Letter from the EGU President

The global water crisis and the emergence of socio-hydrology

In his quarterly message, the EGU President emphasises the need to work in an interdisciplinary way to understand the long-term interplay between the natural water system and the human water system, which is needed to address both local and global water issues.

The European Geosciences Union deals with many subjects that are of enormous relevance to society. Mineral resources, climate and natural hazards, to name a few, are high on the political agenda. It is clear that a better understanding of the underlying processes may lead to more informed and more efficient decision making. Water, hailed as one of the grand challenges facing humans in the modern era, is among the hot topics in the 21st century. What is referred to as the global water crisis summaries an issue people have to face in many parts of the world at the local scale. Globally, 1.1 billion people lack access to an improved water supply and 2.4 billion lack improved sanitation, with more than 3 million people dying per year as a result.

While drinking water and water for household consumption and industry are very often a local and regional problem, it is irrigation that dominates water use at the global scale. Still, on a global average, much more water is available than is actually consumed: about 6400 m^3/yr/capita runs off in the water catchments of the world, with only a fraction of that being used by humans. However, this is just an average. The actual values of available water vary considerably in space and time: over the high and low runoff regions of the world, and through the high and low runoff seasons.

When water demand is greater than the available resource, as is the case in some areas of north-west India, China, northern Africa, and the southern United States, water scarcity prevails. If the consumption, measured as the water volume per year that is extracted from rivers and groundwater, exceeds the annual replenishment, the water use is unsustainable, leading to falling ground water tables and reduced streamflow. These trends may be exacerbated by population dynamics – increasing population translating in increases in water demand – and life-style changes. For example, in China the per capita meat consumption has increased almost threefold in the past three decades which has resulted in exponential increases in water demand.

Local and global water issues are naturally monitored by water managers, who have a portfolio of options to address them:

- Technical approaches, including more efficient irrigation methods (e.g. drip irrigation instead of sprinklers), water storage and water transfers (to balance the temporal and spatial variability of water availability), and sanitation measures.
- Organisational approaches of integrated water resource management, using only renewable resources (i.e. sustainable water use), cross-sectorial management strategies (e.g. agriculture, industry, households), and demand management (e.g. providing incentives to users to use less water).
- Economic approaches, such as water pricing, trading water permits and strengthening the economy. The latter is particularly relevant in areas where water scarcity is not due to a lack of freshwater resources but to an inability to use these resources efficiently due to economic reasons (such as in much of subsaharan Africa and parts of northern India).
- Political, legal and social approaches, where the focus is on setting up an appropriate governance structure to support integrated water resource management, strengthening the role of water management within relevant sectors, raising awareness of the role of water resources, and improving education.

In all of these approaches, the physical aspects of freshwater are only one component of the entire problem. They are closely intertwined with the human components associated with the technical, organisational, economic, political, legal and social facets of the issue.

Traditionally, the scenario approach has underpinned the decision making process in water management. Here, the term scenario is

Men and children withdraw water for irrigation in the Dogon plateau (Mali) during a sandstorm day. Ensuring the population has safe and sustainable access to water is one of the major challenges in the region. (Credit: Velio Coviello, distributed via imaggeo.egu.eu)

Historically, windmills have been used for keeping the water levels down in polders in the Netherlands. (Credit: Anna Nadolna, distributed via imaggeo.egu.eu)

used in the geoscientific sense: as a synonym for a forecast, or a number of alternative forecasts or projections each of which includes (rather than excludes) the main uncertainties. This kind of scenario approach is often used in water management with certain assumption on water demand, water availability, and their space-time distribution. On the basis of these scenarios (and other factors such as politics) decisions are taken to manage the water resources in some optimum way.

While the scenario approach has served us well for decades, there is now growing awareness that it may not embrace the full spectrum of the possible futures of the water system. Importantly, the human factors (technical, organisational, economic, political, legal and social aspects) are almost always prescribed as a boundary condition, i.e. as an external forcing. This does not allow for long-term, dynamic feedbacks between the natural water system and the human water system to be captured. However, in a planet where humans have changed almost all aspects of the world, these feedbacks may, in fact, be the main control on how the system evolves. We are living in the Anthropocene, the era when the human footprint is omnipresent, so treating humans as mere boundary conditions may be anachronistic and may not lead to desirable decisions. Natural scientists cannot continue to ignore the human factor.

Therefore, to understand water cycle dynamics over long time-scales, we need to take into account the interactions and feedbacks with human systems. This new way of thinking, of treating humans as part of the system rather than as an external factor, has given rise to the emergence of 'socio-hydrology', a science aimed at understanding the dynamics and co-evolution of coupled human-water systems.

The defining characteristics of socio-hydrology over the traditional way of dealing with people and water are the following:

- Capturing feedbacks of the human-natural water system in a dynamic way, going beyond the traditional practice of prescribing human factors as external. The essence of socio-hydrology is the co-evolution of humans and water. A co-evolutionary system includes a general process of generating a 'new variation', with new variations or 'emergent behaviour' being brought about by feedbacks between processes at a range of scales. This may lead to exceedance of 'tipping points', which may result in systems evolving into new, potentially unobserved, states.
- Quantifying system dynamics in a generalisable way. The traditional scenario approach has always been context dependent and tailor made to the local conditions. While for the immediate decision making this is undoubtedly essential, for a more long-term view of the scientific approach one would hope to learn from other cases, to abstract a more uniform knowledge base. This knowledge base should be quantitative to go beyond the traditional practice of dealing with the human factors in a qualitative way. In fact, there have already been a few early attempts of proposing coupled differential equations to represent the system dynamics, including the social system.
- Not necessarily predictive. The coupled human-nature system is inherently non-linear and this non-linearity may prohibit full predictability. Lack of predictability doesn't come as a surprise if one looks at the history of humankind, so predictability should not, in fact, be expected. However, the socio-hydrologic approach may still be predictive in a statistical sense, as are other non-linear systems researched in the geosciences. Perhaps even more importantly, the emergent behaviour, the possible futures that would not easily be predicted by traditional forecasts, may prove extremely important for decision making, and very interesting from a scientific perspective in its own right.

Socio-hydrology may pursue a number of lines of enquiry. An historical perspective would be to learn from reconstructing and studying the past, while in comparative socio-hydrology one learns from the similarities and differences between catchments in different places. Process socio-hydrology, on the other hand, focuses on studying a small number of real human-water systems in detail to gain more fundamental insights into causal relationships.

The 21st century water problems are complex, involving feedbacks across multiple scales, sectors and agents. Addressing these complicated issues requires radical new ways of thinking and it is fundamental to focus on co-evolution and emergent patterns, without forgetting the unexpected. Socio-hydrology implies a change in the way we research and teach as humans begin to play a much bigger role in water cycle dynamics. To generate viable solutions to the water challenges we face today, it is fundamental to carry out such joint efforts.

Socio-hydrology embraces processes beyond the purely physical, chemical and biological relationships, shifting the science towards more holistic descriptions, with process interactions becoming increasingly important. In fact, there may be a lesson learned here for other geosciences beyond hydrology. The human imprint is certainly not limited to freshwater, it is omnipresent. Other areas of the geosciences within the EGU may face similar challenges. We need to work in an interdisciplinary way to understand the long-term interplay of humans and geoprocesses, which are needed to address a plethora of both local and global management issues. It may no longer suffice to treat humans as boundary conditions in an isolated way but as an integral part of the coupled human-nature system when advancing Earth system sciences in the Anthropocene.

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