Towards food security:
Promising pathways for increasing agricultural water productivity

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Abstract

To meet the acute freshwater challenges facing humankind over the coming 50 years and to fulfil the food gap to feed 8-9 billion people, directing all the efforts to improve water use and management in agriculture is now a must.

Many promising pathways for raising water productivity are available by adopting proven agronomic and water management practices. However, despite adequate technologies and management practices, achieving net gains in water productivity is facing numerous constraints with low adoption rates. The adoption of such techniques requires an enabling policy and institutional environment that aligns the incentives of producers, resource managers and society and provides a mechanism for dealing with trade-off.

The promising pathways to achieving higher water productivity and the way to achieve are fully discussed in this paper.

Introduction

Irrigation represents between 70-80 percent of all water uses with some countries using 90 per cent or more for irrigation.

In the few coming years, the increments in the water demand by the other sectors will have to come mostly from agriculture mainly due to the fact that there is a high potentiality to reduce water losses and increase water saving in the irrigation sector in comparison with the other sectorial water uses.

FAO (2003) has estimated- that overall water use efficiency in irrigation ranges around 38 percent in developing countries and has projected only a minor increase in overall water use efficiency in the forthcoming decades.

Rather than water use efficiency, the concept of water productivity is now widely accepted as a measure of performance in agricultural water use. It is clearly documented that water productivity levels in today large irrigation systems are well below the potential in many areas.

Increasing the productivity of water in agriculture will play an important role in easing competition for scarce water resources, prevention of environmental degradation and provision of food security.

However, improving the productivity of water in agriculture through an appropriate water management is not an easy process. Significant challenges still remains in the areas of technological, managerial and policy innovation and adaptation, human resources development, information transfer and social environmental considerations. Our success and/or failure is a matter of our capability in finding sustainable solutions to the challenges.

Water productivity and its means

Water productivity in its broadest sense reflects the objectives of producing more food, income, livelihood and ecological benefits at less social and environmental cost per unit of water used, where water use means either water delivered to a use or depleted by a use.

Physical water productivity is defined as the ratio of the mass of the agricultural output to the amount of water used and economic productivity is termed as the value derived per unit of water used.

Simply, water productivity means growing more food or gaining more benefits with less water.

Food, water and productivity links

The amount of water consumed in producing today's diets is on average 1,200 m3/P yr. It varies from 600 m3/P yr in the poorest regions up to 1,800 m3/P yr in richest regions with the most meat based diets.

The net amount of water required for an acceptable nutritional level based on 80% vegetarian, 20% animal has been estimated as 1,300 m3/P yr, whereas for purely vegetarian is about half of that

Table 1 Crop water productivity for selected importers and exporters of cereals

Selected Exporters Countries			
Selected exporters 1995	Exporters as % of world's total	Water productivity in kg/m^3	% met by irrigation
USA	48%	1.26	15%
Canada	10%	0.88	4%
West Europe	10%	1.59	5%
Argentina	7%	0.49	5%
Australia	5%	0.54	28%
India	3%	0.34	41%
Exporters Average	=	*0.81*	*26%*
Selected Importers Countries			
Selected importers 1995	*Importers as % of world's total*	*Water productivity in kg/m^3*	*% met by irrigation*
Japan	14%	0.73	73%
China	14%	0.75	46%
Egypt	4%	0.78	97%
Indonesia	5%	0.51	23%
Iraq	1%	0.21	89%
Sub Sahara Africa	<1%	0.19	2%
Importers Average	=	*0.49*	*4%*
World Average weighted by the countries total production		*0.60*	*34%*

In assessing tomorrow's water needs to feed the two billion increase in population, the additional consumptive water needs can be calculated to another 3,800 km3/yr by 2025, growing to 5,600 by 2050. The 3,800 km3/ye is a huge amount and close to all the water withdrawals at present to support municipal, industrial and irrigation needs.

The questions are:

how and where to find all this water?

what the options and the possibilities to be followed to meet the tremendous increase in the water demand?

The answer:

increasing the water productivity is the appropriate answer to meet the future challenges towards water and food security, particularly in the arid and semi-arid regions where water supply is becoming more and more restricted due to source availability and financial constraints.

Water productivity: the net gains

Achieving net gains in water productivity is rather difficult due to numerous reasons, among them:

gains achieved by one group often come at the expense of another;

incentive systems do not support the adoption of existing technologies, and

gains are often captured by more powerful users and the poor are left behind.

