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THEME: DEVELOPMENT FOR WATER, FOOD AND NUTRITION SECURITY IN A COMPETITIVE ENVIRONMENT

BACKGROUND PAPER – Sub-Theme 3

ST-3: Improving Agricultural Water Productivity with Focus on Rural Transformation

Contributors:

Mr. IJsbrand H de Jong (World Bank), Team Leader

Eman Ragab Nofal, Researcher, Research Institute for Groundwater, (RIGW), National Water Research Center, (NWRC), Egypt

Klaus Röttcher, Professor for International Water Management, Ostfalia University of Applied Sciences, Faculty of Civil and Environmental Engineering in Suderburg, Germany

Narges Zohrabi, Assistant Professor, Department of Water Sciences and Engineering, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran, Islamic Republic of

Patel Neelam, Principal Scientist, Water Technology Centre, Indian Agricultural Research Institute, New Delhi-110012, India

Sigit Supadmo Arif, Professor in Agricultural and Biosystems Engineering, Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta 55281, INDONESIA

Dr K Yella Reddy, Dean, Agricultural Engineering and Technology, ANGRAU, Guntur-522034, AP, India

Paavan Kumar Reddy Gollapalli, Project Manager, Watershed Organization Trust (WOTR)

ICID•CIID

International Commission on Irrigation and Drainage (ICID)
48 Nyaya Marg, Chanakyapuri, New Delhi - 110021, India
E-mail: icid@icid.org, Website: http://www.icid.org

Background Paper

Improving Agricultural Water Productivity with Focus on Rural Transformation

ABSTRACT

As a result of population growth, economic development and climate change, feeding the world and providing water security for all will require important changes in the technologies, institutions, policies and incentives that drive present-day water management, as captured among others in Goal 6.4 of the Millennium Development Goals. Irrigation is the largest and most inefficient water user, and there is an expectation that even small improvements in agricultural water productivity, defined as a biomass, production or output price relative to water withdrawn, applied or consumed, will improve water security.

This paper argues that improvements in water productivity that irrigated agriculture is expected to deliver involves complex and comprehensive rural transformation that goes beyond mere adoption of water saving technologies. Rural-urban migration, improved living standards and changes in diets, and access to internet, mobile phones, energy and affordable technologies all play a role. Many of the measures to improve water productivity require significant changes in the production systems of farmers and in the support that is provided by public and private service providers – extension services, input suppliers, agricultural off-takers, and others.

The paper uses Molden's four pathways for increasing water productivity at the irrigation system or at basin level, and provides concrete cases that are located on each of these pathways, showcasing the diverse experience in the use of technologies, institutions, policies, and incentives to improve water productivity.

Looking forward, water use and competition over water are expected to further increase. By 2025, about 1.8 billion people will be living in regions or countries with absolute water scarcity. Demand for water will rise exponentially, while supply becomes more erratic and uncertain, prompting the need for significant shifts of inter-sectoral water allocations to support continued economic growth. Advances in the use of remote sensing technologies will make it increasingly possible to cost-effectively estimate crop evapotranspiration from farmers' fields.

1. INTRODUCTION

Estimates show that with current population growth and water management practices, the world will face a 40% shortfall between forecast demand and available supply of water by 2030. Population growth has led to dwindling per capita water resources (see Figure 1) and to intensifying competition over scarce water resources. In many countries, groundwater tables have declined precipitously, and water quality is becoming a growing concern. Climate change and more volatile water availability are putting additional pressure on those sectors that use water inefficiently to conserve water and use it more efficiently. In addition, as countries and economies develop and people move out of poverty, eating habits change in favour of more water intense diets. Growing competition over water, climate change and changing diets all require a more thoughtful use of water to ensure that water makes the highest possible contribution to achieving societal objectives.

As a vital resource, water is an important factor fuelling the growth and development of human societies. During the past two decades, and in the latter years of the 20th century in particular, water and its management have turned into a daunting global challenge. A comparison between the countries located in temperate areas and those located in semi-arid and arid areas shows that water scarcity (especially good quality water) has acted as an important factor hindering the agricultural, economic, and social development activities in those countries that are located along the belt of arid, semi-arid, and tropical areas across the world.

