Appropriate Water Management Objectives for Irrigation in Asia

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Sectoral Perspectives

Consider a group of water sector specialists meeting to discuss problems of water scarcity and environmental degradation in a river basin: representing "upstream" areas, the catchment management specialists and foresters plan to re-invigorate degraded landscapes by contour bunding and other water-retaining features; downstream, the rain-fed agriculturalists plan water harvesting to maximize the exploitation of "green" water. Municipal and Industrial (M&I) Water Supply authorities plan to reduce leakages and unauthorized use, and promote low flow showers and toilets. And finally, in the irrigated areas, investments in new irrigation technology are planned to improve "irrigation efficiency" and reduce losses

But the language our specialists use tends to be land-based: the catchments and forests will be more stable, greener, rainfed agriculture will be more productive; irrigation will be expanded or intensified and yields per hectare will increase.

If water rather than land is the topic, we must rethink our language.

Neutralizing the language

So if our sectoral specialists are to communicate about water, they need a set of terms that can describe what is happening in their water sector in a way that is transparent to other water sectors. ICID has proposed such language, as follows:

- Water Use is the application of a quantity of water to any particular purpose—fisheries, hydropower, irrigation, factories, etc. The water source may be rainfall, surface or groundwater withdrawals, and all of the water used goes to one of the following fractions:
- Consumed fraction Water that is converted from liquid to gaseous form, and is no longer locally available for further use, of which:
  - Beneficial consumption (such as transpiration) contributes to the intended purpose of use,
  - Non-beneficial consumption (such as evaporation) makes no contribution to the intended purpose of use
- Non-consumed Fraction Return flows to rivers or aquifers that are either:
  - Recoverable for further use, or
  - Non-recoverable—going to a saline sink or the ocean.

If we re-visit the inter-sectoral perspectives with this water-based framework, the following picture emerges: healthy forests and catchments retains and beneficially consume more water that degraded ones do (perhaps releasing the recoverable, non-consumed fraction more slowly, reducing floods). Rainfed agriculture in general and water harvesting in particular has the specific aim of increasing water use (ie water available for the planned purpose), and increasing the fraction of that captured water that is beneficially consumed.

M&I use is predominantly non-consumptive—the vast majority of the water use returns to the system as a recoverable resource (the important exception being large cities at the coast).

Irrigation (the major user and by far the dominant consumer) of water in Asia is a particularly interesting case. Since irrigation engineering began (Egypt, 8,000 years ago?) the objective has been to maximize consumptive use for the simple reason that biomass formation—production—is strongly related to transpiration. The purpose of irrigation is to consume more water, and in that process, grow more crops.

A common measure of irrigation performance is to evaluate production per unit of water use.Literally hundreds of papers have been published demonstrating that yield per hectare can be maintained while reducing water use. But plant physiology tells us that there is a strong (for many crops linear) relationship between beneficial consumption (T), and yield. So what is going on?

The reductions in water use that are observed when irrigation technology improves are typically almost entirely reductions in the non-consumed fraction—the water that used to go back to a river, or recharge an aquifer. Indeed, if production increased, then in all probability transpiration increased too—improving irrigation efficiency increases the consumed fraction.

None of the above is to argue that the sectoral improvements described are not "good", nor that it is not useful to pursue irrigation efficiency. There are many scenarios where it is an excellent idea—but the real danger comes in assuming that reduced water use is the same as saving water, and many publications, policy statements and project descriptions do precisely that.

But returning to the hypothetical debate outlined at the beginning of this note, the environmental specialist, worried about declining aquifers, drying wetlands and occasionally dried up estuaries will probably be reassured—more water will surely be available downstream once all these improvements are in place.

But unfortunately, the environmental specialist would be wrong: if successfully applied, each one of these interventions will reduce the amount of water flowing downstream (with the possible exception of the urban improvements, which will be neutral).

Tracing the Consequences

Many countries in Asia face water scarcity, and while every country and every basin has its unique features, a generic description of excessive withdrawals from rivers, persistently over-drafted aquifers and degraded ecosystems is a reasonable point of departure for thinking about priorities.

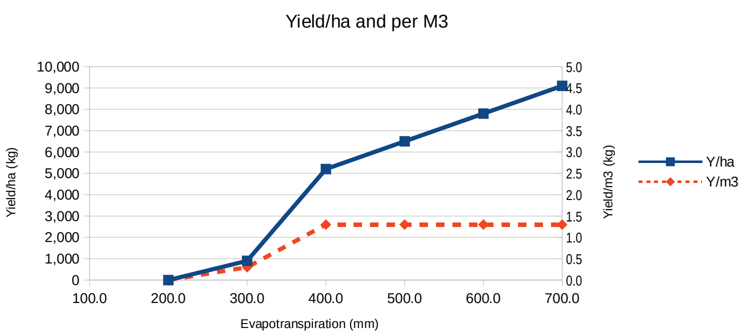
Once we describe the situation in water terms, things become clearer—but no less challenging. Degraded catchments need restoration and this will probably reduce runoff; rainfed farmers will try to capture as much water as they can to increase production; bigger cities need more water—and all while the "environment" of aquifers and wetlands and estuaries are suffering.

