

Water, Energy, and Food: The Ultimate Nexus

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Abstract

Our global community is facing unprecedented risks and challenges that are directly linked to the way we currently understand and manage our resources. Providing sustainable solutions to overcome present challenges poses the need to study the existent interlinkages between these resources. This entry presents water, energy, and food as main systems that form a nexus, which itself is affected by defined external factors. Promoting integrative thinking in the process of strategic planning comes through highlighting the intimate level of interconnectedness between these systems.

INTRODUCTION

With global population growing over 7 billion, accompanied by escalating economic crises, mismanagement of natural resources, climatic changes and uncertainties, and growing poverty and hunger, the world is living in a critical period defined by global challenges. These challenges are linked with social, economic, and political risks and unrest that present and future generations face. Different nexus combinations, including water, food, energy, trade, climate, and population growth, are being studied in an attempt to identify the types of interconnectedness present between those systems. The creation of those nexuses comes as a result of realizing the multidimensionality and complexity of the issue. This entry explores the synergies between water, food, and energy and presents a framework for this nexus that can help address the interfaces and further quantify these linkages.

FROM SILOS TO NEXUS

Water security, energy security, and food security are intimately linked. In simple terms, food production demands water; water extraction, treatment, and redistribution demand energy; and energy production requires water. Energy inputs via fertilizers, tillage, harvest, transport, and irrigation and processing have their influence on food prices. Environmental pressures and climatic changes, as well as growing economies and populations, both intensify the existent relations between the three systems. “A new nexus oriented approach is needed to address current levels

of insecurity in access to basic services; one that better understands the inter-linkages and inter-dependencies across water, energy and food sectors as well as the influence of trade, investment and climate policies.”^[1] According to the Global Risk 2011 report^[2] presented by the World Economic Forum, the water–food–energy nexus is a global risk that fundamentally threatens human, social, and political security. Unintended consequences are common as policy makers seek to solve one part of the nexus and end up worsening another. Therefore, there is a need for creating a holistic framework that explicitly defines the links between systems and understands the effect one has on another.

Fig. 1 shows a conceptual framework of the nexus with the existent linkages between water, energy, and food. It also presents the factors that affect the nexus, including rising economies, climate change, global population, international trade, and governance. The following sections will provide further explanation of the framework.

WATER–ENERGY LINKAGES

Water and energy are interdependent as they are major consumers of one another. The water system is an energy user mainly through electricity consumption for pumping fresh water, drainage and water table management, desalination, water treatment, and water distribution in farms and cities.

In desalination, for example, reverse osmosis plants consume 4–6 kWh/m³ of treated water versus 21–58 kWh/m³ for multistage flash.^[3] These values include