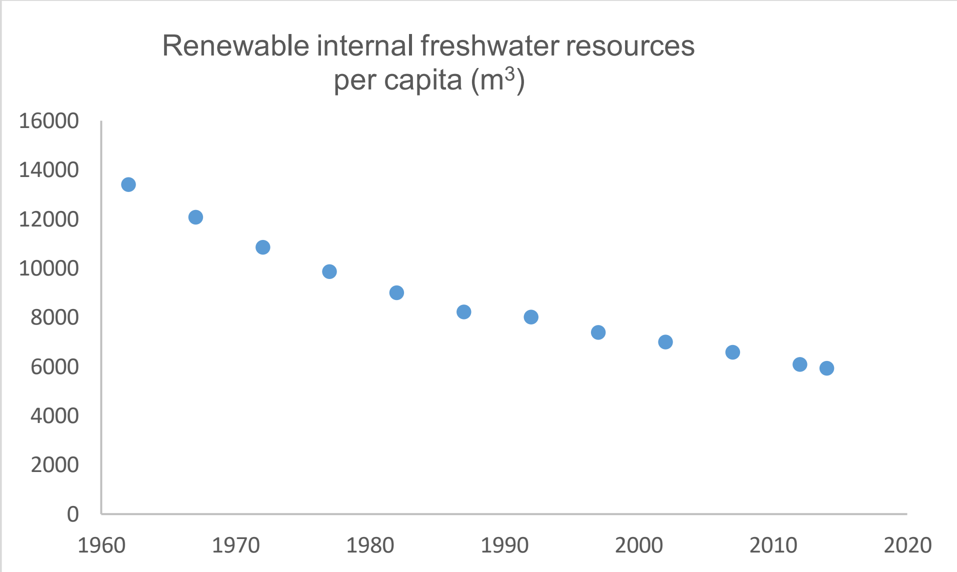


Figure 1: Global per capita water availability (FAO Aquastat)

Today, not only water security but also food security is facing high levels of risk. Fundamental reasons behind these elevated levels of risk include the rapid population growth in parts of the world, reduced availability of water resources due to excessive exploitation, human interventions in natural cycles, and the use of chemical contaminants (Kadi et al., 2003). In the near future, competition for water is likely to occur between agriculture, potable water use, industrial uses and the environment. The challenges will be even worse in semi-arid and arid areas. Some 7% of the world's population live in areas suffering from water scarcity[1]; the figure has been forecasted to increase to more than 67% by 2050 (Howell et al., 2001).

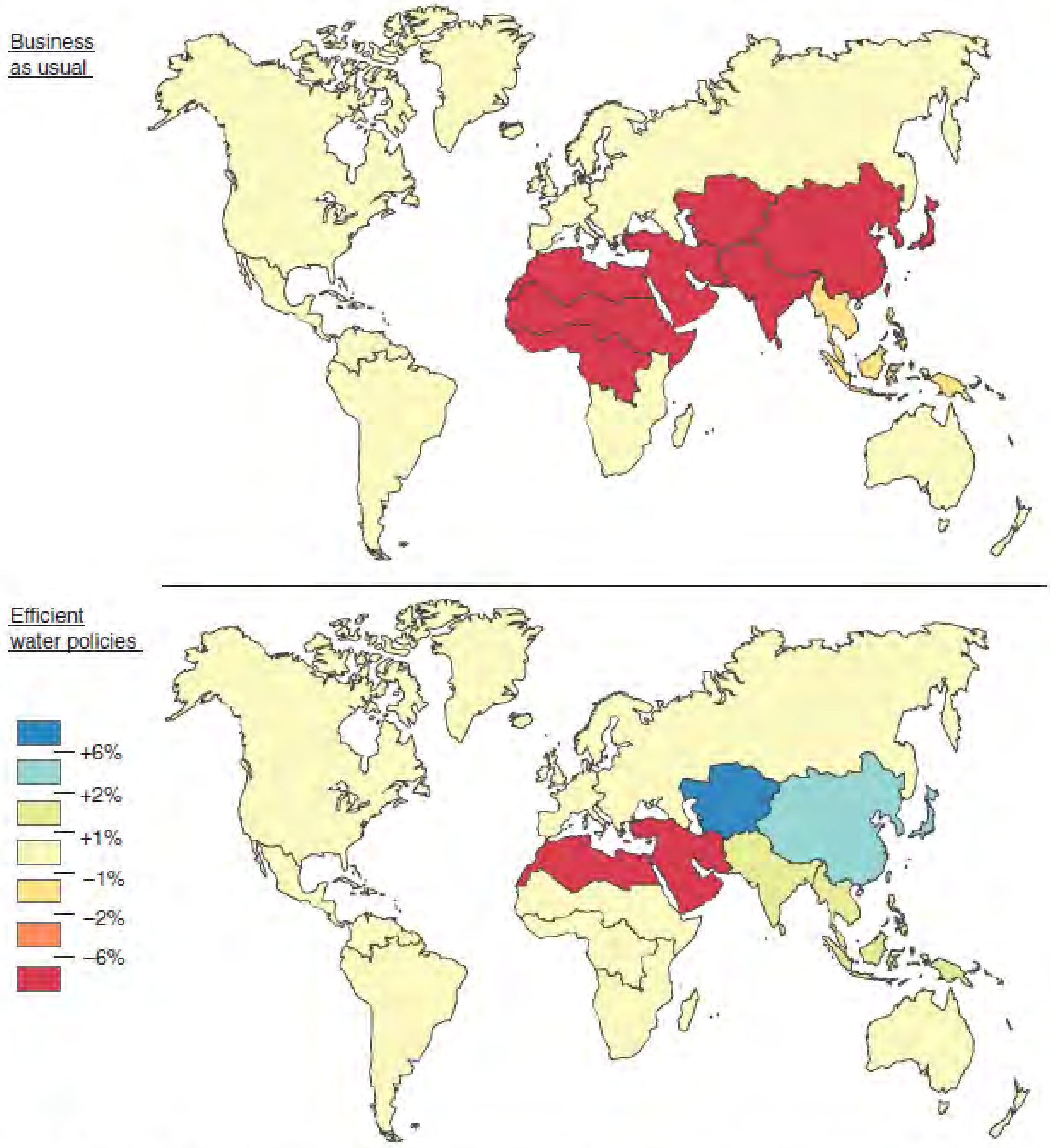
In view of the above, feeding the world and providing water security for all will require important changes in the technologies, institutions, policies and incentives that drive present-day water management. Irrigation is the largest and most inefficient water user, and there is an expectation that even small improvements in agricultural water use could have significant implications for local and global water budgets, and therefore for the water security of other water users. While feeding more people, agriculture will need to use less water to produce more. The associated water savings should be allocated to other parts of the economy so that overall each drop of water contributes most to achieving agreed societal objectives.

