Globalization TrendLab 2016

WATER

Scarcity, Excess, and the Geopolitics of Allocation

The Lauder Institute
Wharton · Arts & Sciences
University of Pennsylvania

Santander
UNIVERSITIES

Globalization TrendLab 2016

WATER

Scarcity, Excess, and the Geopolitics of Allocation

Based on a conference organized by the Joseph H. Lauder Institute of
Management & International Studies at the University of Pennsylvania,
sponsored by Santander Universities, and distributed worldwide
through the Knowledge@Wharton network.

Executive Summary

Water is an essential resource whose use is increasingly coming under scrutiny as acute and chronic shortages proliferate around the world. Population growth, the rise of the global middle class, and urbanization are putting stress on existing water resources. Water security and geopolitical stability are contingent on the effective resolution of both the global and the local tensions affecting the efficient and equitable use of this resource.

Water is normally considered to be a renewable resource, but its quality and distribution around the world are the subject of innumerable debates, frictions, and conflicts. Most natural disasters, as many as 90 percent, are water related. Major refugee crises have erupted as a result of droughts or conflicts over water. The OECD has estimated that by the year 2030 almost four billion people—nearly half of the world's predicted population—will live in areas with serious water shortages, mostly in Africa, Australia, East Asia, South Asia, and the Middle East.

Nearly 700 million people lack access to clean drinking water, and about 2.8 billion face water scarcity during at least one month a year. The scarcity problem can be driven by physical/environmental or economic factors. Some parts of the world lack enough water to support present and future population levels, while in other areas, water scarcity is due to economic reasons such as lack of infrastructure or mismanagement of resources. Water pollution further limits supplies.

More than two-thirds of worldwide human-related water consumption is for agricultural purposes, while industrial usage accounts for 20 percent and households for the remaining 10 percent. Sustainability in agriculture thus poses the greatest challenge, and it involves not just the efficient use of water but also the judicious use of soil, fertilizers, and other inputs. New irrigation techniques, genetically modified water-efficient crops, wastewater reuse, and to some extent desalination may increase water efficiency while reducing soil pollution, but may never become the fix to our growing water needs, especially in inland areas. More importantly, behavioral change, especially in terms of dietary preferences (e.g., meat consumption), could make a big difference in terms of reducing water-to-calorie ratios.

Water is also essential for almost every source of energy. According to the United Nations, about 90 percent of all electric power generation is water-intensive. Water is needed to extract, wash, and sort raw materials and fossil fuels; cool thermal power plants; cultivate biofuels; and power hydroelectric turbines. The risks affecting the water-energy connection are manifold. Pollution of aquifers needed for human consumption or agricultural use due to mining or fracking operations is on the rise. Anthropogenically-driven climate change will be a disruptive force, changing precipitation and evaporation rates on land, and more generally changing the systemic interconnections among land, oceans, and the atmosphere. Policymaking and planning needs to take into consideration the constraints and the risks inherent to increasing demand for both water and energy.

Water issues also figure prominently on the global development agenda. According to the 2015 Update of the joint UNICEF and World Health Organization report, 9 percent of the world's population lacks access to an improved drinking water source. The Sustainable Development Goal for the year 2030 is to "achieve universal and equitable access to safe and affordable drinking water for all."

A variety of technologies—from desalination to waste water reuse, and from information-driven innovations to new market-based mechanisms—have the potential of improving efficiency and making available new sources of water and opportunities. An especially important challenge is the diffusion of knowledge and best practices around the world, especially in least developed countries.

The geopolitics of water has also emerged as a new field of study and concern. The Middle East, the Nile, the Colorado River Basin, and the Tibetan Plateau are among the hotspots of geopolitical conflict over water. Sharing the world's water wealth will require not only better management, infrastructure, and technology but also delicate diplomacy, especially given the potential effects of climate change on the world's hydrology.

Novel technology; new, better-managed, and lower-impact infrastructure; innovative market solutions; effective governance and institutional mechanisms; and education and behavioral change all must play a role in ensuring water sustainability over the long run. ■

Introduction—The Worth of Water

Rengarajan Ramesh, Terry Anderson, Miriam Balaban and Charles J. Vörösmarty

When the well is dry, we learn the worth of water," said Benjamin Franklin. We take water for granted as essential to our way of life. Water may be a renewable resource, but its quality and distribution around the world are the subject of innumerable debates, frictions, and conflicts. The changing geographical distribution of population growth, the process of urbanization, and the growth of the middle class of consumers will fundamentally reshape the economics and politics of water, according to Lance Donny, Founder and CEO of OnFarm, a provider of farm management data systems. Growing demand for food, which requires huge amounts of water, will be met in the future not so much by expanding the land used for cultivation but by productivity increases. As Charles Vörösmarty, a professor and water expert at the City University of New York, puts it, water is "the great integrator" that brings all of the great issues of our time together: economic crises, poverty, sustainability, infrastructure, and the role of the state.

Water and water management lie at the root of large-scale human civilization, especially in the wake of the agricultural and industrial revolutions. Every major civilization, from Ancient Egypt and Mesopotamia to the Indus Valley, Ancient China, and Ancient Rome developed water-management infrastructure and technologies to feed and sustain large concentrations of population. At the same time, most natural disasters, perhaps as much as 90 percent, are water related (United Nations University 2013). Major refugee crises have erupted as a result of droughts or conflicts over water, as in Somalia in 2011 or Sudan and Mali, both in 2012. In its 2011 report, *Towards Green Growth*, the OECD estimated that by the year 2030 almost four billion people — nearly half of the world's predicted population — will live in areas with serious water shortages, mostly in East Asia, South Asia, and the Middle East.