Net gains in water productivity are to be potential in certain areas having specific features, such as:

areas where poverty is high and water productivity is low;

areas with physical water scarcity and intense competition for water;

areas where water resources development is limited, and

areas of water degraded eco-system

Water productivity and MDG's development

Improving agricultural water productivity is the key element towards freeing humanity of extreme poverty and hunger and ensuring environmental sustainability.

Meeting future water and needs: options and tools

A - The sustainable use of water in irrigated agriculture is putting all together crucial issues and options to provide a better understanding of the problems and their consequences, possible solutions and the interconnections and trade-offs among them.

B - An intensive work to modernize irrigated agriculture, through technological upgrading and institutional reform

C - Changes in attitude, well targeted investments in infrastructure modernization, institutional restructuring and upgrading of the technical capacities of farmers and water managers.

Increasing water productivity and why is it needed

Improving the productivity of water in agriculture requires:

- the integrated efforts of many players: breeders, natural resource management specialists, physical scientists, sociologists and above all the synergistic efforts of the farmers and the water resources managers;
- combining our knowledge to the maximum effect, in order to meet the complex challenge: *producing more food of better quality while using less water per unit of output;*
- enabling policy and institutional environment that aligns the incentives of producers, resource managers and society and provides a mechanism for dealing with trade-off.

Why is it needed?: to produce enough food to feed the burgeoning population in the developing countries and get it to where it needs.

Increasing water productivity: major principles

The key principles for improving water productivity at field are:

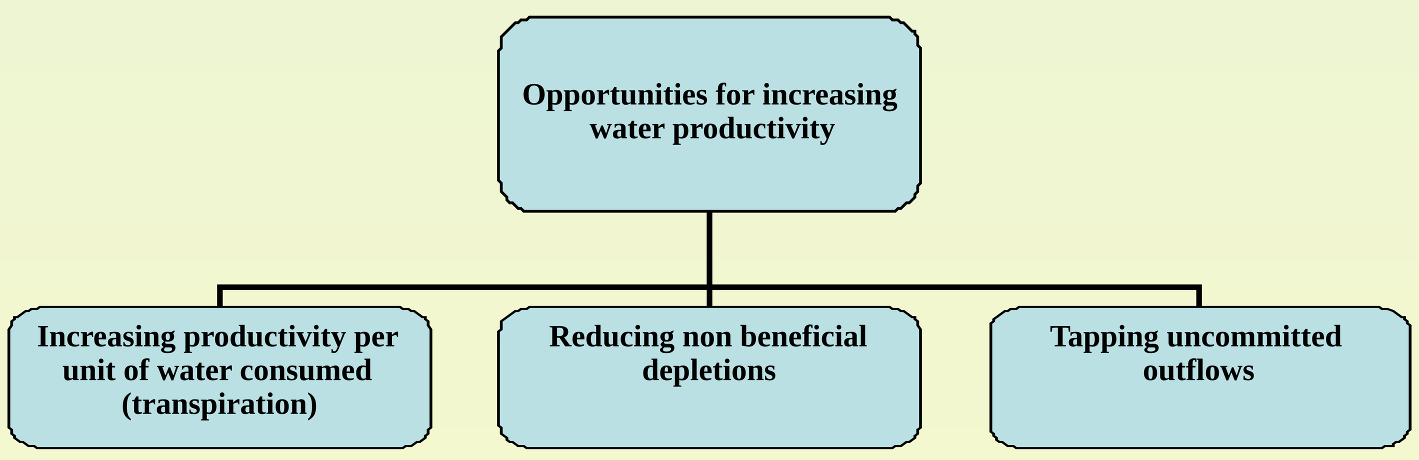
(i) to increase the marketable yield of the crop per each unit of water transpired;

(ii) to reduce all out flows (e.g.: drainage, seepage and percolation, including evaporation outflows, other than the crop stomatal transpiration), and

(iii) to increase the effective use of rainfall, stored water and water of marginal quality.

The three principles apply at all scales, from plant to field and agro-ecological levels. However, option and practices associated with these principles require approaches and technologies at different spatial scales.

Opportunities for increasing water productivity at farm level



Increasing productivity per unit of water consumed (transpiration)	Reducing non beneficial depletions	Tapping uncommitted outflows
-Changing crop varieties	- lessening of non beneficial evaporation	-improving management of existing facilities
-Crop substitution	reducing water flows to sinks	- reducing return flows
-Deficit supplemental or precision irrigation	-minimizing salinization of return flows	-Adding storage facilities
-Improved water management	- shanting pollution water to sinks	
-Improved non water inputs(land preparation and fertilization	- re-using return flow	

To produce more food with less water: major issues

In the arid regions there is and urgent need to:

upgrading the implemented strategies with greater focussing in rain-fed areas on optimising supplemental irrigation using the limited available water from renewable resources;

to establish the proper pathways to ensure generalization and transferability of the research results among dry region;

to promote the concept of integrated research sites has together with work on agro-ecological characterization and modelling to develop the strategies and technology packages to be extended and transferred to other larger dry areas.

