a removal of trade barriers for products in which they have a comparative advantage and a reduction or reversal of tariff escalation for processed commodities; more and deeper preferential access for the poorest of the least developed countries; open borders for long-term foreign investments (FDI); and improved quality assurance and food safety programmes that enable developing countries to compete more efficiently in markets abroad. The resources gained by trade liberalization and reductions in domestic protection could be channeled into additional development funding.[38]

An alternative at the international level to the modification of existing international rules is to address water distribution problems through a separate multilateral agreement, such as the proposal of an "International Virtual Water Trading Council."[39] Such proposals suggest that virtual water council could play a role in ensuring that the basic nutrition requirements of people are met through securing food imports and the water saved by these imports could subsequently be used to meet their basic water requirements. This entity could act as an independent arm of the World Trade Organization and coordinate international aid efforts with its goals.[40] This would be a very valuable contribution to efforts to incorporate virtual water accounting in emerging biofuel trade regimes, as the assurance of basic food and water requirements could serve as a foundation for assessing the capacity for biofuel feedstock cultivation in a given country. In addition, international compacts or conventions among countries to agree to reduce "water footprints," (the extent of water use internally and externally in relation to consumption) could provide incentives for countries to create water-efficient trade regimes for biofuel stocks.[41] Such a compact could be loosely modeled on previous agreements such as the Kyoto Protocol, which governs countries' emissions of carbon dioxide.

Self-Regulation Within the Industry

A final proposal is voluntary self-regulation by the biofuel industry through greater attention to corporate social responsibility ("CSR"). CSR appears in many forms, including internal codes of corporate conduct, which serve as important barometers for raising awareness and changing behavior. One CSR approach is for biofuel companies to establish voluntary water saving and cost saving standards, and commit to the application of water-saving irrigation technologies. A second approach is sector-wide agreements on best management practices among companies, like those existing in the coffee sector. Another approach is the creation of general corporate and government adopted codes that are not specific to particular organizations or industries, but rather apply to a suite of issues (e.g., the Global Compact or the Coalition of Environmentally Responsible Economies). These three CSR approaches could establish criteria on water use and re-use including water efficient technology and pollution prevention made visible to consumers through product labelling. Additionally, such measures may provoke a diffusion of sustainable water management measures.

Need for More Information on Global Water Requirements

The above types of policy proposals are complementary and far from mutually exclusive. Efforts can be made at all levels to begin to incorporate water-related concerns in trade and development policies using virtual water accounting. Common to all solutions addressing sustainable development of biofuels is the need for more information on global water requirements. Currently, significant information exists on global land use competition between biofuels and food crops and in varying future scenarios, as does the quantification of global virtual water flows within and between regions due to trade in food crops and livestock.[42] The necessity of changing the global distribution of freshwater resources to meet the needs of the poorest people and endangered aquatic ecosystems is also well established.[43] However, much of these data are currently reported at a highly aggregated global level and are not directly applicable to particular countries. Additionally, there are not sufficient data on the trade (real or potential) in biofuel crops.[44] Evaluating these areas is an important first step for all of the sectors and interests involved, including those hoping to mainstream biofuel trade, virtually redistribute water, and secure resources for impoverished people and ecosystems. Such an effort should come from the global community in order to fulfill its own commitments and interests. However, academics and NGOs may also have a significant role to play in securing the data and interpreting the information to promote sustainable global water use.

Conclusion

Virtual water accounting is a useful way to think about, and empirically assess, the global chain of events that contribute to particular patterns of water use, scarcity, and the implications of the production of biofuels. As mentioned above, establishing causal links in a global chain is difficult to do through thought experiments, let alone as an empirical exercise. However, virtual water accounting has been developed as a quantitative tool that can and should be used as a criterion for trade and development regimes.

Such quantification is not the end of the story. Virtual water can give us the "what," of global water distribution, but it is still up to us to discover the "why."[45] Underlying political and economic conditions may or may not be persuaded by virtual water methods. Incorporating these values into decision making is a worthy goal and should be viewed as an opportunity for future problem solving. It would also be valuable to evaluate not only the virtual water content of agricultural products, but the whole production chain for biofuels and how virtual water flows and distribution may coincide with other resource use such as "virtual land" or "virtual timber." Ultimately, it should be recognized that there are externalities to most of the actions we take as individuals or collectively within market economies and as we continue to develop new energy sources such as biofuels, internalizing these externalities at the global level is a difficult but important task.

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