More than two-thirds of the earth's surface is covered with water, but 97.5% of that water is salt or brackish, and unsuitable for sustaining life. Linking suitable water sources to human populations remains an enormous challenge. The planet contains about 35 million cubic kilometers of freshwater, or 2.5 percent of the total volume of water. Most of that freshwater, perhaps as much as 70 percent, is also beyond the easy reach of human populations—frozen water in ice sheets, glaciers,


Meredith Giordano

permafrost, and permanent snow cover. About 30 percent is groundwater, and less than 1 percent is in rivers, lakes, wetlands, and other reservoirs. Around 1.2 billion people lack access to clean drinking water, and about 2.8 billion face water scarcity during at least one month a year. The scarcity problem can be driven by physical or economic reasons. Some parts of the world just lack enough water to support present and future population levels, while in other areas, especially Sub Saharan Africa and parts of South Asia, water scarcity is due to lack of infrastructure, mismanagement of resources, or other economic factors. In some of these regions, women and children spend up to five hours per day procuring water for their families during droughts.

Roughly 70 percent of worldwide human-related water consumption is for agricultural purposes. Industrial usage accounts for 20 percent, leaving the remaining 10 percent for households. Sustainability in agriculture thus poses the greatest challenge for water management, and it involves not just the efficient use of water but also the judicious use of soil, fertilizers, and other inputs. Since only 11 percent of Earth's surface is suitable for agricultural use, and the indiscriminate use of fertilizers, erosion, and global warming might further reduce it, wise agricultural management is important not only for the present but also for the future. Consumers, governments, NGOs and the agricultural community itself need to continue encouraging long-term planning. Subsidized water prices for agricultural use, which in some cases discourage conservation, pose another serious challenge. New irrigation techniques, genetically modified water-efficient crops, and desalination may expand the universe of opportunities. More importantly, however, behavioral change, especially in terms of protein consumption, could make a big difference in terms of reducing water-to-calorie ratios and reducing the pressure that agriculture exerts on water supplies. As consumers we need to also recognize that we are the ultimate end users of the water that goes into agricultural production.

Water is also needed for almost every source of energy to be useful. According to the United Nations, about 90 percent of all electric power generation is water-intensive. Water is needed to extract, wash and sort raw materials and fossil fuels; cool thermal power plants; cultivate biofuels; and power hydroelectric turbines. The risks affecting the water-energy connection are manifold when energy needs and the preservation of water supplies collide. Pollution of aquifers needed for human consumption or agricultural use due to mining or hydraulic fracturing ("fracking") operations is on the increase. Climate change will be a disruptive force as well. Policymaking and planning need to take into consideration the constraints and the risks inherent to increasing demand for both water and energy. Thus, there is a "water-energy nexus," as well as a "water-energy-food nexus," according to Ralph Exton, Chief Marketing Officer for GE Power, Water & Process Technologies. Another angle is that of resilience of water systems, as in the wake of natural disasters. Meredith Giordano, Principal Researcher and Advisor for Research Strategy and Management at the International Water Management Institute, argues that solutions to water challenges can often

> “Sharing the world’s water wealth will require not only better management, infrastructure, and technology but also delicate diplomacy.”
>
> *– Miriam Balaban*

be found through linkages with other sectors, for example by creating policy synergies between agriculture and energy sectors. For instance, hydroelectric power is compatible with usage of the water downstream for agricultural purposes.

Scarcity of water in different parts of the world and at various points in time continues to be a key challenge for local communities and, in some cases, for entire cities or regions. Giordano notes that water scarcity is a “complex issue” that manifests itself in different forms. “It is a function of quantity, quality, distribution across time and space, and access.” Simple measures of water scarcity may not account for this complexity, so we need to be careful in how we interpret for policymaking; “it is very important to assess the underlying causes of water scarcity and if it is a chronic or an acute issue.” Dale Whittington, a water economist and professor at the University of North Carolina at Chapel Hill, further argues that individual acute crises, such as a drought in California or a monsoon in South East Asia, if they coincide in time could have global repercussions. Nevertheless, argues Exton, experts today prefer to avoid the “doom and gloom” concept of scarcity and frame the issue in terms of sustainability, “putting a more positive spin on it, and bringing technology and policy to bear” on possible solutions.

One specific controversy that stands at the beginning of any discussion of water supply and access is whether one may accurately talk about “peak water” the same way that analysts have assessed the implications of “peak oil”: the point when the maximum rate of extraction of petroleum is reached, after which it is expected to enter terminal decline. Terry L. Anderson, Senior Fellow at PERC, argues that water is, after all, a renewable resource, and thus the concept of “peak water” is not accurate. For Noam Lior, an Engineering Professor at Penn, and Rengarajan Ramesh, a partner at Wasserstein & Co., LP, by contrast, it does make sense to think about peak water because humanity could well be on its way to depleting all fresh water resources on the planet. They argue that water is a finite resource. “Water is the most overused, abused, and underpriced resource in the world, and a large fraction of it is not renewable or is returned undrinkable,” notes Lior. “Governments are reluctant to intervene. Nobody wants to undertake a thorough cost analysis and to formulate policies based on it.”

Over time, much progress has been made in terms of preserving water resources. Since the 1960s

Thayer Patterson, Peter Jaffé, Noam Lior and Irina Marinov

Ian Lyle

conservation efforts and new technologies have reduced consumption from 0.3-0.4 cubic meters per dollar of GDP to less than 0.1 in most developed countries. Developing and emerging economies have also reduced water use to comparable levels (UNESCO 2009: 88, 99, 108, 109, 111). Still, for major water crises to be avoided in the next two decades, large-scale technological, policy, and behavioral changes will be needed.

Water issues also figure prominently on the global development agenda. According to the United Nations' *Millennium Development Goals Report* of 2012, 780 million people, or 11 percent of the world population, lack access to safe drinking water. Nearly half of them live in Sub Saharan Africa. That is still a very large number, although back in 1990 some 24 percent of the population at the time were affected by this severe problem. Water scarcity, meaning the lack of sufficient water during at least one month a year, affects about 2.8 billion people, or 40 percent of the population.

The geopolitics of water has emerged as a new field of study and concern. The Middle East, the Nile, and the Tibetan Plateau are among the new hotspots of geopolitical conflict over water.