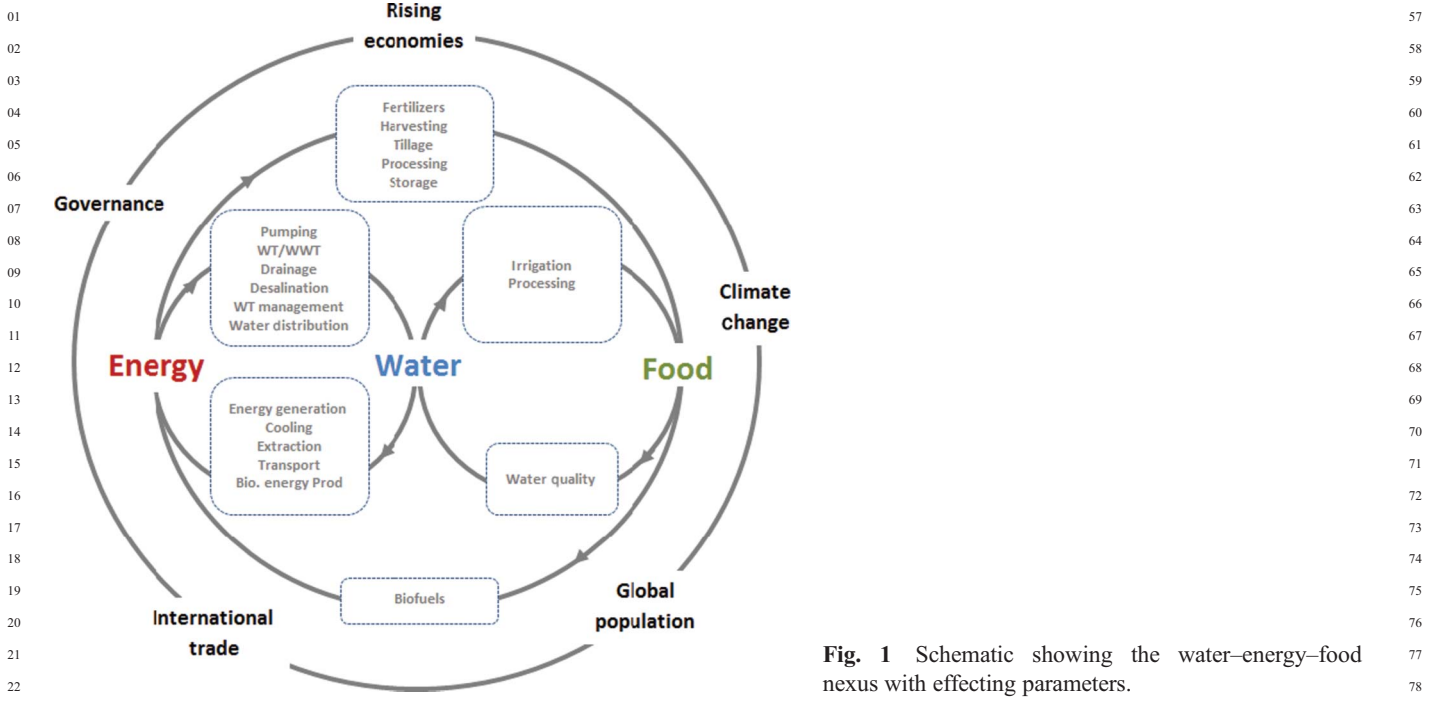


Fig. 1 Schematic showing the water–energy–food nexus with effecting parameters.

thermal and electric energy consumed to produce desalinated water. Energy needed for groundwater pumping is highly dependent on its source. “Groundwater supply from public sources requires 1,824 kilowatt-hours per million gallons – about 30% more electricity on a unit basis than supply from surface water, primarily due to a higher requirement of raw water pumping from groundwater systems.”^[4] Water transport is also an energy consumer, a fact that is often overlooked.

Energy in return is a major water consumer (Table 1). Water is needed for energy generation, cooling, resource extraction and refining, transportation, and bioenergy production. “Energy end use and waste disposal also use and contaminate water resources. For example, the largest withdrawal of water in the United States and most other industrialized countries is for power plant cooling.”^[6] The dependency of one system on the other is largely defined by the choice of technology used in energy–water-demanding activities.

Current policies are in search of alternative energy sources to decrease their reliance on expensive and

increasingly scarce fossil fuels. Controversy arises when the sustainability of these alternatives is investigated. Biofuels and nuclear energies are among those sources.

Biofuels are the most water-intensive fuel sources, consuming over 1000 gal/MMBtu on average, “a water consumption one or two orders of magnitude greater than that of alternative sources of liquid fuels.”^[7] Nuclear energy, itself, is the highest water-demanding thermoelectric technology, consuming 200–800 gal/MWh depending on the technology used.^[7] There is a policy and institutional dimension to this part of the nexus that needs to be properly communicated through a common global agenda in order to relax any stresses water and energy systems are encountering due to current practices. There is a need to explore the potential of relying on renewable natural resources like wind and solar energy that would contribute in solving the challenge of meeting increasing demands without exerting more pressure on the nexus.

