



## Ven Te Chow Memorial Lecture: Localizing water and food security

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## VEN TE CHOW MEMORIAL LECTURE

### Localizing water and food security

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Ven Te Chow made significant and immense contributions to the field of hydrology, namely deterministic hydrology, stochastic hydrology, open-channel hydraulics and water resources in general, to name a few. His biggest contribution in my opinion, however, is his inclusiveness in opening the hydrology discipline to other fields. The interdisciplinarity is evident in the membership of the International Water Resources Association (IWRA), representing not only science and engineering but also including those from social sciences, law and other disciplines that affect and interact with water. It is in this spirit that I look at the contributions of Ven Te Chow and acknowledge that his vision lives on.

In that same spirit, I would like to talk about the localization of water and food security as a way of building resilience in a non-stationary world. This passion of mine grew, from my childhood, in the hills of Lebanon where I heard and still recall the my father's stories about his childhood and about the way in which land, food and water securities were treated. A vivid memory that I grew up with is his story about a terrace that was so steep that people could not get to it. They would tie a farmer to a rope and lower him down to plough the land after a rainfall and seed it with either fava bean or barley.

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After seeding, they would pull him up and a few months later lower him down again to harvest. I recall images of local farmers struggling to grow wheat. The point is that I grew up with the passion that an area be self-secure in food. Although things have changed since then, the dream of the child lives on. I would like to share with you some of these thoughts that have pretty much shaped me as a professional; I would like to take you on a journey, starting with the of global challenges of today and concluding with the hope that there are ways in which we can, not necessarily fully, but to an extent, realize some of those localizations of food and water security.

I would like to capture some of the geophysical changes happening today: there are a lot of climate change projections and I would like to speak with you about two sides of these climate change projections. First, it is expected that with climate change we will see a reduction in soil moisture in the subtropics and this will directly affect food security in that area. A similar decline is expected in surface water, and some of this we are already seeing (Intergovernmental Panel on Climate Change (IPCC) 2013). Combine the soil moisture decline with the surface water decline and we are pretty much looking at two challenges that are compounded in terms of water security and food security.

Among many other factors, population growth and urban sprawl have significantly reduced available per capita crop land. This reduction in many areas of the world, combined with the rising prices of oil, has compounded into an expected increase in the prices of basic commodities such as rice, beef, wheat, maize and poultry, with or without climate change. I would like to look for a moment at a very significant number: 45–50% of the food produced, depending on location, is lost to waste. It is very important to analyze this waste, based on location: developing countries have a loss (before and during harvest), but it is very different from the loss in Organisation for Economic Co-operation and Development (OECD) countries (post-harvest and post-processing), especially the United States and the UK. Trying to reduce that waste means we need to better understand the reasons for it. This is what is happening in the biophysical sphere.

I would also like to stop briefly to examine the World Economic Forum (WEF) global risk report (WEF, 2015), based on the perspectives of global leaders, noting what is on their mind when it comes to global security. The significance of what I see over the last 8–10 years is that the meaning of risk has changed from geopolitical risks into resources and economics scarcity. So, in 2015, the water crisis is ranked as the number one risk to impact and livelihood. You can imagine that food security and energy security are also in the top 10 of these risks. This is a significant change in how we look at risk, not only the biophysical but also the perception of risk, over the last 10 years and it calls for serious reflection regarding how we look at resource scarcities.

Figure 1 illustrates the interconnectedness of resources. I would like to stop at two aspects of this busy slide. One is the projected growth in our basic primary needs for water, energy and food. We are looking at 80% expansion in energy demand, for which we lack the infrastructure to support. We are looking at a 55% water gap, if we continue ‘business as usual’. We are looking at a 60% increase (some experts are saying perhaps doubling) of the demand for food by 2050. The second side of the story is the interconnectedness that exists between these resources: 15% of our global fresh water supply is consumed for energy production: cooling of power plants, generation of electricity and many other water-thirsty processes. More significantly, in our urban world, 55% of the water bill is for electricity production. On the third side of the triangle, the energy/food side, 30% of the world’s energy goes into food