Sharing the world's water wealth will require not only better management, infrastructure, and technology but also delicate diplomacy, argues Miriam Balaban, Editor in Chief, *Desalination and Water Treatment Journal*, publisher of *Desalination Directory*, and Secretary General of the European Desalination Society. Global water diplomacy will become especially relevant in the context of the potential effects of climate change on the world's hydrology. An especially thorny issue involves transboundary water, i.e., water systems that straddle national borders. Two- thirds of the approximately 275 major transboundary watersheds in the world, involving 148 countries, are not covered by a treaty specifying how the water is to be shared. There are also over 300 aquifers located across two or more countries (United Nations University 2013). Furthermore, desalination technology can offer water at affordable prices to neighbors with water scarcity.

Changes in the climate cycle will inevitably affect the water cycle in unforeseen ways, exacerbating episodic droughts and floods. In addition to these recurring challenges of water management, global warming poses new threats and will have several immediate effects. First, evaporation will increase and divert water that would otherwise fill streams, rivers, and lakes. Second, changes in vegetation will alter rainwater patterns. Third, warming will make glaciers recede, thus depriving streams and rivers of their steady flow of water. Fourth, water available for irrigation will become scarcer. And fifth, sporadic heavy rainfall will stagnate in warmer temperature, and provide mosquitoes with new breeding areas, posing significant new public health challenges.

The concept of "water security" captures many of these old and new challenges. It is defined by the United Nations University Institute of Water, Environment & Health (2013: vi) as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring

> “Water is the most overused, abused, and underpriced resource in the world, and a large fraction of it is not renewable or is returned undrinkable. Governments are reluctant to intervene.”
>
> *– Noam Lior*

protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.” The central idea is that security, sustainability, economic development, and human well-being all depend on a reliable and safe supply of water. As such, water security implies access to safe drinking water, the protection of livelihoods, the preservation of ecosystems, the supply of sufficient water to support economic activity, the reduction of pollution, and the ability to cope with water-related hazards. Managing scarce water resources, argues Ian Lyle, Director of Federal Affairs for the National Water Resources Association, largely involves the three Es: engineering, environmental impact management, and economics. And then there is politics, with all the challenges that they bring. As Lyle notes: “In the Western United States, there is an old saying that whiskey is for drinking, and water is for fighting. However, that dynamic is shifting in many areas as resources, both economic and environmental, become more limited. It is not uncommon to see agricultural and municipal water providers, tribes and, in some cases, environmental groups working together to find solutions to water supply challenges. That said, political challenges remain and need to be worked through continually.” ■

The Systemic Interconnections among Oceans, Land, and the Atmosphere

Thayer Patterson, Peter Jaffé and Noam Lior

In addition to covering 71 percent of the Earth's surface, oceans play a central role in everything, from food production to cargo transportation and from the water cycle to global climate patterns. The balance of systemic interconnections among land, oceans, and the atmosphere is intricate and delicate.

One major development putting stress on water systems around the world is climate change. According to Princeton Engineering Professor Peter Jaffé, climate change has not yet produced a large enough increase in average temperatures to have an easily detectable effect on biogeochemical cycles of nutrients, but it has exacerbated the impact of extreme climate and weather patterns and events, (droughts and floods), which do have a very noticeable inter-annual effect on nutrient transformations and fluxes of nutrients from soils to rivers and then oceans, resulting in varying degrees of anoxia in water bodies such as the Chesapeake Bay or the Gulf of Mexico. Penn Assistant Professor Irina Marinov, an oceanographer and climate modeler, points out that often it is the rate of change rather than the net value in a climate variable that matters most: The rate of change of temperature we observe today and the rate of temperature and CO_2 increase projected for the next 100 years are unprecedented, many times more abrupt than other well-known transitions in the climate record. The recent increases in temperature are due to the anthropogenic emissions of greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, with carbon dioxide having the most important global role because of its abundance relative to the others. Over the past million years, atmospheric CO_2 concentrations have fluctuated on a 100,000-year pattern between 180 and 270 parts per million (ppm) from cold glacials to warm interglacials, respectively. We are currently in a warm, high CO_2 interglacial period; and over the past 200 years the CO_2 concentration has increased in response to human emissions from 270 to 400 ppm. As Marinov notes, "we have changed the system more in 200 years than nature usually does in 100,000-year cycles."

One key limitation when it comes to effective assessment and policymaking is our lack of a complete picture of the interaction among land, oceans, and atmosphere, and the implications of sustained disturbances such as global warming, argues Marinov. Oceans have absorbed as much as 90 percent of the additional heat that human activity has generated over the last 2,300 years. This begs the question of how much absorptive capacity oceans will continue to have under a warming climate. It is very important to understand and model both the heat and carbon cycles of exchange between oceans and the atmosphere, which could reinforce and accelerate patterns of global warming. As Marinov notes, "as oceans become warmer, carbon in the ocean will become less soluble and more carbon will be released into the atmosphere by the oceans." This is an example of an ocean-driven positive feedback on atmospheric CO_2 and climate warming issues. Another is ocean acidification, which in turn results in a decreasing capacity of the ocean to hold future carbon.

Irina Marinov and Huijuan Wu

Small changes in climate in one part of the world may have major consequences in other parts, with important implications for the water cycle and the availability of fresh water locally. In some of their recent research, Marinov and her group address these tight global climate interconnections. For example, the rain belt between the Tropics, which accounts for most rainfall in the world, can be affected by very small changes in ocean surface temperatures in specific areas, such as the Weddell Sea, a small but climatically important sea in the Southern Atlantic close to Antarctica. Temperature oscillations or trends in the ocean surrounding Antarctica and generally in the Southern Hemisphere, which holds most of the world's salt water, can change the rainfall levels in the Sahel region of Africa, for example. People and ecosystems are being affected by drastic swings that produce either scarce or excess rainfall. Lior agrees that oceans are increasingly under stress and are interconnected with the rest of the climate system.