The need to use water more efficiently has among others been recognized in the Sustainable Development Goals (SDGs). In particular, Goal 6.4 aims to "by 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity, and substantially reduce the number of people suffering from water scarcity." Irrigated agriculture will need to invest in water savings so that these savings can be allocated towards sectors that produce more value for society (see Figure 2). The productivity of water use, however defined, is increasingly becoming an important metric to benchmark the performance of irrigation.

This paper will review the experience in technologies, institutions, policies and incentives to improve agricultural water productivity. The paper recognizes that increasing water productivity requires no less than a rural transformation. At the same time, on-going changes in rural areas prompt farmers to respond, adapt and seize emerging opportunities. Business as usual is no longer an effective response.

[1] Based on existing international standards, water scarcity refers to a situation where a country consumes more than 1,000 m^3 per person per year.

The paper will contribute to a better understanding of the key issues and the roles and responsibilities associated with scaling up water productivity, as well as practical action on the ground.



Source: World Bank calculations.
Note: The top map shows the estimated change in 2050 GDP due to water scarcity, under a business-as-usual policy regime. The bottom map shows the same estimate, under a policy regime that incentivizes more efficient allocation and use of water.

Figure 2: The Estimated Effects of Water Scarcity on GDP in Year 2050, under Two Policy Regimes

2. WHAT IS AGRICULTURAL WATER PRODUCTIVITY?

Numerous definitions of water productivity have been proposed, and none has been broadly accepted or consistently applied. In this paper, we define water productivity as a biomass or production relative to water withdrawn, applied, or consumed. Water productivity is expressed as yield or biomass in relation to one of the measures of water use for the case of a particular crop at the field or farm level. If water productivity is estimated for more than one crop at the farm level, for example, output prices are often used for aggregation, and water productivity is expressed in economic terms[2]. We will use consumption (i.e., evapo-transpiration, ET) as the measure for use and ignore return flows or rainfall.

According to the definition provided in this paper, "agriculture water productivity" is an index ratio with consumed amount of water (ET) in its denominator and various quantities in its numerator. These can include crop yield, net income (profit), produced amount of caloric energy, value-added, etc. In general, physical water productivity and economic water productivity are more popular for water management analyses and decision making. Physical water productivity refers to the produced amount of crop (biomass) per unit volume of consumed water, which is usually expressed in kg/m^3. On the other hand, economic water productivity considers the economic value of the benefits produced per unit of water used, i.e. how much economic value is generated for the consumed amount of water It is usually expressed in US$/m^3.

In order to draw a more comprehensive picture of the "agriculture water productivity" index, it is necessary to identify the specific part(s) of the crop which is (are) considered as final product. Indeed, although all parts of a plant need water before it can grow, only specific part(s) of the plant generate profit (i.e. carry economic value) for the farmer. Therefore, depending on the type of the cultivated plant, the cropping pattern, various farming operations, and merchantability of the produced crop all play a role in the definition of "agriculture water productivity."

Using agricultural water productivity to benchmark the performance of irrigated agriculture has sometimes been questioned because the over-emphasis on the performance of just one production factor. Agricultural productivity depends on a number of inputs, and each farmer will strive to use the proper mix of these inputs to obtain optimal results within the particular context that he or she operates. Maximizing production per cubic meter of water may often not be the only or even the most rational thing to do; maximizing nutrition or labour input per cubic meter might be a better option for many farmers.

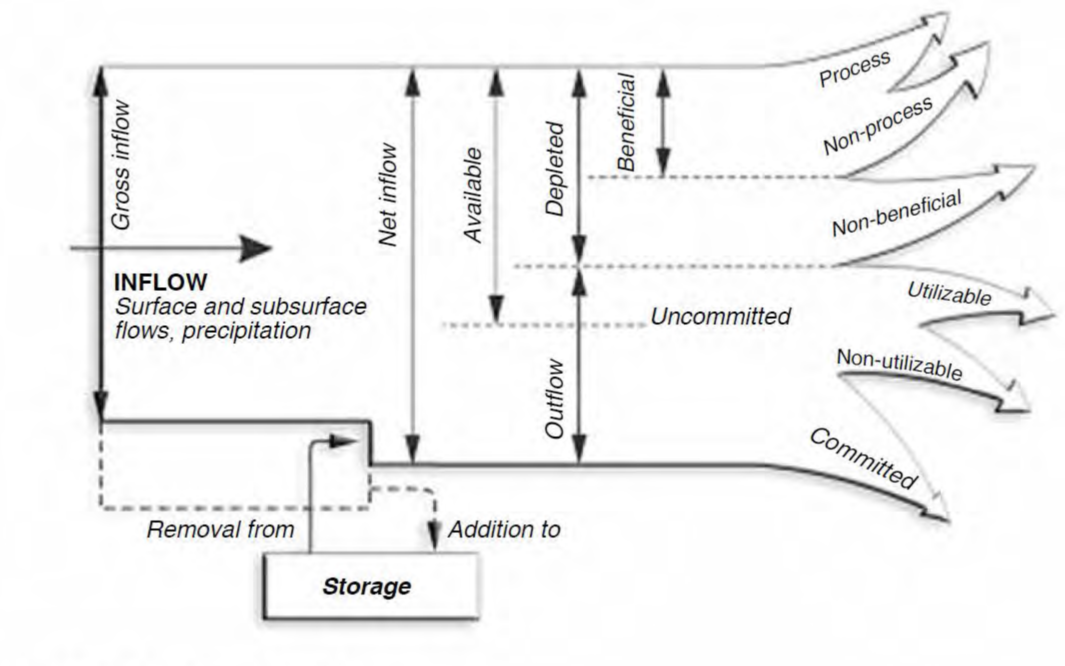
Similarly, the concept of agricultural water productivity has sometimes met with skepticism because it doesn't consider the costs and risks to a farmer. Water productivity is often not the driver of investment decisions; the ratio between the costs and benefits of investing in more productive water use is, it is argued, a more appropriate yardstick.