Implications for the sector

First, efficiency enhancement is not a panacea. It has many merits, but if saving water is the priority, then efficiency is not the solution. Nor are all farmers going to get rich growing vegetables and cut flowers… the main grain crops, plus sugar cane, and cotton will remain dominant.

Second, the debate needs to be formulated in productivity terms: everyone knows what a good yield per hectare of wheat is, but how many know the corresponding yield per m3 of water consumed for the crop and area of interest? We need an idea of the pattern of production per cubic meter, to present to the politicians and decision makers with a clear explanation of the production effects of decreased water consumption—where is most water being consumed? Which areas are least water-productive? Which irrigated areas can be shut down with minimum impact (because for sure, the only way to substantially reduce water consumption in agriculture is to reduce the irrigated area).

The graph below is a stylized representation of data for a large, water-short basin in the People's Republic of China. It shows yield per hectare, and production per unit of water consumption plotted against ET.



The data are derived from satellite data, which can be used to estimate both water consumption (ET) and biomass formation at resolutions of 30m or less. This process generates many thousands of pixels throughout the growing season, and allows estimation of yield/ha and yield per cubic meter as a function of ET.

Yield per hectare (the continuous, upper line) rises erratically until an ET level of 400mm, above which the familiar linear relationship between consumptive use and production applies up to the maximum observed yield of about 9,000kg/ha (the data are annual, and include two grain crops) and corresponding ET of 700mm.

If we are short of LAND, we would like to shift farmers as near as possible to the 9,000 kg/ha level. Many other constraints will prevent this being fully achieved (soil quality, salinity, waterlogging, etc), but the target is clear.

If we are short of WATER, the target is more nuanced. Note that the productivity of water (kg/m3) is constant for all levels of ET above 400mm, at 1.3 kg/m3. Thus our target is to shift as much of the area as possible to this level of water productivity—and provided we achieve that, we will have maximised total production from the available water resource, even though many farmers will be operating at well less than maximum yield per hectare.

Of course there are many complicating factors—most importantly, the "points" in this graph are actually averages of a distribution of observations at each ET level—but the analytical approach, based on consumptive use of water, and the production achieved per unit of consumptive use rather than water applied and yield per hectare, is a necessary paradigm shift in the way we plan under conditions of water scarcity.

Implications for irrigation system design and operation

For many years, it has been argued that the irrigation service should be adequate, equitable, and reliable. System operators have been judged on the extent to which the service meets these criteria (and mostly found to have failed.)

In a large measure, these objectives were poorly related to the reality facing operators. Farmers often plant a larger area than can fully be served (and the operators cannot prevent that) so by definition the supplies are often "inadequate" to meet the full consumptive demand of the crop. Equity depends significantly on the orderly behaviour of the farmers, and the general experience is that head enders take what they need, and tail enders get what is left. And finally, since, the irrigation sector tends to come last after service is provided to M&I, surface irrigation is left with the entire variability of the hydrological cycle—an unsuitable source for a "reliable" supply.

But there is a difference between an "unreliable service" and the absence of any information or definition of what the "service" will be. Anyone who has seen the successful farmer owned and operated systems from the Andes to the Yemen will have observed that when the farmer can identify with the source, and learn over time what the likely pattern of supply will be, they develop ways of sharing water that are essentially fair, robust and to the extent possible “reliable”. The challenge for irrigation agencies is to define what the service will be, in as much detail as possible, at some realistic interface with farmer groups. The more detailed that information becomes, the better farmers will be able to plan and organise distribution, and as they grow more confident in the minimum level of water they will receive, the more they will be prepared to invest the resources necessary to maximise productivity of water.

Some irrigation systems operating under conditions of scarcity and uncertainty, are able to do this: water allocations to farmers in the Murray Darling, in Australia are based on a two stage process. Each farmer has an entitlement to water; a fixed volume per year. But the water actually allocated in any year depends on both the underlying entitlement as well as water availability in the river system in the particular year in question. There is this no certainty about the precise quantity that a farmer will receive in any year, but there are rules and transparency about how that volume is determined, so that over time the farmers learn what to expect. Irrigation systems in the US are often allocated water on a “seniority” basis: the most senior rights are fulfilled in turn until the water runs out. Again, while there is no certainty, the farmers at various levels of seniority have information, and can learn what to expect.

In India (and parts of Pakistan), the warabundi system provides another example of sharing uncertainty—a rotational system of delivery that is designed to broadly match the pattern of demand over the season, while randomly allocating shortage among all farmers. The result is assurance to the farmer that in all but the driest years there will be sufficient water for part of his farm to grow a high yield, high input crop. In consequence (even before the groundwater revolution) yields per hectare and per unit of water consumed were regularly the highest in India—easily exceeding those in areas that nominally had a “demand based” system of delivery, and more adequate water.

Thus rewriting the “adequate, equitable, reliable” mantra to “defined and transparent” might offer agencies a hope of meeting their performance targets, and farmers the potential to better utilise scarce and unreliable supplies. By explicitly defining service performance objectives, the design for irrigation infrastructure, whether new build, rehabilitation or modernization, can be designed to provide a reliable service—within the bounds of the realistic and achievable.

The lesson from history is that if “the service” is over-specified, and agencies cannot deliver it with the infrastruture and resources at their disposal, the farmers react by taking matters into their own hands, “modifying” the infrastructure and taking what they can.