> "As oceans become warmer, carbon in the ocean will become less soluble and more carbon will be released into the atmosphere."
>
> *– Irina Marinov*

Another key issue involves nitrogen, a key nutrient for all known forms of life. Jaffé observes that nitrogen pollution is becoming a major issue affecting watersheds. Industry and agriculture now generate more nitrogen compounds than natural processes. Of the 500 million tons of fertilizer used every year, nearly half ends up in watersheds. Once this nitrogen is flushed into surface waters, it will stimulate algae growth, depleting oxygen in the water and thus making life harder or impossible for many creatures. This is especially critical in estuaries and the near shore environment. Furthermore, climate change will make fertilizer use even more extensive as farmers seek to

> Forests transfer large amounts of water into the atmosphere through plant transpiration, which in turn contributes to cloud formation and rainfall.

maintain or increase yields to feed a growing population, thus intensifying nitrogen concentrations.

There are other sources of environmental concern. Lior worries about the melting of the permafrost in the Northern hemisphere's high latitudes, which would release huge amounts of methane into the atmosphere. Ramesh observes that deforestation has implications not only for global warming but also for the water cycle. Forests transfer large amounts of water into the atmosphere through plant transpiration, which in turn contributes to cloud formation and rainfall. As a result of deforestation, more water flows downriver and is discharged into the sea. Deforestation in Brazil, for instance, has slowed down, but only after forest clearings increased significantly over decades. The depletion of bushes and trees for charcoal production in developing countries also contributes to deforestation.

The interdependent implications of climate change, nutrient pollution, and deforestation on global water security are significant. Further research is needed to assess not only the potential magnitude of these effects on water cycling and use at the local and global level but also, as Lior indicates, the extent to which policymaking has a chance of making a relevant change for the better. ■

Water and Infrastructure

Miriam Balaban and Charles Vörösmarty

There is no doubt that investments in infrastructure, and better management of the existing infrastructure, will be needed to address the impact of climate change and natural disruptions to the water cycle and to meet the needs of an expanding population and growing cities. According to McKinsey & Co., water is the third most important and costly area for infrastructure development to the year 2030, after transportation and energy. Among all areas of infrastructure, water happens to be the most difficult to tackle for a variety of technological, economic, and political reasons. Water is difficult or costly to store and to transport over large distances. In the developed world, a variety of government agencies at national and local levels have authority over water, creating a fragmented policy and regulatory landscape. In developing countries, infrastructure per se may not provide all the answers given that culturally ingrained habits and practices need to be addressed as well.

In developed countries, problems range from the aging water infrastructure to the changing climatic and economic demands. Lyle, who represents water users in the western United States, notes that more than 60 percent of U.S. Bureau of Reclamation-managed dams are over 50 years old and a sizeable portion of Reclamation infrastructure is more than a century old. Similarly, more than 50 percent of the dams operated by the U.S. Army Corps of Engineers have reached or exceeded the 50-year service lives in their initial designs Moreover, Reclamation infrastructure was largely designed to spur economic development through irrigated agriculture. However, as the U.S. has grown, many of these projects are now being used to supply urban areas and support these economies. Lyle also notes that maintaining this infrastructure is important because it continues to provide water that produces 60 percent of U.S. vegetable production and more than 25 percent of U.S. fruit and nut production.

Another important issue is the lack of comprehensive planning. Vörösmarty observes that projects within the global water sector are worth 700 or 800 billion dollars annually, and may more than double by 2020. Most projects aim to remedy problems with water supply, such as the overuse or contamination of water in the world's major watersheds. Infrastructure investment in remediation is the pandemic response to water challenges, which create arguably local-scale solutions but create broader-scale and more long-lived impacts on the environment. This approach is in lieu of problem-prevention strategies and solutions that will provide for long-term sustainability.

Massive projects that deal only with individual issues can have multiple long-term consequences, some of them unexpected and unintended. Kimberley Thomas, a postdoctoral geographer at

> “We might need to think in terms of the ‘water matrix’ in the same way that we learned to use the concept of the ‘energy matrix.’”
>
> *– Mauro Guillén*

the University of Pennsylvania, has studied the impact of large engineering projects originally intended to protect farmers from flooding in Bangladesh, for example, and has noted the very negative long-term effects on hydrological systems and ultimately agricultural yields of building polders and other similar infrastructure. Many of these projects cost tens if not hundreds of millions of dollars, generally funded by multilateral agencies such as the World Bank or USAID, but end up creating new difficulties. Thomas especially notes the effort to construct massive embankments in the name of flood control, which also eliminated the traditional spreading of sediment that previous floods would have brought, leading to dislocation of traditional agricultural and social patterns.

Huijuan Wu, a Research Fellow at the Institute of Water Policy of the National University of Singapore, advocates comprehensive river basin management to address water issues at the local level, citing the example of China’s management of the Yellow River. China’s development of a system of permits that can be shared and traded among regional authorities has helped manage that massive river basin, which sustains 10% of China’s population and 50% of its agriculture. Wu proposes that collecting extensive data to conduct sustainability assessments is needed to formulate policy, design regulatory frameworks, and make political decisions, using a battery of indicators to assess water management and to track progress over time. As part of her Environmental Performance Index, Wu includes metrics on environmental flow, water quality, river channel capacity, sediment transport, biodiversity, and land use. She has also developed a Social Wellbeing Index measuring flood risk, drought risk, water consumption, water access, wastewater discharge, water allocation, and public health. Finally, she recommends using an Economic Development Index to track infrastructure, hydropower, water utilities, wastewater treatment, and institutional capacity.

Water security requires smart thinking, long-term planning, and diversification in addition to large investments, argues Wu. Singapore exemplifies this approach. The city-state imports water from Malaysia, has invested in a comprehensive water catchment infrastructure, NEWater (high-grade reclaimed water produced from treated wastewater), and desalination. These multiple sources provide greater long-term security for a country that would otherwise suffer from water limitations. Mauro Guillén, Director of the Lauder Institute, suggests that we might need to think in terms of the “water matrix,” in the same way that we learned to use the concept of the “energy matrix,” starting in the 1970s, a change that helped many countries around the world develop more coherent and effective energy policies. ■

Water and Technology

Ronald Granieri, Lance Donny, Dale Whittington and Stuart Woolf

Technology can make many different kinds of contributions to water sustainability, by expanding the horizons for efficient use and even by making alternate sources of water available. Information technology also promises to revolutionize the field.

