IMPROVING WATER AND LAND MANAGEMENT FOR EFFICIENT WATER USE IN IRRIGATED AGRICULTURE

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For millennia, civilisations developed in water scarce environments. The respective cultural skills are an essential heritage of those nations and peoples, and the humanity as well. However, progress in XX century questioned the traditional know-how, which has been often replaced by modern technologies and management imported from different environments and cultures.

A water economic culture is now following a technical one, imposed when the large irrigation schemes were built. Both are generally imported from different cultural and institutional environments:

Management faces therefore difficult challenges due to the fact that irrigators have a perception of problems, practices and objectives different from the non-farmer managers.

Pressures about water use in irrigation are coming from an ever growing urban society that understands less and less the rural world and, mainly, the peasants. Most common include:

- “decrease water consumption” - when it should be said “control water demand”
- Farmers may not have access to other and better technologies, and may not know how to improve those they are using after centuries

‘We need to stop looking at the government for the solution.’ But we need to help providing our know-how accepting farmers cultures and perception

Oasis of Turpan, Xinjiang

A turn in viewing traditional irrigation is starting in the non-technical media

Old ways of water management spring up again in arid regions

Water-scarce India, too, weighs a return to ancient practices

In Africa, a search for homemade solutions
Reducing the demand for supplemental irrigation of cereals may be feasible if to decreasing Gross Margins per unit land (GM/ha) correspond increased GM per unit water. The farmer incomes then reduces but, when water is lacking, that income is higher than reducing the cropped area.

However, for crops having a high demand for water such as summer crops, including if they have a favourable ratio between yield price and water cost, e.g. tomato in Tunisia, when GM/ha decreases due to less water application the GM/m3 do not increase. It is then questionable to adopt deficit irrigation without knowledge about water-yield-revenues.

The GM/m3 do not increase. It is then questionable to adopt deficit irrigation before advocating deficit irrigation for demand reduction.

Impacts of water prices on water demand, cropping pattern and income at farm level, Alentejo, Portugal

If multifunctions of irrigated agriculture are recognized, the water is "fully" valued and farmers will pay what is socially and economically acceptable.
“improve irrigation efficiency”, but farmers generally know they need to apply water in excess to leach salts, to store water in the soil when deliveries are not reliable, or to overcome the distribution uniformity of the system.

The depth of applied water $D$ depends upon the technologies available. Improving them to achieve an high uniformity $UC$ that provides for making $D$ close to $D_{opt}$ relates to the relationship between the price of the yield commodity ($PY$) and the cost of the water ($PW$).

Maximizing Yields or maximizing $WP$ follow different objectives which relate to the socio economic farming conditions.

There is a contradiction between water and land productivity that is solved differently by a water manager $Max(WP)$ and a farmer $Max(LP)$.

A key issue is to know the relationship between “applied water” and “costs” and “revenues”, mainly these ones.

Moreover, a peasant farmer, having 0.5 ha/family, do not understand the water productivity concept. He needs to increase land not water productivity, because it relates to the revenue he may get from his land.

English et al., 2002

Molden et al., 2003

Mantovani, 1993

Qingtongxia, Ningxia
The farm’s socio-economic conditions dictate options that may be different than those of water managers.

Max net income for commercial farming is below max yield (near max WP).

Max total income for small (family) farmers is near max yield (far from max WP).

Where this water goes? To irrigation only?

May be it is worthwhile to adopt new water use concepts.

Tank irrigation in Sigirya, Sri Lanka.

WATER USE = Diverted for any purpose

CONSUMED FRACTION

NON-CONSUMED FRACTION

Preserved Quality

Degraded Quality

REUSABLE

NON-REUSABLE

CONSUMED FRACTION

NON-CONSUMED FRACTION

Preserved Quality

Degraded Quality

REUSABLE

NON-REUSABLE

Beneficial

Non-beneficial (waste)

Non-beneficial

WATER USE

CONSUMED FRACTION

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Non-beneficial (waste)

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LOSSES

Pathways to improve water use

- Identify the water pathways
- Maximize beneficial uses
- Minimize non-beneficial uses
- Control, avoid water losses

A new approach looking the Basin and not the irrigated fields alone has been developed by IWMI along these lines.
On farm water management for efficient water use

<table>
<thead>
<tr>
<th>Objective</th>
<th>Technology</th>
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<tr>
<td>Reduce demand</td>
<td>• Select low demand crop varieties/crop patterns</td>
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<td>• Adopt deficit irrigation</td>
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<tr>
<td>Water saving</td>
<td>• Improve irrigation systems uniformity and management</td>
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<td>Water conservation</td>
<td>• Reuse water spills and runoff</td>
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<td>• Soil management/surface mulch</td>
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<tr>
<td>Higher yields per unit of water</td>
<td>• Adopt best farming practices</td>
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<td>Higher farmer income</td>
<td>• Avoid crop stress at critical periods</td>
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<td>• Select cash crops</td>
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<td>• Adopt appropriate irrigation technologies</td>
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Modern sprinklers may produce excellent performances in set systems, ...  

If design is adequate and the selected system is appropriate for the local environmental constraints and farming conditions

• Select low demand crop varieties/crop patterns
• Adopt deficit irrigation
• Improve irrigation systems uniformity and management
• Reuse water spills and runoff
• Soil management/surface mulch

... and to the modern sprinklers in moving laterals. They produce excellent performances with low energy when design and management fit the environmental constraints

Excellent performances may be achieved with surface irrigation when land levelling and irrigation technologies are appropriate

... and to the modern sprinklers in moving laterals. They produce excellent performances with low energy when design and management fit the environmental constraints

The same applies to moving gun sprinklers under non-windy conditions ...

When micro-irrigation - drip, SDL, micro-sprinkling - are well designed and managed, performances can be excellent, but ...

