Using less water in crop production systems; targeting irrigation efficiency gains using a multi-pronged approach

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Background and scale of water use

The World Water Development Report (UNESCO, 2012) demonstrates that water underpins all aspects of development, and that a coordinated approach to managing and allocating water is critical. Worldwide, agriculture evapotranspires approximately 20-25 km^3 of water per day and the 270-300 million hectare irrigated component of this evaporates about 6-9 km^3 of water per day (withdrawals for urban and domestic use are around 10% of this (CAWMA, 2007)). Rainfed cropping consumes soil water (known as green water) but not freshwater or blue water. There are technologies to boost rainfed productivity such as fertilisers and seeds, and that also reduce soil water depletion (SWD) (such as mulching). However, the range of measures available to manage SWD is limited compared to that for irrigated cropping. In abstracting water from rivers or aquifers, irrigation is responsible for about 70-80% of freshwater depletion in most developing countries. Such depletion places more hydrological stress on tropical or sub-tropical river basins than climate change, and uneven consumption within river basins can be a source of water conflict. Water shortages concern many communities that share rivers: from the local scale where irrigators attempt to close down neighbouring irrigation intakes, to the national and international scales, such as the discussions between the 10 countries that share the Nile Basin.

Irrigation is believed to 'waste' significant amounts of water that might otherwise be used to extend or intensify agriculture or be allocated to other uses – for example to cities and for environmental flows. It is commonly cited that much of the world's irrigation is about 40% efficient (e.g. Seckler, 1996), suggesting that 60% is the waste fraction. In reality, the situation is much more complex. For example, often 'waste' water is not 'lost' when it is reused downstream (Perry, 2007). Furthermore, water is rarely traced in detail throughout irrigation and river basin systems. Yet despite the limitations of current irrigation efficiency (IE) metrics (van Halsema and Vincent, 2012), most scientists agree that productivity can be boosted by using water in a more careful and timely manner (CAWMA, 2007; Molden *et al*., 2010). On the basis of experience and limited research (e.g. Machibya, 2003), it appears that effective efficiency can be increased by 10-20% (and more) by adopting new technologies or adapting existing practices from water-short farmers – efficient producers by necessity – within the vicinity.[i]

Irrigation and efficiency complexity

Irrigation poses significant challenges when trying to apportion limited amounts of a varying water supply using gravity to many thousands of farmers and small plots. Working on irrigation performance involves simultaneous consideration of technological, social and economic points of view. Irrigation management requires the right quantity, quality and timing of water while minimising waste – in the face of changes in supply, land, soil, ownership, climate, weather, culture, economics and claims and counter-claims for water to be used in other sectors such as urban supply. As irrigation systems grow, either individually or coalescing at the basin scale, their complexity grows geometrically.

Improving IE requires an understanding of both the complexity of irrigation and of efficiency. Water lost from one field is often captured by other users further downstream in the catchment. This phenomenon of *nested* efficiency allows scientists to distinguish between classical and effective IE (Keller and Keller, 1995; Perry, 2007; and Box 1).

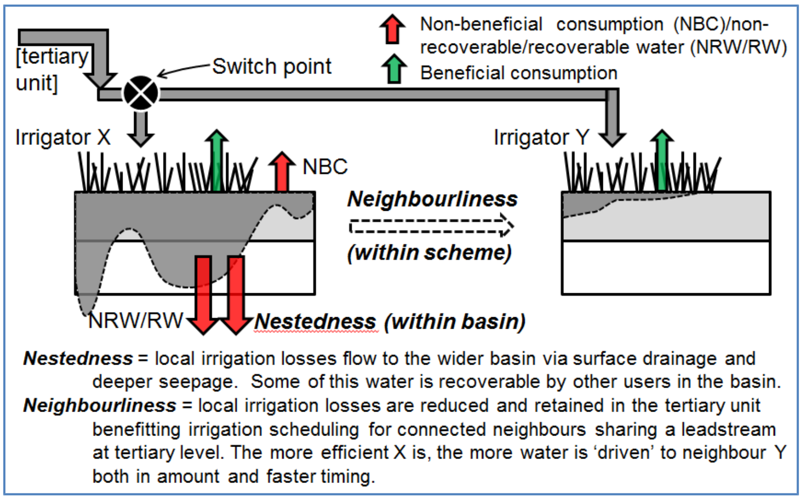

Fig. 1: The flows involved in nestedness (at basin level), neighbourliness (at scheme level) and effective irrigation efficiency

Efficiency is also *neighbourly* – firstly, local losses are picked up from drains by nearby farmers and secondly, local losses delay the progress of irrigation completion of fields (Fig. 1; Lankford, 2006; 2012). It is these and other sources of complexity that mean efficiency is difficult to measure, which means scientists should be sceptical of common beliefs that IE is low, or that installing drip/micro irrigation can reduce water consumption (Ward and Pulido-Velázquez, 2008). Pressurised irrigation also requires a constant supply of cheap energy – often unavailable in the agricultural zones of developing countries.