One exciting frontier is desalination, argues Balaban. While desalination has become more cost-effective and established as a viable industry over the years, some experts argue that it can at best have a marginal effect on the overall picture and that it applies only to coastal areas. Nevertheless, much progress has been made. For centuries, desalination technology involved vaporizing water in a boiler to collect and condense it into distilled water. In the late 1950s the multi-stage flash (MSF) desalination technique was developed in Scotland. It used the condensed heat in the vapor to heat more water, eventually enabling the production of up to 10 tons (or even more than 20 in some pilot plants) of distilled water with one ton of steam. In the 1960s, reverse osmosis was pioneered in the U.S.by pumping water at high pressures through a membrane that would filter out most of the salt. Incremental improvements to reverse osmosis have made this technology more energy-efficient than MSF. It is now possible in many locations around the world to desalt water through reverse osmosis at an energy cost equivalent to the average cost of bringing fresh water from a distant source. Both rich and poor countries benefit from this technology, with over 300 million people presently relying on desalinated water for their daily needs, mostly in the Middle East, North Africa, Spain, and Australia.

A true water matrix, however, needs to include water reuse alongside new technologies for water extraction and production. We need to “break with the old linear cycle of water extraction and discharge, especially the question of water reuse,” according to Exton. Ramesh agrees that water reuse holds great promise. In Israel, up to 80 percent of water is reused. Balaban thinks that the greatest constraint is psychological, and Vörösmarty holds that people do not realize how much water reuse already occurs downstream in the world’s major watersheds. “Up to 80 percent of the world’s sewage returned to watersheds is untreated,” he asserts, and greater awareness of that already existing situation may help overcome public resistance against official reuse, which would

Regina Abrami, Ralph Exton, Meredith Giordano and Ian Lyle

explicitly embody purposeful treatment. Ramesh argues further that one does not have to turn wastewater into drinking water, given that one may use it for many other ends. Agriculture can be an especially effective place to reuse partially treated wastewater.

It is clear that "instead of discharging it into oceans and rivers, you can treat it further so that it can be reused for things like agriculture, industry and even drinking water," argues Exton. "And by the way, it uses about half the energy of desalination and it costs about half as much on average. So that is really the thing to focus on as we search for solutions." There are many real and psychological obstacles to exploiting opportunities in wastewater. "If you ask me," Exton notes, "those barriers are things like concern about whether reused water is safe for things like agriculture and drinking water. It's a lack of clear standards; so a lot of industries don't know if they can treat wastewater and use it to do something like, for example, wash their chickens in a poultry processing plant. They don't know because there aren't clear standards in many cases telling them what is allowable." The other big problem involves relative prices. "It's often cheaper to take water from the ground or river or even a potable municipal system, where it's almost universally underpriced, than it is to implement reuse technologies."

Equally impactful will be technological improvements that make more efficient use of water. Perhaps the biggest potential gains could be realized in agriculture, where up to 50 percent of usage might be reduced through the development of water-efficient seeds and by deploying drip irrigation more effectively. A big obstacle to efficiency increases is the fact that most people, farmers, and manufacturers pay only a fraction of the true cost of the water they use. In part, this is because access to water has been defined as a human right. It is clearly an institutionalized cultural assumption we all make, i.e., water is a given, until, as Benjamin Franklin once put it, the well dries up.

One way to make consumers at all levels more aware of water usage is through the application of new monitoring technologies. Donny notes that deploying information technologies in the form of sensors, drones, satellites, and software can vastly improve efficiency in water use, especially in agriculture. The recent history of agriculture is one of rapidly multiplying yields per acre. In Donny's experience, technologically savvy farms in California can save up to 10 percent of irrigation water. Whittington concurs: efficiency in water usage is very dependent on the technology used and on proper pricing, not just in agriculture but also in all areas of water usage. Vörösmarty argues that ground-level data gathering, with a proven track record, could ultimately prove to be more reliable, accurate, and dependable than more experimental satellite-based surveillance systems

> “Efficiency in water usage is very dependent on the technology used and on proper pricing, not just in agriculture but also in all areas of water usage.”
>
> *– Dale Whittington*

that are costly, prone to single-point failures (e.g., recent soil moisture radar failure aboard a NASA satellite), and need long-term commitments from governments to keep operational systems flying. The advantages of synoptic-scale monitoring afforded through remote sensing and the ground-truth securable from in situ monitoring mean that in reality some combination of both approaches will be necessary.

Measuring and mapping water resources around the world at the local level is also much needed as an input to policymaking and business decisions. Andrew Maddocks, Communications Lead for the World Resources Institute’s Water Program, argues that developing tools and methodologies to collect information on the quantity, quality, and regulatory and reputation risks around the world will also help develop a better overall view of what is needed to address global water security issues. ■

Markets, Prices, and Water

Catherine Brölmann and Eric Cooperström

One issue at the heart of the debate over water is the question of whether it can be considered an economic good. As Whittington notes, in many parts of the world sensible pricing of water for both irrigation and residential use is resisted, on the grounds that water is something more than a traditional commodity. Catherine Brölmann, Board of Directors of Waterlex, Geneva, and Associate Professor of International Law at the University of Amsterdam, observes that the relatively recent concept of water as a human right has carried with it significant practical, political, and even moral implications. It has changed the legal discourse on water, which traditionally hinged on" sovereign rights of states" (in a transboundary context), and on "water rights" of individuals (in a national context). But, Brölmann argues, even if the emerging human right to water for all has made a significant contribution to the various debates and may help for example in the prioritization of usages, the human rights approach is too one-dimensional to constitute a comprehensive normative framework for the governance of water resources. It will need to be combined with other approaches to water. Related but much more widely accepted is the idea that water supply is a publicly provided service As water becomes more chronically scarce in certain parts of the world, however, its character as a public service has come under criticism, leading in turn to more explicit invocation of human rights, with significant if sometimes unclear implications.