... those are not achievable without appropriate support to farmers

Adopting zigzag furrowing, shortening the basin strips and using a PE pipe and valved tubing available in the market, this farmer reduced the demand from about 1500 to near 1000 mm. But DU still is very low because land is unlevelled!

The challenge is to pay adequate attention and provide incentives to support farmers in improving their systems
With poor nozzling design, without assistance, what can this farmer do to get an uniform crop?

The reality is far from ideal: without technical assistance, this farmer was unable to adequately use drip irrigation – he was using more water and expecting less yield than for his surface irrigated field, ...

Near a tower, a well developed crop

In between the towers, a less developed crop

...but Services in his region were just advising to move from surface to drip

1st case: basin irrigation in the Yellow River Basin

Huinong Irrigation System

This is an arid region, with very cold winter and rain generally < 200 mm

Main crops are wheat and maize, often intercropped, and rice

Present Irrigation Performances

Uniformity DU is acceptable to very good
Efficiencies Ea are very low because
•Irrigations after the first are applied when there is too much water in the soil (lack of watertable control)
•Applied depths are much above required
•Percolation very high

Pre-conditions for farm water savings and increased productivity:

1st: cut to about half the diversions from the river

2nd: rehabilitate the drainage system (without great investments)

3rd: reduce percolation (to the level required for leaching, upland crops)

Irrigation number | q (l s⁻¹ m⁻²) | D (mm) | Zreq (mm) | Eₛ (%) | DUₗq (%) | Percolation (mm)
---|---|---|---|---|---|---
1st | 1.0 - 1.4 | 107 - 109 | 92 | 77.8 - 85.9 | 61.4 - 90.9 | 15 - 24
2nd | 0.7 - 1.3 | 90 - 136 | 30 | 22.0 - 33.5 | 56.8 - 95.6 | 64 - 106
3rd | 0.4 - 0.9 | 94 - 114 | 51 | 44.8 - 54.4 | 82.9 - 87.3 | 43 - 63
4th and 5th | 1.2 | 105 - 157 | 50 | 25.6 - 35.2 | 84.4 - 92.7 | 12 - 77
6th | 0.7 - 0.9 | 97 - 141 | 14 | 9.9 - 14.4 | 99.3 - 94.3 | 33 - 127
Irrigation depths may be optimized according to pre-defined objectives. If yields are to be improved the total water application may have to increase but percolation is controlled.

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Improved Irrigation Performances
- improved schedule
- controlled water table
- zero levelling
- higher inflow rates

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Using a DSS multicriteria model applied to the system to analyse the foreseen improvements. Results relative to water use and to utilities show that more stringent improvements (after level 4) have relatively reduced impacts.

Combined improvements in delivery conditions, drainage, farm irrigation scheduling and basin irrigation systems lead to reduce the demand at system and farm levels, and to increase the consumptive use.

Gross margin per unit water use, Huinong

Present

Improved to level 4
Improvements at farm – land levelling, inflow rates, irrigation scheduling – reduce the non-consumed and non-reusable fraction (percolation), and the non-consumable but reusable fraction (runoff), mainly relative to paddies

Arid climate where excessive water use produced enormous changes in Aral Sea and river ecosystems

Main crops are wheat and cotton, furrow irrigation

Furrow irrigation with continuous flow to alternate or every furrow

Efficiencies (Ea) are low except for alternate furrow irrigation due to excessive time of application. Uniformities (DU) are good/very good

Reducing cutoff times the irrigation depth D reduces, Ea improve, and DU decreases

Water use is less for alternate furrows (A) than for every furrow irrigation (E) and also decrease from continuous to surge flow

Every furrow continuous flow provides for maximizing yields (Ya/Ymax) but to minimal water use ratios. Opposite, alternate surge irrigation do not achieve maximal yields but highest WP(irrig) and highest beneficial water use fraction

However, if prices of production factors are high and those of commodities are low the farmer option is to maximise Ya/Ymax

Comparing continuous and surge flow, the later tends to provide for better performances

However, the highest land/farm productivity is for continuous flow in every furrow
Using a DSS in a GIS environment to evaluate alternative improvements operating

Irrigation network layer
Fields layer
Satellite image

Application to Fergana, Uzbekistan

Comparing alternative improvements through multi-criteria analysis, for the actual farming conditions in Fergana, the best alternatives are the present one - no changes - or Sched + AC: The price of products do not compensate for improving farm irrigation. Surge flow has not enough economic return

Concluding: Knowledge and technologies exist that allow to make a more efficient the use of water in irrigation

These should mean capability to transfer into practice and to improve the existing irrigation, both at farm and system levels. However, knowledge and technologies progress much faster than technology transfer in case of small family and peasants farms

Technologies are easily available when manufacturers have an easy market, as it is for a variety of irrigation scheduling equipment adopted by commercial farms and for sprinkler and micro-irrigation equipment, the so-called "modern irrigation". But when the markets have no quality exigences and control, the farmers may be purchasing less good equipment, poorly designed and demanding too much energy.

In case of surface irrigation such market is generally not existing and surface irrigation becomes synonymous of "old fashion"

Knowledge and technologies that exist to provide for a more efficient use of water in irrigation need that appropriate quality control of equipments and management tools be enforced to support farmers in modernizing the systems

The constraints imposed to farmers, which they know well, need to be recognized, such as:
- inappropriate delivery conditions
- high costs of production factors, of irrigation equipments,
- low prices of commodities, low incomes
- lack of technical assistance and poor systems design

Using indicators need to be carefully done and taking into consideration the irrigator constraints, not to be used to describe environmental and managerial objectives

Incentives that compensate for the upgrading costs, society responsibilities, recognition of cultural skills, farmers decision making and not only PIM, need innovative approaches.