Water efficiency and water productivity are sometimes used interchangeably. Yet, they refer to very different concepts and apply to very different contexts. Water use efficiency often relates to the amount of water used to meet crop ET. Any excess over and above the amount of water required to meet ET is counted towards inefficiency. Water productivity relates to the value produced with a given volume of water. Water productivity can increase even if water use efficiency does not, e.g., by growing higher value crops with the same amount of water and the same amount of return flow. Water productivity does not only relate to agriculture – in fact, saving water in agriculture and reallocating these savings away from agriculture can often increase water productivity as the value produced with a given amount of water is often higher outside agriculture. In open river basins (those basins that have unused water available), the emphasis is often on capturing more water for productive uses. In closed basins (i.e., no usable water is left in the basin), increasing water productivity and allocation water to those users that add most value to the economy becomes increasingly important.

The schema prepared by Molden (2003, Figure 3) is helpful in better understanding water availability and efficiency.

Molden et al. (2001a, 2003, 2007b) identifies the following four pathways for increasing water productivity at the irrigation system or at basin level: (i) increase yield per unit of water consumed, (ii) reduce non-beneficial depletion, (iii) tap uncommitted flows, and (iv) re-allocate water among uses. While the pathways relate to different definitions of water productivity, they are helpful for water practitioners to define strategies to increase water productivity.

[2] Beyond Crop per Drop Assessing Agricultural Water Productivity and Efficiency in a Maturing Water Economy. Susanne M. Scheierling and David O. Tréguer



Source: Adapted from Molden et al. 2003.

Figure 3: Water Allocations

Partly as a result of misunderstandings in the definition of water productivity and its application, myths associated with water productivity abound. The ones encountered most frequently include:

(a). Efficiency at scheme level is often confused with efficiency at river basin level. While there is a general recognition that irrigation efficiency at scheme level is often low, some authors have pointed out (Horst 1992, Seckler 1996) that, when excess water from inefficient irrigation is returned to the river and used for irrigation in downstream irrigation systems, overall efficiency at basin level can actually be high. E.g., in cascades of tank irrigation systems, downstream tanks often rely on the return flows from inefficiently used irrigation water in the upstream tanks. In fact, increasing irrigation efficiency at tank level may lead to reduced return flows and reduced inflows into the downstream tanks in the same cascade. Efficiency improvements turn out to be zero-sum efforts.

(b). Recent research has provided a growing body of evidence that suggests that investments in more efficient irrigation don't necessarily unlock water for use for alternative purposes. In many cases, investments in more efficient irrigation technologies have led to an expansion of the irrigated area and to *more* and not *less* water consumption. This is particularly true when farmers don't save money when saving water. In these cases, the only rational reason for a farmer to invest in water savings is to expand his irrigated area using the saved water. Where farmers do pay per m^3 of water, they use it more efficiently: in Spain, for example, groundwater irrigators apply less water than surface water irrigators and achieve higher returns for their output per unit of water applied (Garrida et al. 2005, Shah 2014). In West Bengal, research found that electricity metering resulted in a significant reduction of hours pumped during the summer season, and that the resulting 33% decrease in water use did not affect the crop yield of summer paddy or cropping patterns (J.V. Meenakshi et al., 2013).

In summary, there is an urgent need to develop a clear definition of water productivity and apply this in a consistent and coherent manner. The definition should account for the fact that in many basins, return flows are recycled numerous times, make a clear distinction between water efficiency and water productivity, and consider the benefits from agriculture and other sectors.