Even if one endorsed the idea of water as a "normal" commodity, creating an exchange market for it will also require mechanisms so that farmers can trade in water, argues Terry Anderson, a Senior Fellow at Stanford's Hoover Institution. Stuart Woolf, President and CEO of Woolf Farming & Processing, agrees. In California some farmers have water available to sell, and others need to buy. The latter are willing to pay, but they need to have a stable and clearly identified market in which to pursue such transactions. Donny and Woolf agree that one cannot and should not induce farmers to abandon farming for trading in water, but they should still have the possibility of trading their water rights in order to maximize efficiencies within the overall agricultural economy. The

In some cases the market for water is distorted by energy subsidies making groundwater extraction more economical.

challenges of creating a reasonably efficient market for water are huge, according to Anderson, but he is still optimistic that markets will play an important role in the allocation of scarce water, as in some experiments of "water banks" in Colorado, which enable different users to agree on an exchange price when they attach very different values to using it. Lior questiones whether markets, which are dominated by short-term financial data and reactions and do not consider human equity and welfare ("no brains nor heart"), have, by themselves the capability for long term planning for sustainability.

Economists approach water scarcity in two ways, argues Anderson. One is in terms of costs and benefits, and the other is in terms of institutional analysis, including markets and regulation. From the latter perspective, most economists suggest that water should be priced according to the principles of marginal cost and full cost recovery, and thus assess users a price that is a combination of a fixed and a marginal tariff. In addition, it may be good practice to charge a marginal rate that increases with volume to encourage water conservation. As of now there is no such uniform approach. As several participants pointed out, water is a heavily localized issue. National, regional, and local governments around the world charge water customers using very different systems for political, economic, and technical reasons. For instance, in some developing economies it is simply impossible to charge based on volume because metering is not universal, and the administrative capacity to collect the information and to use it for pricing purposes is not available. In addition, many governments lack the capacity to enforce regulations and to collect payments, with water bills routinely going unpaid. In many instances, water costs are billed to entire apartment buildings or complexes and not to individual households. In some cases the market for water is distorted by energy subsidies making groundwater extraction more economical, as in India, where there are nearly 40 million wells providing two-thirds of the water used for irrigation and 85 percent of the drinking water.

There is also wide disagreement as to what full-cost recovery means. In most countries, it includes operational and capital investment costs. The European Water Framework Directive of 2000 adds environmental costs to the calculation, an approach that France has already implemented. In any event, governments cross-subsidize agricultural use at the expense of industrial and residential consumption, and they often subsidize lower-income households, although doing so requires much more administrative effort than offering more general income support not tied to specific goods or services.

Terry L. Anderson and Scott Moore

> The price of water is “what people are willing to pay and, as in real estate, location makes a difference.”
>
> *– Ian Lyle*

A perfect model for pricing water may be too difficult to calibrate or impractical to implement and enforce. At the end of the day, Lyle argues, the price of water is “what people are willing to pay and, as in real estate, location makes a difference.” In many parts of California, as well as in Las Vegas, users pay more for their water in escalating tiers of volume consumed. In any event, “without some kind of price corrections,” Exton argues, “we will continue to have problems with water scarcity.”

Moreover, “any attempt at water sustainability over the long run must make good economic sense,” he notes. Otherwise, “the effort at sustainability will not be itself sustainable.”

Pricing water more or less accurately, however, may not be enough in developing countries. There are many market failures that may need to be addressed through government intervention or entrepreneurship, or both. Giordano mentions the role of entrepreneurs in South Asia and Sub Saharan Africa offering pump rental services to farmers who cannot afford to purchase pumps. Eric Cooperström, a Principal at the Skoll Foundation, thinks that social entrepreneurs can help the world use water resources more efficiently and improve the lives of the poor. Innovations in this area range from the use of sensors and other technologies to providing new financial solutions to facilitate investments so that access to safe drinking water and improved sanitation can be expanded to the billions of people who lack it. ■

Education and Behavioral Change

Ronald Granieri, Lance Donny and Dale Whittington

As in the case of energy use, education and behavioral change can make a great difference when it comes to promoting the sustainable use of existing water resources. Exton argues that the fundamental problem is that "many people do not understand where the water comes from, how much it costs, and how the water cycle works." Although many people in developed countries receive a bill for their water use, few of them take the time to understand how much they actually consume and how they can be more efficient, unless there is a shortage. Both Jaffé and Lior believe that eliminating unnecessary waste is the absolutely essential first step, which means both repairing aging and leaking infrastructure and developing regulatory practices to manage use and, if necessary, to punish misuse. Lior also suggests that educating children about the importance of water and its use and conservation is most effective. For Wu, many water-related problems in the world can be overcome through simple common sense, especially when it comes to conservation and efficient use.

For Vörösmarty the key is to create opportunities for educational and behavioral change that lead to a better appreciation of the systemic character of sustainability. In his view, school curricula do not yet help students understand all of the interconnections and implications, and could do much better. Ramesh notes that water is not yet a hot topic for most people, and hence it does not have enough prominence in public discussions. In countries such as Israel, where water is more of an immediate concern, policymaking and education are much more proactive and effective in shaping public awareness. Ramesh further argues that the entire water sector has not produced the kinds of returns that would attract the best minds as well as avid investors, with the possible exception of desalination, which has also limited the economic and technological investments in new and more effective technologies.

Brittany Montgomery, a researcher at MIT's Urban Studies and Planning Department, notes that education does not necessarily result in behavioral

Andrew Maddocks

change, and efforts to improve awareness of households' water quality through in situ testing have been unsuccessful. Exton mentions that true behavioral change occurs only when social structures and habits are taken into consideration. In many parts of rural Sub Saharan Africa, for example, women spend hours going to wells to obtain water, and they view this activity as an important part of their social lives because they meet people along the way. Any improvements in water deliverability to such communities will have to take those kinds of social situations into account. In general, all participants agreed that it is important to understand the social and cultural underpinnings of people's habits in water use if regulators or officials at any level—governmental or non-governmental—hope to intervene effectively.