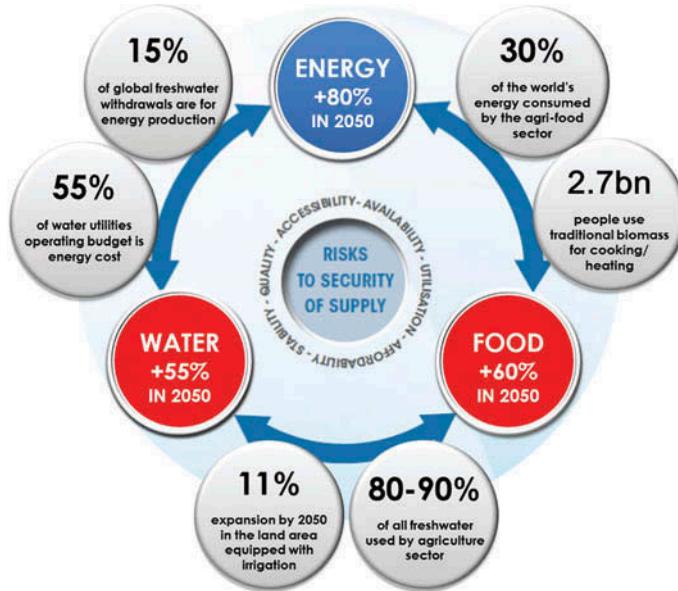


Figure 1. Resource interconnectedness. Source: Ferroukhi et al., (2015).

production. This is the processing, tillage and fertilizer needed for food production. The picture becomes complete when we look at the fact that 80–90% of *consumptive* water use goes into food production. The point is that there is not only growth in the demand for these finite resources but also very tight interconnectedness between them. Thus, there is only one way to look at them: as a nexus interlinking water–energy–food (Ferroukhi et al., 2015).

There is a lot of argument in the academic community today about adding factors such as population growth, health, nutrition and other dimensions. We are not going to reach a consensus, but I would say that the simpler we keep the modelling and the framework the better for us at the moment: it is about resource management and resource allocation. The simpler we keep the model the better: the constraints posed by social, economic, political, natural and technological pressures are all part of a very complex system that requires we look at it as a nexus.

Nevertheless, this is only half of the story, until we define and quantify the interlinkages and ground these to the nexus ‘hotspots’ that allow us to intervene by analyzing the tradeoffs. These analytics must guide the trade-offs, as shown in Figure 2.

I would like to acknowledge that the integrated water resource management community (IWRM) has been an inspiration in moving into a nexus framework. Proudly, this IWRM community has been instrumental in developing the nexus. The framework of IWRM starts with economic efficiency, social equity and ecological sustainability, acknowledging institutional roles, enabling environment and the roles of management institutions. IWRM has already called for interdisciplinarity: water for people, food, nature, industry, etc. It has already broken down the silos. So what does the nexus add to IWRM? Building on IWRM, the nexus was built as a two-way dialogue, a neutral platform that is not water centric, but rather where the water community, energy community and food community can discuss resource allocation as a nexus of resource

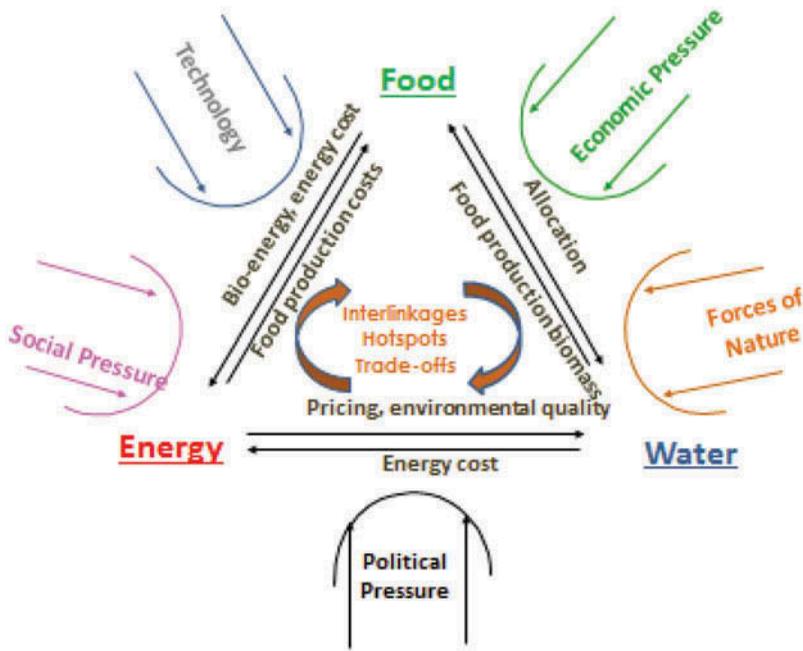


Figure 2. Water–energy–food nexus. Source: World Economic Forum (2011), published with permission.

interrelationship. It is not a one-way street: it is also energy for water and energy for food: a two-way dialogue.