3. WHAT IS RURAL TRANSFORMATION?

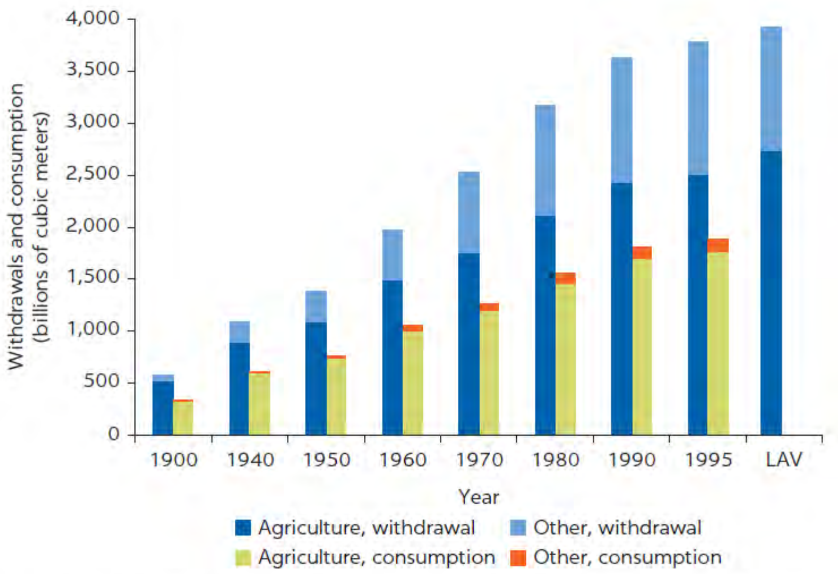
Rural transformation is an active, positive procedure of change and development in rural communities in terms of social and economic national and international changes (Long, Zou, Pykett, & Li, 2011; Wang, Khan, & Zhang, 2013). This often includes a growing urban influence on rural livelihoods and changes in the systems and processes, which often significantly affect the lives of those living in villages. It is essential to note that rural transformation is not equivalent to rural development. Rural development is the process of improving people's livelihoods in rural areas (Moseley, 2003). Rural development is traditionally focused on utilization of natural resources including agriculture and forests. Rural transformation is a more dynamic notion than rural development; in fact, transformation concerns the people's attitudes in life (Shaw, 2011).

Rural transformation may be defined as a process of comprehensive societal change whereby rural societies diversify their economies and reduce their reliance on agriculture; become dependent on distant places to trade and to acquire goods, services, and ideas; move from dispersed villages to towns and small and medium cities; and become culturally more similar to large urban agglomerations. (Julio A. Berdegué, Tomás Rosada, Anthony J. Bebbington (2014).

Rural transformation should be supported with adequate policy decisions along with intervention from the private and public sectors so that the rural space turns into a more sustainable, society-based ecologic entity.

4. HISTORICAL DEVELOPMENT

Both total and agricultural water withdrawals have increased dramatically since 1900, but their rates of growth have declined since about 1980 (see Figure 4). In most Organisation for Economic Co-operation and Development (OECD) countries, total and agricultural water withdrawals have tended to remain stable or decrease (OECD 2015).



Source: Scheierling and Tréguer 2016a, based on FAO 2016a; Shiklomanov and Rodda 2003.
Note: LAV = latest available value.

Figure 4: Global Trends in Agricultural and Total Water Withdrawals and Consumption

Evaluation of past trends in water productivity is problematic because of limited data availability. It is only in the past 20 years that remote sensing technologies have become available that have spurred more accurate estimates of water productivity. Most historic analyses are therefore based on crop-hydrology models. E.g., Cai and Rose grant (2003) use the IMPACT-WATER model for the analysis of water productivity for irrigated rice. Figure 5 presents water productivity estimates for irrigated rice based on the IMPACT-WATER model.

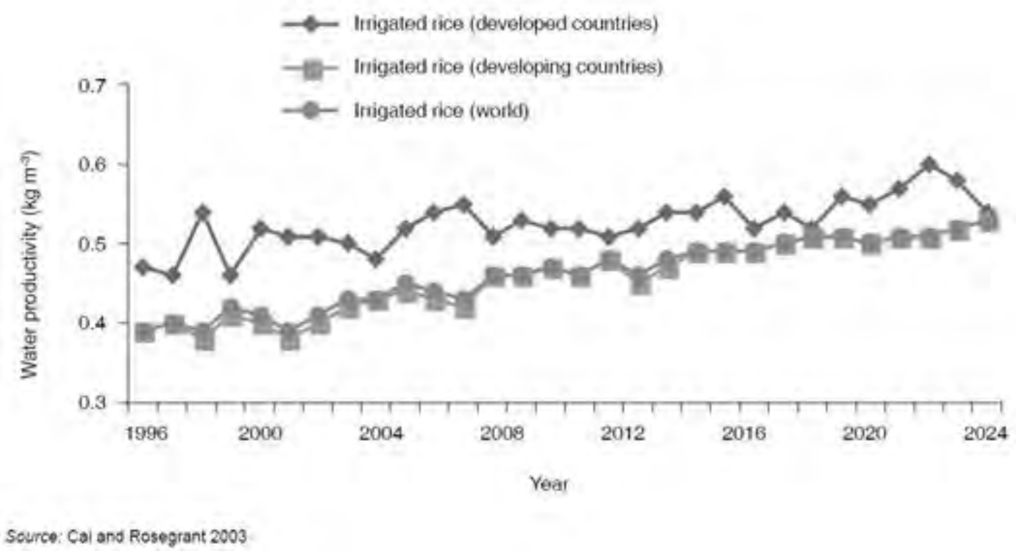


Figure 5: Water Productivity Estimates for Irrigated Rice

In addition to water productivity increases, important transformations are happening in rural areas that have an impact on and are impacted by water use. Increasing agricultural water productivity is both driven by and is a driver of rural transformation. Significant changes in the population and its build-up have taken place, with a higher percentage of young people, and migration of many of these young people to cities. Standards of living in rural areas have been rising, triggering among others a change in diets. Infrastructure services have reached rural areas, including internet and mobile phones, while access to energy (including through solar panels) has improved. Affordable technologies have become available for farming, including low-head pumps, micro irrigation and solar powered irrigation systems that in combination with "net-metering[3]" have the promise of revolutionizing the productivity of agricultural water.

