Irrigation, water and river basin sustainability

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Introduction

A significant fraction of the water in arid and semi-arid river basins around the world is withdrawn and depleted by irrigated agriculture. This leads to concerns regarding the allocation of scarce water between irrigated production and other sectors such as riverine ecologies and growing towns and cities. It seems logical that, to address the sustainability of 'water', a deeper knowledge of management of irrigated systems should be included in that challenge. Yet surprisingly, often this is not the case. Moreover, where irrigation is being addressed, this is by a piecemeal approach that may not resolve complications in irrigation or in the wider basin. How then might irrigation be the pathway to address the sustainability of water and river basins?

The pivotal position of irrigation in food and water

Some of the contributions and impacts of irrigation on water and food are:

- The global area of approximately 350 million hectares of irrigation withdraws daily about 6-8 km^3 per day of water (withdrawals for urban and domestic use are approximately a tenth of this.) The presence of irrigation depletes about 70-80% of freshwater in most river basins (CAWMA, 2007). Moreover about 85-90% of this area is under gravity (canal) irrigation rather than pressurised technology such as sprinkler and drip. From these few indicators, we can see why irrigation stresses river basins more than climate change and why uneven consumption within river basins can be a source of conflict. Temporary or long-term water shortages concern many communities and countries that share rivers: from the local scale, where irrigators attempt to close down neighbouring irrigation intakes, to the national scale where countries that share the Nile Basin attempt to table discussions on new volumetric apportionments.
- Rice, a key carbohydrate and vital to world food security, is grown under some form of field water control - a mix of irrigation and levelled and drained water from rainfall. Just five highly populous nations (China, India, Pakistan, Indonesia, Bangladesh, Philippines) that commonly eat rice daily account for nearly half the world's population.[i] Adding together 20 populous nations that eat irrigated rice we arrive at about 60-65% of the global population.
- Irrigated agriculture provides about 40 per cent of the world's food (Schultz et al., 2009). Other key foodstuffs include fruit and vegetables and increasing amounts of meat via irrigated pasture.
- Irrigation is believed to 'waste' significant amounts of water that can be used to extend agricultural lands or be allocated to other uses – for example environmental flows. Although there are significant misunderstandings about waste and savings (water losses are not 'lost' when collected downstream (Grafton et al., 2018)), crop productivity can be boosted by using water in a more careful and timely manner (Lankford et al., 2020; Molden et al., 2010).

Sustainability dimensions of irrigation, water and river basins

The sustainability of irrigation, water and river basin has many dimensions:

1. *Supply and demand sufficiency*: The viability of irrigation is at stake where water withdrawals are depleting groundwater stocks, such as found in parts of India.
2. *Water allocation scarcity*: High irrigation water consumption can bring water shortages to other sectors such as urban and industrial demand.
3. *Social sustainability*: Within irrigation systems farmers often struggle to come together to manage water collectively; water user associations don't function as well as they might.
4. *Group knowledge sustainability*: Irrigation does not only depend on farmer groups working well together, but how groups; a) learn from events such as drought; b) engage with the 'not easy to

discern' spatial and temporal balances of water supply and demand; and c) know when and how to ask for external help in achieving (a) and (b).

5. *Infrastructural and design sustainability*: The hardware of an irrigation system influences how water can be apportioned out to individual crops in a timely manner. This 'water control' not only comes from the operation and maintenance of infrastructure, it also depends on its design. The design of existing canal irrigation systems rarely offers a combination of criteria, for example; tight control (to improve efficiency); equitable apportionment of flow-to-area served (to improve uniformity between farmers and fields); flexibility (to accommodate drought and non-drought periods); and manageability (to make adjustments in an easy and transparent way).
6. *Water management within irrigation systems*: Water management on irrigation systems comprises countless daily and weekly activities that together create wider performance outcomes. Examples include scheduling irrigation, communicating with neighbours on shared networks, experimenting with different soil furrows and bunds within fields, adjusting canal flows after rain; and testing new in-field capture of rainfall. Irrigation management is much more than 'adding drip irrigation', 'lining canals', or 'water accounting'.
7. *Service and support sustainability*: Support services are not only about the range of services on offer (e.g. drone mapping, legal interpreting, design reforms, training on book-keeping), and how they are tailored to farmers, it is also about a deeper philosophy. Organisations working with irrigators sometimes struggle to hear and see the problems that irrigators face, what terms and words they are using, how water is actually shared between farmers, or even to notice which farmers, especially those at the tail-end of systems, are careful water managers.
8. *Agricultural productivity sustainability*: Poor timing of water schedules, caused by low irrigation efficiency, reduces yields and undermines the timing of fertiliser, labour and soil management.
9. *Economic and investment sustainability*: The costs of irrigation construction and rehabilitation are often very expensive at over 10,000 USD per hectare (Inocencio et al., 2007). This applies to nearly all forms of irrigation interventions (including micro-systems) once total project costs are included.
10. *Environmental sustainability*: In irrigation systems, difficulties of controlling soil salinity result in land lost to salinization (for example in the Lower Indus Basin and the Murray Darling Basin). Excessive depletion particularly at the wrong time of year leads to shortfalls in environmental and ecological river flows, in turn harming freshwater species.
11. *Energy sustainability*: To reduce the energy requirements of irrigation and associated carbon emissions, a continuing emphasis on gravity systems rather than pressurised systems is required (Lankford et al., 2016).

By not addressing all of these management and sustainability dimensions, we end up with many irrigation systems not performing across a range of sustainability criteria.

Ways forward: new interventions

If we accept that irrigation is multi-scale and multi-dimensional, a new comprehensive approach should be considered. Its aim would be flexible, frugal and purposeful water management nested at all levels of irrigation systems and river basins, giving farmers more predictable, timely and upper-limited supplies of water. While many aspects of a new approach to irrigation and water sustainability could be described, key elements are:

1. New postgraduate qualifications in irrigation systems management.
2. New support for the scientific organisations involved in irrigation, e.g. International Water Management Institution (IWMI) and International Commission for Irrigation and Drainage (ICID), at global, regional and UK levels, including investments in research programmes.
3. Support action-research and mentoring programmes that work with farmers on gravity/canal systems, constituting the majority part of global irrigation by area.

4. Projects and programmes that promulgate ownership of systems by their users yet in close partnership with service and science providers (see next point.)
5. The fostering of non-governmental organisations (an irrigation equivalent of WaterAid) and of the commercial stewardship of irrigation systems.
6. On-going institutional reform of government irrigation bureaucracies to orient them towards service provision to water users, setting out professional expectations of government engineers.
7. Success will be defined by widespread performance improvements at a cost of less than US$5,000/per hectare.

Conclusions

Given the scale of global irrigation, its nature and its impact on surrounding basins, aquifers and water supplies, society can demand that irrigation should perform better; to produce more food with less water. Yet there are worrying institutional and technological gaps that threaten to destabilise the sustainability of water and irrigation. By the two measures of postgraduate teaching and relevant research programmes on irrigation, global science has lost nearly all capacity to offer expertise in contemporary irrigation management – the kind of knowledge that would aim, not to develop new lands, but to sustainably and cost-effectively rehabilitate existing systems. The fruits of this work would be considerable – enhanced water security and performance; increased food production; reduced carbon emissions; and water allocated to other sectors including the environment.

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[i] Calculations via World Bank statistics for population.