Over the years the academic community has mastered these systems, the water–food system and the energy system. They have provided modelling and knowledge: we are not starting from scratch. The academic community needs to develop these interlinkages for hotspot tradeoffs and interlinkages; however, that is still only half the road. The tradeoffs need to be discussed in a dialogue aimed at shifting the current conflict status into a status of cooperation for impact, whether through change in action, change in politic or change in technology. There are two processes involved: the complex process dominated by economy and intergovernmental relationships and, to a greater extent, the supply chain governing the flow of water, the flow of food and the flow of energy. Thus, two different discussions need to happen – that around the trade-offs and that of engaging the dialogue – to move beyond the trade-off analysis and into that dialogue which will help us move forward with action (Mohtar and Daher, 2014).

I would now like to focus on the water–food dimension: which I believe to be the ‘hotspot’ for us in terms of bridging the water and food gap worldwide. If we look at bridging the water gap there are many technologies and levers that we could use. I start with conservation: in the state of Texas, which expects a 40% water gap by 2050, which is very comparable with the global figure (Texas Water Development Board (TWDB), 2012), I predict that 24% of the water gap in Texas, and probably of the global water gap, can be bridged through conservation. Trade is also extremely important, particularly the virtual water trade, in bridging the water gap, but not one about which I will speak today. Rather, I would like to discuss new water, that water which is rejected by industry; the water produced in oil and gas exploration. It is the water produced in our

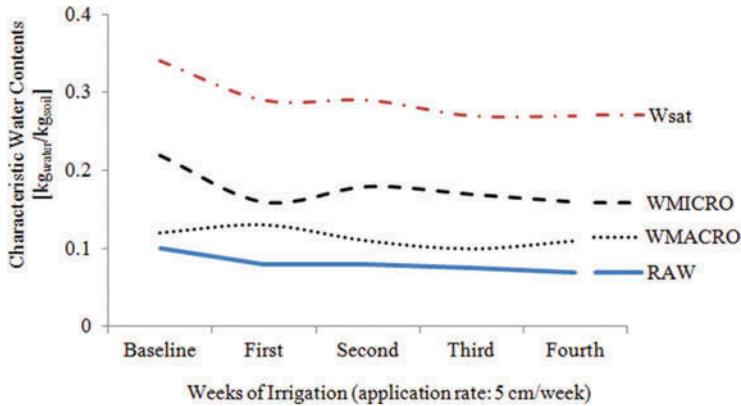


Figure 3. Effect of greywater on soil water-holding capacity.

cities. It is all that compounded water which many of us do not take advantage of. Referring again to our studies done in Texas, preliminary analysis predicts that 16% of the Texas water gap can be filled by using this ‘new water’. We expect a 180% increase in water demand due to population growth alone. Three of the top projected US growth cities are in Texas. There is a lot of wastewater being generated, which can be used for bridging the water gap in agriculture. However, there is a slight issue that I would like to address.

Figure 3 demonstrates the preliminary analysis of soil moisture characteristics before and after irrigating cycles with greywater. To our surprise, there are significant changes in the hydrostructural properties of the soil as it is exposed to greywater for different water cycles. The changes are significant. I will focus on one that I believe needs to be addressed: the water-holding capacity. These changes are sufficiently significant to demand revision and reconsideration of what this means in terms of water management.

Figure 3 shows that the water-holding capacity of the soil *significantly* changes with the recycling or reuse of different cycles of the water for agriculture. Now, I am not suggesting that we should not use greywater, but rather that we must treat it and look at what this really means in terms of the on-farm long-term water management.

Switching to green water, and as a frame of reference, over 60% of the food we eat, on a daily basis, globally, comes from green water – rain-fed agriculture, including most of the wheat and cereals that we eat. There is a lot of resource there that must be looked at (Figure 4).