5. STATE OF THE ART

This paper distinguishes between different interventions to increase agricultural water productivity: technologies, institutions, policies, and incentives. Each one of these may operate on the four pathways identified by Molden.

With the emergence of remote sensing technologies, monitoring of water productivity and evaluation of the effectiveness of efforts to improve it have come within reach. This is important as a clear understanding is required of what works and what doesn't. Similarly, the use of drones in irrigation management, e.g., to detect non-beneficial ET and leakages is being scaled up throughout the world. Innovative ICT products and services include Irrigation Analyst, Geographic Information System and IrriSat system, and numerous mobile apps that have been developed. Advanced hydrological models such as Groundwater Flow Modelling for Managed Aquifer Recharge in Thailand also help in monitoring, forecasting and evaluating water productivity. In Nebraska (USA), the Agricultural Water Management Network installed soil moisture sensors in highly efficient irrigation systems and conducted extensive farmer outreach. As a result, over USD $35 million was saved in energy costs through increases in water use efficiency (Irmak, 2012). In western India, farmers are using mobile phones to activate electric irrigation pumps in their fields (PC World, 2009), and pastoralists in Kenya are uploading on-the-ground water conditions to calibrate satellite data, forming a real-time map of forage and water conditions

3 *Net metering* credits owners of solar energy systems for the electricity they supply back to the grid.

(Kamadi, 2012). In Iran, Khoshnavaz et al. (2016) used satellite images and applied SEBAL algorithms to estimate productivity across farms in Qazvin Plain, Iran, using estimates of water productivity as per the satellite images.

In a research, Diani et al. (2004) prepared a geographic information system for Kowsar Irrigation and Drainage Networks in Khuzestan Province, Iran, and provided the farmers with the required amount of water for irrigating different parts of the farms by identifying critical parts of the farm based on salinity and drainage, selected cropping pattern, meteorological parameters, and local soil properties .

Water Accounting + in Sri Lanka[1]

Water accounting is the process of communicating water resources related information and the services generated from consumptive use in a geographical domain, such as a river basin, a country or a land use class; to users such as policy makers, water authorities, managers, etc.

A study was conducted to assess the annual water balance for each of the 103 river basins in Sri Lanka by using observed rainfall and remotely sensed actual evaporation rates. The SEBAL algorithm was used to assess the actual evaporation and storage changes in the root zone on a 10- day basis. The water balance was closed with a runoff component and a remainder term. Evaporation and runoff estimates were verified against ground measurements. The remainder term appeared to be less than 10% of the rainfall, which implies that the water balance is sufficiently understood for policy and decision making.

The results show that the irrigation sector uses not more than 7% of the net water inflow. The total agricultural water use and the environmental systems usage is 15 and 51%, respectively of the net water inflow. The consumptive use of rain-fed and irrigated agriculture is approximately equal. The study found that evaporation rates in agriculture and mixed vegetation are similar, so that low productivity rangelands can be transformed into rain-fed agriculture without detrimental effects on water availability to downstream users. The unused water flow to the Indian Ocean is 34% of the net inflow, hence there is scope for further water developments in Sri Lanka.

[1]http://www.wateraccounting.org

Agronomic innovations to improve water productivity include zero tillage, *systemerizicoleintensif* (SRI) in combination with rice ratooning as practiced in West Sumatra, laser land levelling, use of “happy seeder”, mulching, changing crop planting dates to match periods of less evaporative demand, and intercropping (e.g., of wheat and maize in China). It may also include the added value of tourism, e.g., in Bali’s subak system. Improvements in the access to agricultural markets, reduction of post-harvest losses, and grading and standardization (to name a few) all have a demonstrated impact on water productivity. Greenhouse agriculture represents another approach to optimal use of water for crop productivity. Saliha (2005) found that irrigation with magnetized water adds to crop yields and quality of the final product. Zanganeh (2006) showed that magnetized water can be used to enhance water productivity and germination rate.

Important improvements in water productivity can also be achieved through better linkages between farmers and markets. In many cases, farmers don’t adopt higher value crops because the markets for higher value products either don’t exist, or are too demanding in terms of the harvest date, the quality and the uniformity of the produce. Higher value crops are often perishables and require well performing markets with adequate critical mass of buyers and sellers. In view of these challenges, farmers often prefer to continue growing lower value cereals, thereby foregoing the benefits of higher water productivity.