Box 1. Some terms

- Classical irrigation efficiency (%) = crop evapotranspiration/total water withdrawn into irrigation system
- Effective irrigation efficiency (%) = crop evapotranspiration/total water depleted in irrigation system
- Irrigation productivity (kg/m^3) = crop yield/ total water depleted in irrigation system

Genuinely using less water in irrigation

A multi-pronged approach is required to deliver substantial and verifiable reductions in water consumption over large areas of irrigated lands. The aim is to achieve this at a reasonable cost using technologies and ideas appropriate for, or already practiced by, irrigators with support from external engineers. Paradoxically, a reliance only on technologies such as drip irrigation (without other measures such as capping or reducing withdrawals) risks increasing total consumption. While water may be 'saved' on a per-hectare basis through drip irrigation, the saved water may be employed by the farmer elsewhere to increase the cultivated area, preventing its allocation for industry, energy or ecology elsewhere. There are four key dimensions of a multi-pronged approach, each with many other sub-issues.

Diversity and spectrum of irrigation types

Such is the diversity of irrigation types and circumstances that policies for improving IE and productivity need to be continuously adjusted according to the specific mix of stakeholders, characteristics and trajectories of the systems. However, whether building from new or via the rehabilitation and upgrading of existing schemes,; US$10-20,000 per hectare is spent on irrigation programmes by donors, often irrespective of whether canal, drip or farmer micro-irrigation is the selected technology. This expense is not sustainable.

Mixing and merging local and expert knowledge

The grave risk with efficiency complexity is that 'expert opinion' too readily dominates, meaning solutions such as drip and sprinkler technologies or canal lining are selected. These may not be appropriate if they cannot be managed and maintained to an appropriate standard. A more suitable approach would involve experts and farmers working together on methods to raise efficiency – many of them relatively simple (Box 2). This means taking a local and social approach, especially listening carefully to marginalised irrigators who subsist with very small amounts of water at the tail-ends of irrigation systems (Lankford, 2006).

Who gets the saved water?

If water can be saved by farmers at the field level, the material physical gain of the 'saved' water can be delivered to a variety of players or destinations: the irrigator making the saving; his or her immediate neighbour(s); the natural environment and the wider economy (Lankford, 2013).

Efficiency measurement

Finally for effective delivery, IE must be better measured. It is insufficient to measure water saving at the field level.

Box 2. Multiple solutions to increase efficiency in canal systems

	Requiring
- Canal system management and flow rotation - Canal leakage - Canal weeding - Canal density and number - Canal flow control technology - Adjusting the hydromodule/water duty - Field and in-field design, e.g. gradient, basin or furrow morphology - In-field walkways for visibility and infield control - Deficit scheduling - Adjusting crop season length - Field ploughing to improve infiltration - Field pre-watering to reduce seepage losses - Crop selection, patterns and location - Command area control - Accommodating rainfall - Cessation of water at end of season	- Farmer and user groups - Bye-laws - Agreed targets - Monitoring - Budgets - Sanctions - Meetings and training; field transects and visits

Progress in measuring efficiency throughout an irrigation or river basin system should be part of any programme to boost efficiency.

Conclusions

A 'systems' holistic approach to efficiency is required if irrigation systems are to consume less water while sustaining or boosting food production. Although productivity can be increased through other crop inputs (such as fertilisers and varieties), higher IE also promotes more timely irrigation, reducing water consumption at the field level and raisings yields. Given the range of social, institutional and physical configurations of irrigation systems globally, a reliance on a narrow range of technologies is risky, despite their promise or track-record elsewhere. Key dimensions of a broader approach include; (a) understanding the need for diverse solutions; (b) uniting farmer and expert knowledge; (c) capping withdrawals and agreeing the purpose and destination that 'saved' water volumes are reserved for; and (d) comprehensively measuring and monitoring water flows. In some respects, the water productivity gains delivered over the last 15 years in the Murray-Darling Basin were predicated on versions of these approaches (Grafton, 2010) where a policy framework (e.g. the 2007 Water Act and the 2008 Plan 'Water for the Future') set an ongoing context in which farmers and groups of farmers consider which efficiency technologies to adopt.

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[i] Fieldwork by Machibya (2003) measured water-short tail-end smallholders growing approximately 3–4 t ha rice from 927 mm water; top-end smallholders growing approximately 4–5 t ha from 1385 mm; and state farms producing approximately 2.5–3.5 t ha from 2544 mm (all depth equivalents are consumptive). This demonstrates enormous scope for adopting highly efficient techniques that are simple and locally available.