WATER–FOOD LINKAGES

The world is facing a water scarcity challenge, where agriculture is its predominant consumer. It accounts for approximately 3100 billion m³, or 71% of global water withdrawals today, and is expected to increase to 4500 billion m³ by 2030.^[8] In addition to the increase in water scarcity, the agricultural sector faces an enormous challenge of producing almost 50% more food by 2030 and doubling production by 2050.^[9]

Optimizing the agricultural process is a necessity. A controversial issue lies behind growing the same crops

Table 1 Energy requirements in transporting water.

Energy required to deliver 1 m³ of clean water from:

Lake or river	0.37 kWh/m ³
Groundwater	0.48 kWh/m ³
Wastewater treatment	0.62–0.87 kWh/m ³
Wastewater reuse	1–2.5 kWh/m ³
Seawater	2.58–8.5 kWh/m ³

Source: World Business Council for Sustainable Development.^[5]

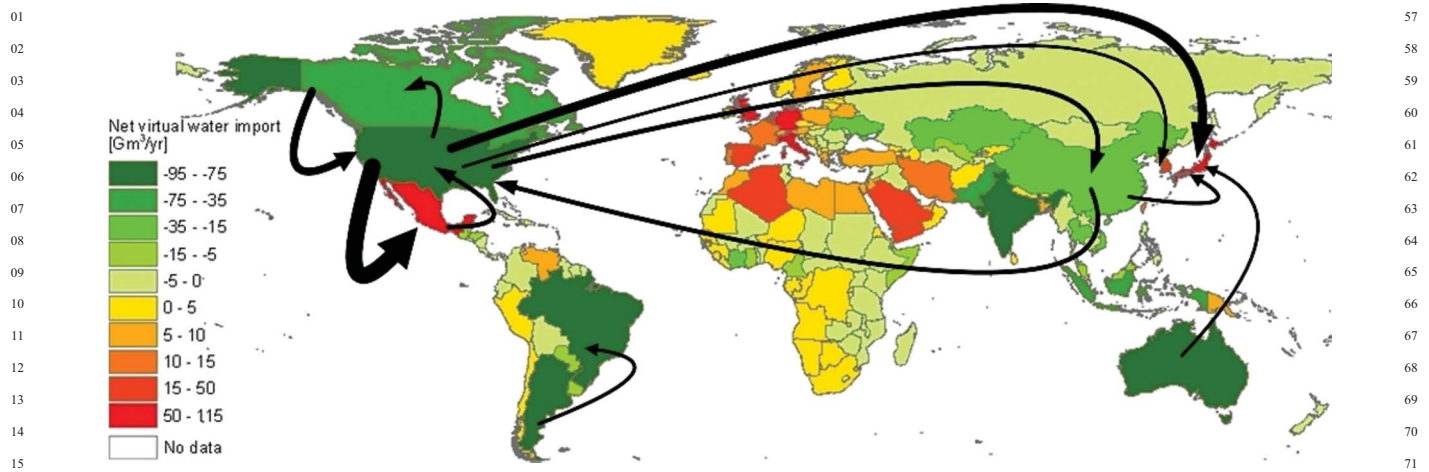


Fig. 2 Virtual water balance per country related to trade in agricultural and industrial products over the period 1996–2005. Net exporters are shown in green and net importers in red. The arrows show the biggest gross international virtual water flows ($>15 \text{ GM}^3/\text{yr}$); the fatter the arrow, the bigger the virtual water flow.

Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011).^[15]

with less water by using more efficient technologies at a local scale. With regard to improving irrigation efficiency, Kendy et al. argue that water is not saved through reducing seepage, as drainage is needed to recharge the underlying aquifer.^[10] It is significant to realize that different countries and areas in the world differ with respect to technological advancement and ability to afford and shift to newer, more efficient practices. There is a need to understand the potential of reallocation of globally grown food products in a manner that maximizes the utility of green water (rain fed). This leads to saving scarce blue water (surface and groundwater) for producing the same amount of food.