Examples of successful technologies include a broad set of pressurized micro- or precision irrigation technologies and sub-surface drainage systems. Other technologies include desalination and wastewater treatment. Better water management and improving the quality of irrigation service delivery can help make water supply more predictable so that farmers can invest in more and better inputs. “Tail to head” supply, such as practiced in Telangana (India), can help reduce wastage and improve water efficiency and productivity, as well as supplemental and deficit irrigation, and alternate wet and dry irrigation of rice. Increased water storage can help transfer excess water from the wet season to the dry season, while ensuring a more productive use of water at basin level throughout the year. Agricultural mechanization often serves as a fundamental and effective factor in enhancing the production and productivity of water. Among others, through the utilization of agricultural machinery (for land preparation, planting, cultivation, and harvesting) contributes to enhanced production and water productivity (Abbasi et al., 2017).

Improving livestock water productivity in sub-Saharan Africa (SSA)[1]

Livestock keeping is the fastest growing agricultural sector in SSA. Besides the economic benefits, rising livestock production could also deplete water and aggravate water scarcity at local and global scales. Innovative and integrated measures are required to improve water productivity and reverse the growing trends of water scarcity.

The study found that livestock water productivity (LWP), defined as the ratio of livestock outputs to the amount of water depleted, could be improved through: (i) raising the efficiency of the water inputs by integrating livestock with crop, water and landscape management policies and practices. Improving feed water productivity by maximizing transpiration and minimizing evaporation and other losses is critical; (ii) increasing livestock outputs through improved feed management, veterinary services and introducing system- compatible breeds; and (iii) because livestock innovation is a social process, it is not possible to gain LWP improvements unless close attention is paid to policies, institutions and their associated processes.

Policies targeting infrastructure development would help livestock keepers secure access to markets, veterinary services and knowledge.

[1]Amede, Tilahun et al (2009)

https://www.researchgate.net/publication/235961349_Harnessing_benefits_from_improved_livestock_water_productivity_in_croplivestock_systems_of_sub-Saharan_Africa_Synthesis

Incentivizing farmers to adopt micro-irrigation[1]

Many investments can contribute to on-farm water saving—but in the end it will only happen if the farmer him/herself is both motivated and enabled. On-farm technologies like piped distribution, drip, and bubbler are widely available, and can cost as little as US$250 to $500/ha. Treadle pumps that can irrigate up to 0.5 ha using family labour cost only $50 to $100. A wide range of water management and crop management improvements is known. Yet adoption of water saving technologies has been slow and performance below potential.

Investment in water saving will be optimal in the private and public interest only where both available technology and favourable incentive and institutional structures are present. In the end, the incentive structure is the key: if water is too cheap, markets are dysfunctional, or water rights are insecure, farmers will not save water. In the end, only the prospect of higher farmer net income and lower risk will drive investment and water saving.

[1] World Bank (2005)

http://web.worldbank.org/archive/website00660/WEB/PDF/WATER_FO.PDF

Improving water productivity requires 'institutions of innovation' that involve a range of actors, from public and private actors, academia and research institutions, producers, and water management agencies. E.g., the International Water Management Institute (IWMI) presented new approaches to rainwater management in Ethiopia which involved the integration of technologies, institutions and policies (Sharma, 2012). Institutions for improving water productivity include in particular grassroot organizations (e.g., in the Urmia Lake Basin) that monitor water use and use social collateral for reducing losses. Introduction of cooperative water management of canals can also improve the quality and quantity of water supply. The Natural Resources Districts in Nebraska provide an interesting example of how local level management and control of groundwater can improve both productivity and sustainability (Bleed, 2013).

Innovative Financing for Water **Productivity: Gujarat's Drip Pool Programme**[1]

To promote adoption of micro-irrigation, the government of Gujarat has formed a Special Purpose Vehicle (SPV) called Gujarat Green Revolution Company (GGRC). GGRC provides subsidies to farmers to install micro-irrigation technologies, such as drip irrigation. These subsidies cover about 40 per cent of the cost of installation and the remaining amount is expected to be borne by the farmers themselves. As small and marginal farmers do not have the financial resources to pay this additional amount, large and medium farmers constitute 60 per cent of the beneficiaries of this subsidy.

To address the gap, the Drip Pool Programme has set up a community financing mechanism to provide interest-free loans to such farmers. The loans help them avail the subsidy by providing the additional amount required for installation of drip irrigation units. The fund is currently managed by Farmer Producer Companies (FPCs). The programme is also strengthening capacities of FPCs to manage the fund on their own and by connecting farmers to the market.

About 98 per cent of the farmers who availed the subsidy are small and marginal farmers.

[1]https://www.candafoundation.org/en/our-work/results-and-learning/drip-case-study.pdf

Water Users Associations and Irrigation Water Productivity in Northern China[1]

A study was conducted in China to examine the underlying causes of differences in WUA performance by analyzing the impact of WUA characteristics on the productivity of irrigation water. Applying a random intercept regression model to data collected among 21 WUAs and 315 households in Minle County in northern China, the study found that a number of factors that are commonly identified as common pool resources need to be taken into account if WUAs are to be successful in promoting higher water productivity. E.g., group characteristics is an important factor in water productivity: large groups tend to have greater difficulties in overcoming problems of collective action and free-riding. A large number of sub-groups, i.e., water users' groups (WUGs), within a WUA can promote water productivity by allowing more crop diversification and by a better tuning of planting and irrigation decisions among member households. Another group characteristic that affects water productivity is heterogeneity of land endowments, which is found to have a positive effect on water productivity of member households in a WUA.