Increasing water productivity: strategy selection

Strategies for increasing water productivity include a wide range of variable options:

a part of those options are related to plant physiology which focus on making transpiration more efficient or productive;

some are dealing with agronomic practices by the aim of reducing evaporation, and

others those focussing on farm agricultural engineering approaches in order to make application more precise and more efficient.

Many of these different strategies could be combined together and each strategy is complementary to the other.

The choice of strategy for increasing water productivity will be guided by economic and social factors. Existing water rights will often constraint choices, especially when there are options of reallocation.

Increasing crop productivity in irrigated agriculture

A On farm integrated water management

In irrigation, production gains can be made through having:

policies of water resources management that looks the whole set of technical, institutional, managerial, legal and operational activities required to plan, develop, operate and manage the water resources systems at all scale, i.e. farm, project, basin and national scale, while considering all sectors of the economy that depend on water.

integrated natural-resources management strategy that responds to the urgent need for improved productivity using less water at the farm level;

developing on-farm packages for increased water productivity and soil and water qualities as well as on the conservation and sustainable utilization of renewable groundwater resources;

close attention to water flow paths-reducing unproductive evaporation and eliminating flows that encourage salinisation, high water tables or cause ecologic damage.

B - Adoption of deficit irrigation

The adoption of deficit irrigation implies that:

the relationship between yield and water deficit has to be well known when planning deficit irrigation;

knowing the appropriate knowledge on crop water use and response to water deficits within the whole cropping period and during the critical growth stages;

to provide firm and ready information, hence, there is a great need for application research in this area.

Deficit irrigation: management options

From the practical point of view, there are different ways to manage deficit irrigation. The irrigator can:

reduce the irrigation depth, refilling only part of the root-zone soil water capacity

reduce the irrigation frequency by increasing the time interval between successive irrigations

wetting furrows alternatively or placing them further part is one way to implement deficit irrigation in surface irrigation.

Deficit irrigation: gained benefits

The gaining benefits in optimising water use and improving water productivity is a function of different important management factors:

crop management including the selection of crop variety, the crop rotation, sowing dates, crop density,

soil fertility management and

weed, pests and diseases control

soil characteristics such as depth, texture, structure and crusting, salinity and fertility are major soil factors affecting the water productivity are governing the maximum amount of water that can be stored and hence the effective length of the growing season.

soil tillage (form, depth, frequency and timing) and soil surface management, all, play an important role in enhancing water productivity in dry areas.

Water productivity improvement under rainfed agriculture

In agriculture, although much of the debate is focussed on irrigated crop production, the rainfed areas plays an important role in the production of food in many countries around the world. They cover more than 80% of the land areas for cropping throughout the world and produce some of 60% of the total production.

In arid and semiarid regions upgrading rain-fed agriculture is the challenge

In arid and semi-arid countries, particularly those characterised with growing water scarcity to achieve improved food self sufficiency, will require an increase in the water supply which is nowadays questionable. But in such countries there exists at the same time a huge window of opportunity since most of the farmers rely on rain-fed agriculture.

In those water stressed areas, upgrading rainfed agriculture where present yield levels are under of low values 0.5 to 1.0 ton grains per hectare leading to extremely low water productivity is the challenge and to meet the challenge focussing should be on-farm water harvesting or supplemental irrigation both can potentially triple water productivity.

In rainfed dry areas, the productivity of both irrigation water and rain-water is improved when they are used conjunctively (Table 2).

Table 2. Rain-Water Productivity (WP_R) combined Rain and Irrigation Water Productivity (WPR_{+I}) and Irrigation Water Productivity (WP_i) of bread-wheat grains in Northern Syria

Year	Rain (mm)	WP_R (kg m^{-3})	S_i (mm)	WPR_{+I} (kg m^{-3})	WP_i (kg m^{-3})
1991/92	351	1.04	165	1.16	1.46
1992/93	287	0.70	203	1.23	2.12
1993/94	358	1.08	175	1.17	1.43
1994/95	318	1.09	238	1.08	1.06
1995/96	395	0.91	100	0.90	0.73
Mean water Productivity	-	0.96	-	1.11	1.36