If you Google ‘green water’, you will find five different definitions. Because we have not defined green water clearly, consequently we are unable to quantify it. To my surprise, a preliminary analysis based on data from Schuol, Abbaspour, Yang, Srinivasan, and Zehnder (2008) conducted in North Africa (Algeria, Egypt, Libya, Morocco and Tunisia) showed green water resources as over double those of blue water. To remind you, green water is the rain (precipitation) and the water flow through the soil (green water flow). Much of the water is surface water or goes into ground water, but the darker third bar from the left in Figure 4 is blue water stored in the soil: what I define as green water (storage in the soil). You can easily see that

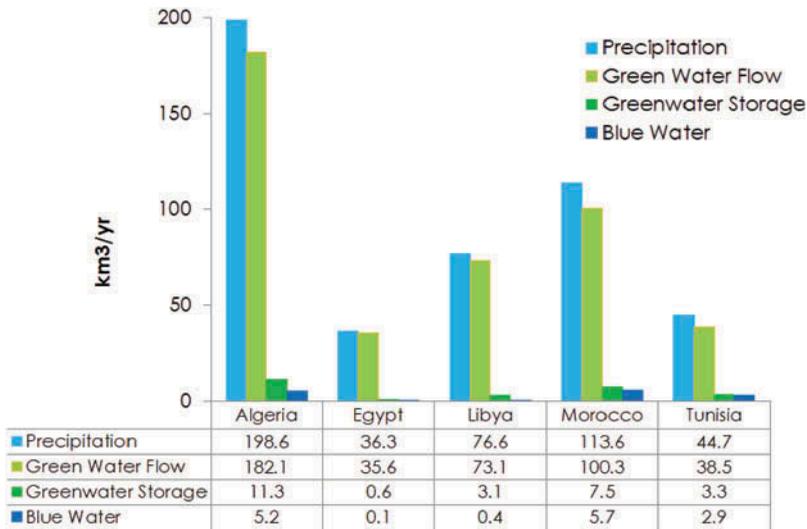


Figure 4. Average available and renewable water for North African Arab countries ( $\text{km}^3/\text{yr}$ ). Source: data from Schuol et al. (2008).

there is double or more of green water in our analysis as compared with blue water. My point here is to demonstrate that, first, we do not know what green water is; we need to define it correctly, as a significant resource, so that we can quantify it correctly. The other striking observation is that in the soil water dynamics, we have relied for the last 50–60 years on mathematical models that we have tried to impose on the soil water processes. But soil does not behave as a differential equation. We must look at the soil as a living and naturally organized medium that shrinks and swells. This organization must be the basis of scaling, characterization and modelling.

I would like to close this point by looking at the nexus: water-yield data. The information on how crop productivity responds to different water use is borrowed from the Food and Agriculture Organization (FAO, 2006, 2013) (Figure 5). Here, I am calling for a nexus that includes not only water use in the crop production data but also energy use, emission and impact on soil to this system. This is the nexus that we need to look at so we can define the optimum level of productivity: starting with the base as green water, moving into blue water, either recycled or fresh, and going up to waste water. Then looking at this system holistically, from all dimensions, considering not only water use but also energy use, emission, impact on the soil and perhaps other dimensions, we begin to look at a more sustainable food system. At the moment we are fascinated by the ‘yield per acre’ model.

We need to look beyond this model, which has been with us for many years. We need to recognize that a structured, naturally organized soil medium is responsible for both our water security and food security. All of us know the role of soil in supporting water security as a major part of the hydrologic cycle and in supporting food security through food production, air quality and other circulations happening within the soil: soil is at the