Another factor that explains differences in water productivity is the pressure on the water resource. The study found that a high pressure caused by a large unmet water demand negatively affects water savings in crop production, while the share of households with migrant heads in a WUA positively affects the productivity of water use. Another noteworthy result is that the study does not find evidence that resource characteristics, i.e., resource size and degree of overlap between the WUA boundaries and natural boundaries, affect water productivity in our research area.

[1]https://www.sciencedirect.com/science/article/pii/S0921800913002711#bb0005

Regulation, policies and demand management are indispensable as part of a comprehensive package of water productivity reform measures. Examples include the introduction of volumetric water fees in the Zhanghe Irrigation District in Hubei Province (Molle and Berkoff 2006), adoption of water withdrawal caps in Australia and introduction of water withdrawal rights. Efforts to reallocate water among users, e.g., through establishment of water markets or the introduction of river basin organizations also need mention. Faramarzi et al. (2010) adopted a virtual water strategy to optimize water consumption and crop yield through regional trade, and found that adjustments in cropping patterns lead to water savings while increasing crop yield.

Irrigation Charges in Morocco[1]

Morocco has a clear policy for irrigation service charges in all major schemes, requiring full recovery of operation, maintenance, and replacement costs, plus a large part of capital costs. Charges, levied volumetrically—at US$0.02 2/m3 or more (equating to $100 to $200/ha)—are high by international standards for surface irrigation. Even at this price, demand for water would exceed supply, because returns on water are about 10 times the volumetric price. Demand management is therefore achieved through quotas specified and measured at farm level. Cost recovery is high, and most systems cover at least operation and maintenance costs.

[1]Source: Cornish and Perry 2003. In: Shaping the Future of Water for Agriculture a Sourcebook for Investment in Agricultural Water Management

6. RURAL TRANSFORMATION AND AGRICULTURAL WATER PRODUCTIVITY

Many of the measures to improve water productivity require significant changes in the production systems of farmers and in the support that is provided by the public and private service providers – extension services, input suppliers, agricultural off-takers, etc. E.g., switching from low value cereals to higher value horticulture crops requires significant changes to the farmers' knowledge, equipment, staffing, marketing channels, fertilizer use, finance, etc. Cold storage needs to be developed in addition to investments in marketing infrastructure and market intelligence. Converting to higher value crops may also require changes in the public policy when lower value cereals are subject to a guaranteed price and other biased support measures that provide a disincentive to convert.

Changes also need to be made to the irrigation infrastructure. Conventional flood irrigation systems need to be retrofitted to accommodate the more frequent supply of smaller amounts of water that are required by higher value horticulture crops. This often requires installation of sub-surface pressurized pipe systems and/or development of on-farm storage. The quality and reliability of irrigation services require a quantum leap; in many cases, on-demand delivery of water will be expected by farmers to meet the demands of markets.

In many irrigation systems, these changes cannot be made by an individual farmer. Converting to higher value production requires rural transformation at the tertiary unit level. Support is required in the early days of this conversion to address market failures, and care should be taken that this support does not provide perverse incentives and crowds out private sector initiatives.

Given the above discussion, it is important to take great care in the design and implementation of the rural transformation process. Increasing agricultural water productivity through rural transformation must strive to achieve the highest societal value of water which requires institutional support, multi-sector capacity strengthening and empowerment of rural communities to provide incentives to adopt the changes. In that regard, taking particular account of the inhabitants' domestic, local knowledge is imperative.

7. FUTURE OUTLOOK

Water use and competition over water is expected to further increase. Freshwater withdrawals have tripled over the last 50 years, and demand for freshwater is increasing by 64 billion cubic meters per year. Today, 70% of global water withdrawals are for agriculture. Feeding 9 billion people by 2050 will require a 15% increase in water withdrawals based on today's irrigation efficiency. By 2025, about 1.8 billion people will be living in regions or countries with absolute water scarcity. The combined effects of growing populations, rising incomes, and expanding cities will see demand for water rising exponentially, while supply becomes more erratic and uncertain.

Significant shifts of inter-sectoral water allocations will be required to support continued economic growth. Due to population growth, urbanization, industrialization and climate change, improved water use efficiency will need to be matched by reallocation of as much as 25 to 40% of water in water stressed regions, from lower to higher productivity and employment activities. In most cases, this reallocation is expected to come from agriculture, due to its high share of water use. However, recent evidence suggests that water savings achieved in agriculture are often used to expand existing agriculture and are not reallocated away from agriculture.

Technological innovations combined with changes in the policy environment will need to play an increasingly important role in agricultural water management. Advances in the use of remote sensing technologies are now making it possible to cost-effectively estimate crop evapotranspiration (the sum of evaporation and plant transpiration to the atmosphere) from farmers' fields and to improve water accounting and management at the regional and basin-wide levels, e.g., in the Xinjiang Turpan Water Conservation Project in China. Institutions need to be strengthened, including Associations of Water Users and councels and agencies for River Basin Management, and institutional and policy reforms need to be pursued and scaled up to underpin the improved capacities.

Most importantly, incentives need to be provided to farmers to use water more efficiently and productively, including through adequate demand management measures. Adoption of appropriate technologies needs to be scaled up and support needs to be provided to accompanying the rural transformation to take the quantum leap in the improvement of water productivity that is required to ensure sustainable use and water security for all.

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