Water productivity, defined as the output per unit of water volume consumed, varies from one place to another. This process is not just a matter of available technology or available human, social, and institutional capital. The fact that different countries have different water productivities creates a comparative advantage for those countries that have relatively high water productivity in producing water-intensive crops.^[11]

The issue goes further beyond the complexity of allocating water-type resources and areas of higher water productivity to actually making use of this knowledge through trade. Trading in agricultural products also means trading of the water embedded in growing these products, which is known as virtual water (Fig. 2). An obvious effect of international trade in water-intensive commodities is that it generates water savings in the countries that import those commodities. This effect has been discussed since the mid-1990s.^[12,13] In the period from 1997 to 2001, Japan (the largest net importer of water-intensive goods in the world) annually saved 94 billion m^3 by not using its domestic water resources. This volume of water would have been required, in addition to its current water use, if Japan domestically produced

products instead of importing them. Similarly, Mexico annually saved 65 billion m^3 , Italy 59 billion m^3 , China 56 billion m^3 , and Algeria 45 billion m^3 .^[14]

A major example of virtual water import is Jordan. Jordan imports close to 90% of its food.^[16] Importing 5–7 billion m^3 of water in virtual form per year is in sharp contrast to the 1 billion m^3 of water Jordan withdraws annually from its domestic water sources.^[17] Taking an extreme side of this issue, if trade of food products did not exist, Jordan would be forced to extensively use its domestic water resource, which is mainly blue water, thus depleting it and rapidly causing hunger threats. Yet by externalizing its water footprint, Jordan is in a weak spot of water dependency, which could be costly on the political and social levels.

Hoekstra^[18] mentioned that according to international trade theory that goes back to Ricardo,^[19] nations can gain from trade if they specialize in the production of goods and services for which they have a comparative advantage, while importing goods and services for which they have a comparative disadvantage.

Water should be viewed and recognized as a global resource, and the actual amount of water saved by countries for food production should be viewed as a reduction to a global water bill. The entire world's responsibility is to bring this bill down.

FOOD–ENERGY LINKAGES

For the period 2006–2008, average world prices of different products rose significantly, leaving a huge portion of the global population unable to afford their basic nutrition needs. Rice price rose by 217%, wheat by 136%, corn by 125%, and soybeans by 107% during this period.^[20] Fred

Magdoff in “The World Food Crisis” relates the soaring in food prices during that period to different reasons, one of which is the rise in petroleum prices.^[20] For this reason, the United States, Europe, and other countries adopted biofuel policies to limit their dependence on petroleum. It is estimated that over the next decade about one-third of the U.S. corn crop will be devoted to ethanol production.^[21] Biofuel policy advocates insist that effects are limited as the additional production of corn for biofuel production between 2006 and 2009 only represented a small portion of globally consumed energy. Though this is true, it ignores the fact that the amount of grain transformed to fuels is equivalent to a year’s supply of cereal for 250,000 people.^[7] According to the Food and Agriculture Organization, 925 million people do not have sufficient food, 98% being in developing countries.^[22] Land that was once used for growing food is now transformed into biofuel production. Arable land is a limited resource that is struggling to cope with the growing demands, especially since yields have already reached their maximum limits.

On another note, there is serious concern regarding the sustainability of biofuels while considering water consumption, water and soil degradation, and other ecological impacts that could prevail due to excessive use of fertilizers. Governments should be aware of the sensitivity that exists between both systems and the unfavorable consequences that could surface as a result of any unplanned shift or tradeoff.

CONCLUSIONS

Water, energy, and food are three highly connected systems. The ability to face the current and anticipated global challenges will be governed by the ability of better understanding the interconnectedness and tradeoffs between these systems. Higher levels of collaboration between governmental entities concerned in setting future resource management strategies and policies are thus a must.

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