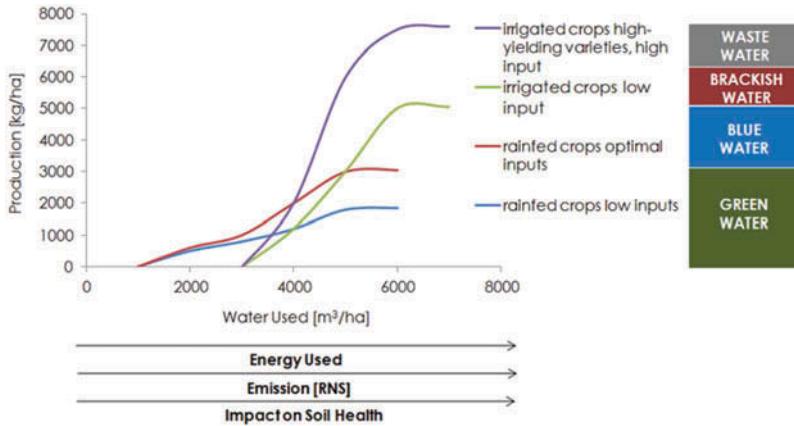


Figure 5. Water productivity–energy–food nexus. Source: Mohtar (2011).

heart of water and food security. It is constrained by a lot of agronomic practices, some of which are conducive to soil sustainability and others which are not, for example, population growth. We need to maintain a certain health index for the soil so that it can do what it is supposed to do in the face of climate change, urbanization, agricultural intensification and disposal. We need to reform our understanding of soil so that it can maintain the role it is intended for. Figure 6 shows the soil system and its role in supporting water and food security.

Soils according to the system’s theory are represented by a pedology plane (morphology and evolutions axis) and a vertical axis of hydrologic or ‘functionality’. This axis and the pedology plane have been separated for many years and it is time to bring the mathematical formulation into a better understanding of the hydrological or pedological plane. This needs to happen in order to allow for the very important scaling. We need to develop the framework that will allow us to move from the microprocesses all the way to the policy scale, and vice versa. At the moment there is no connection between the two planes (pedology and functionality). Unless we develop these multiscale processes that allow us to link behaviour and properties in the same framework, we will not be able to link the two scales of policy and local (Braudeau and Mohtar, 2009; World Economic Forum, 2011).

In conclusion, I would like to emphasize few issues raised in the paper:

- The nexus platform is essential. It builds on the IWRM as a neutral platform that brings not only a water-centred discussion but also an inclusive debate, at both the physical and horizontal scales. It brings different disciplines together and has the potential to achieve integrated water, energy and food security.
- There is a need for us to quantify the implications of farm practices (such as irrigation with greywater) into the soil. We need to value both water and energy for a sustainable food production system.
- I would like to call for a green water revolution to allow us to understand better the implications of rainfed agriculture in allowing us to sustain the additional 2 billion people who will be joining us soon.

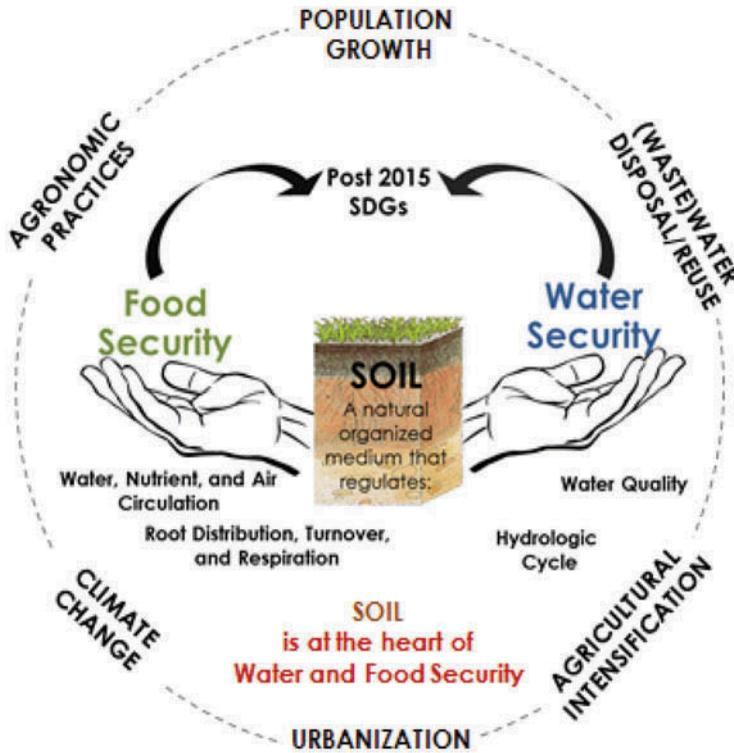


Figure 6. Soil system at the heart of water and food security.

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