In some cases, unintended consequences of incentive schemes must also be addressed. Giordano uses the example of a program in India to encourage the use of solar-power irrigation pumps as a way to promote renewable green energy. The danger is that, given the availability of solar power, the farmers end up extracting more water than they need. A solution to this problem is to enable the farmers to sell the surplus solar power to the grid so they do not use it to pump water they do not really need.

Another area ripe for behavioral change involves food consumption. Water is traded around the world embedded in food. The virtual water trade accounts for about 15 percent of total human water consumption, with the major exporting countries being the U.S., Canada, and Australia. Giordano argues that people's awareness of food waste and the implications for water conservation should play a more important role in efforts at water sustainability. Lyle suggests that efficient water use could be used in the marketing of a product, allowing consumers to make educated choices, as many already do, when purchasing fair trade, organic, or eco-friendly products. Use of product labels to inform people as to the amount of water needed to produce the food they consume could provide valuable information. For instance, producing a pound of beef requires about 1,600 gallons of water. As in other cases, greater collection, presentation, and awareness of data can help shape future decisions about water usage. ■

Local and Global Governance

Scott Moore and Kimberley Thomas

Good and effective governance is essential to achieving water security at the global, national, and local levels. It includes the soft infrastructure of institutions, regulations, and decision-making mechanisms to manage existing and future water resources. For Vörösmarty, governance—from the global to local level— is perhaps the biggest challenge of all regarding water. Governance mechanisms are sorely needed to arbitrate conflicts between upstream and downstream users, the management of globalization-incurred problems on local water systems, and the inevitable disputes that are sure to arise among different water users.

In contrast to Vörösmarty, Exton argues that solutions to water problems are generally local in nature. "The problem is that new technology gets adopted and diffuses slowly. Incentives help sway minds and it also helps develop and improve technologies over time with a reduced cost over time." In Texas, Ramesh notes, water is managed at a very local level, and quite effectively, and should be studied by other agencies for possibly adoption or adaptation. Lyle agrees that local governments and state governments must play a lead role in water management. This is especially important as management relates to water rights in the U.S., where a water right is a property right. He also notes the Texas model may be hard to transplant elsewhere because of institutional and regulatory legacies. In addition, even in California growers are not equally systematic when it comes to managing their water usage. Woolf attributes this to the institutional effect of senior versus junior rights. For instance, he notes that some growers continue to use flood irrigation, which is much less efficient than drip irrigation, taking advantage of their individual access to water without regard to the broader system. Any form of regulation, even at the local level, will have to develop policies that more effectively link the individual user to community standards and requirements.

As in any field of infrastructure, public-private partnerships (PPPs) may be a useful instrument

> “At the global level, effective governance is needed not only for the purposes of policy coordination when the issue affects a multiplicity of countries, but also to diffuse best practices.”
>
> *– Stuart Woolf*

for promoting investments. Lyle, however, notes that, at least in the case of water, PPPs face challenges because private investors and public utilities have very different time horizons and expected rates of return. However, Lyle also noted that water infrastructure could work well for investors looking for secure long-term investments. He also indicated that the PPP model could become more attractive to water suppliers as infrastructure needs increase.

Different actors are involved in improving governance to very different extents. Lior and Whittington argue that planning on the part of policymakers is often poor and typically driven by crises and political interest group pressures. Woolf thinks that governments are not good at adopting a long-term perspective, and farmers are always looking to minimize risks when it comes to securing water. Vörösmarty faults universities for not paying enough attention to treating the study of water problems, and their solutions, more holistically.

At the global level, effective governance is needed not only for the purposes of policy coordination when the issue affects a multiplicity of countries, but also to diffuse best practices. In Mexico, for instance, many farmers lack meters, have little sense of the costs, and receive subsidized energy. Woolf suggests that this problem can be addressed only through the diffusion of knowledge and perhaps also by the willingness of farmers in developed countries to work more actively to share their knowledge and experiences.

Another important aspect is the role of transnational social movements and networks. Scott Moore, a political scientist at the World Bank Group’s Global Water Practice, argues that it is important to “ensure that their energy and creativity translate into constructive actions at the local level,” where most water issues manifest themselves, in addition to rallying support for the cause of sustainability at the cross-border level. “There is no equilibrium answer to that question” of the ideal balance between expert planning and local needs, Moore admits, but the goal should be coming up with a framework that is participatory.

Brölmann notes that the category “transactional networks” is used to refer to a large diversity of actors, including non-governmental organizations, foundations, multinational firms, governments, and multilateral agencies. Although these have as a common trait their being non-state actors operating across boundaries, the involvement of each of these actors does not necessarily unfold in the same way. For Moore, these networks are essential to the diffusion of knowledge and best practices, and they are also important when it comes to overcoming inaction by governments, helping to place important issues on the global agenda. ■

An Agenda for Research, Policy and Business

In light of the debates and controversies, the opportunities and the pitfalls, concerning the roles of technology, education, markets, governance, and other institutions when it comes to meeting the world's water needs and ensuring the sustainability of water resources, there are a number of potentially fruitful paths of action:

- Frame water challenges in terms of the "water matrix," comparing the costs and the benefits of different sources of water, diversifying our exposure to climate change and other types of risks, and improving the overall efficiency of the water sector and its ability to meet all of humanity's needs in a sustainable way.
- In particular, find a balance among water-quality preservation, conservation, efficient use, and reuse that will enable the world to sustain a larger population and an increase in overall economic activity and consumption.
- Develop the technological infrastructure to gather, analyze, and diffuse information about the quantity, quality, and risks associated with water resources in specific locations around the world.
- Continue to research and model the impact of global climate change on the delicate balance among land, ocean, and atmospheric dynamics, and its implications for water resources.
- Generate more sustained interest among all major stakeholders to deal with water-related issues outside of emergency crisis situations, by providing a clear perspective on the future repercussions of not addressing bottlenecks and scarcities before they become more widespread, systemic, and irreversible.
- Educate the public as to the importance of behavioral change and the potential for reusing water to address present and future needs, and to minimize the impact of disruptions stemming from climate change.
- Help farmers in developing areas access knowledge and basic technology to monitor and optimize water use.
- Design and experiment with innovative market and pricing mechanisms, to more efficiently allocate existing water resources.
- Engage users, policymakers, activists, investors, businesses, and universities in a constant dialogue about water challenges and solutions, thus raising global and local awareness.
- Expand investment in basic infrastructure to allow users to capture, manage, convey, and best use this limited resource. ■

Sources

Bureau of International Information Programs. 2011. *Global Water Issues: A Compendium of Articles*. Washington, DC: U.S. Department of State.

Dinar, Ariel, Victor Pochat, and Jose Albiac-Murillo eds. 2015. *Water Pricing Experiences and Innovations*. Cham, Switzerland: Springer International Publishing.

OECD. 2011. *Towards Green Growth*. Paris: Organization for Economic Cooperation and Development.

Sydorovych, Olha and Ada Wossink. 2008. "The Meaning of Agricultural Sustainability: Evidence from a Conjoint Choice Survey." *Agricultural Systems* 98: 10–20.

UNESCO. 2009. *Water in a Changing World*. Paris: United Nations Educational, Scientific and Cultural Organization.

UNICEF and World Health Organization. 2015. *Progress on Sanitation and Drinking Water – 2015 Update and MDG Assessment*. http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-Update-report-2015_English.pdf

United Nations. 2003. Committee on Economic, Social and Cultural Rights (CESCR) General Comment No. 15: The Right to Water (Arts. 11 and 12 of the Covenant), 20 January 2003, E/C.12/2002/11. http://www.refworld.org/docid/4538838d11.html

United Nations. 2016. *Global Issues: Water.* New York: United Nations. http://www.un.org/en/globalissues/water/

United Nations. 2015. *International Decade for Action: 'Water for Life' 2005-2015*. New York: United Nations. http://www.un.org/waterforlifedecade/water_and_energy.shtml

United Nations University. 2013. *Water Security & the Global Water Agenda: A UN-Water Analytical Brief.* Hamilton, Ontario, Canada: United Nations University Institute for Water, Environment & Health.

Globalization TrendLab 2016 Participants

Regina Abrami, The Lauder Institute, University of Pennsylvania
Terry L. Anderson, PERC and Hoover Institution
Miriam Balaban, Desalination and Water Treatment
Alejandro Barragán-Ocaña, Autonomous University of State of Mexico, University Center UAEM-Valle de Chalco
Catherine Brölmann, WaterLex (Geneva) and University of Amsterdam
Rafael Carmona, Universidad Anáhuac México Norte
Semiramis Casas Velazquez, Universidad La Salle, AC
Eric Cooperström, Skoll Foundation
Raymundo Diaz Robles, Monex Casa de Bolsa
Frederick Dickinson, The Lauder Institute, University of Pennsylvania
Lance Donny, OnFarm Systems, California
Georgina Echaniz-Pellicer, Center for Environmental Law and Education, Mexico
Ralph Erik Exton, GE Power Water & Process Technologies
Anne Marie Frohnmayer, The Wharton School, University of Pennsylvania
Meredith Giordano, International Water Management Institute
Ronald J. Granieri, The Lauder Institute, University of Pennsylvania
Mauro F. Guillén, The Lauder Institute and Wharton School, University of Pennsylvania
Peter Jaffé, Princeton University
Noam Lior, University of Pennsylvania
Changhao Liu, Beijing Institute of Technology
Yong Liu, Peking University
Ian Lyle, National Water Resources Association
Andrew Maddocks, World Resources Institute
Irina Marinov, University of Pennsylvania
Andres Samuel Mendez Sobel, Universidad Anahuac Oaxaca
Manuel Montenegro Fragoso, Universidad Panamericana
Brittany Montgomery, MIT, Department of Urban Studies and Planning
Scott Moore,World Bank Group Global Water Practice
Julio Orantes, Universidad Michoacana de San Niclas de Hidalgo
Xinglin Pan, Tsinghua University and University of Pennsylvania
Thayer Patterson, Princeton University
Heather Price, University of Stirling
Rengarajan Ramesh, RWL
Alejandro Rivera, University Foundation for the Development of Public Politics
Luis Santos, UAEM
Francisco Antonio Serrano, University Autonomous of Coahuila

Globalization TrendLab 2016 Participants

Kimberley Thomas, University of Pennsylvania
Charles J. Vörösmarty, CUNY
Carlos Wabi, Universidad Anahuac Mayab
Dale Whittington, UNC and Lee Kwan Yew School, Singapore
Stuart Woolf, Woolf Farming, California
Huijuan Wu, Lee Kwan Yew School of Public Policy, Singapore

Download the white papers from past Global TrendLab Conferences:

http://lauder.wharton.upenn.edu/conferences

- *Global Risk: New Perspectives and Opportunities (2011)*
- *Sustainability: New Perspectives and Opportunities (2012)*
- *Poverty and Inequality: Persistent Challenges and New Solutions (2013)*
- *The Future of the State (2014)*
- *Overcoming the Infrastructure Gap (2015)*

Globalization TrendLab 2016

WATER

Water is an essential resource whose use is increasingly coming under scrutiny as acute and chronic shortages proliferate around the world. Population growth, the rise of the global middle class, and urbanization are putting stress on existing water resources. Technology, infrastructure, markets, education, behavioral change, and governance all need to play a role in ensuring sustainability over the long run. Water security and geopolitical stability are contingent on the effective resolution of both the global and the local tensions affecting the efficient and equitable use of this resource.

Designed and Distributed by:

K@W