Food and Agriculture Organization of the United Nations

FutureWater

BRIEF 1

Real water savings in agriculture

Next Generation Water Management Policy Briefs

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BRIEF
1

Real water savings in agriculture

Next Generation Water Management Policy Briefs

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Next Generation Water Management
BRIEF 1

1. Introduction

Water scarcity is not a recent phenomenon. It has existed for centuries in regions characterized by low precipitation and dry climate conditions. However, in many parts of the world, including in regions where water was once plentiful, such as Southeast Asia, the gap between water supply and demand is widening rapidly, largely due to population growth, economic growth, and associated demands for more water-intensive agricultural products (such as meat). Climate change will play a role in driving water scarcity over the coming decades by exacerbating existing trends (Dinar *et al.*, 2019). Irrigated agriculture consumes the largest share of water for human use by far, signifying that it is within the irrigation sector that solutions to address and manage water scarcity must be found.

Unfortunately, overcoming the water crisis through agricultural interventions is not simple, and increasing attention is now being paid to common misconceptions and overly simplistic (and often erroneous) views in agricultural water management. In particular, the role that "increasing water-use efficiency" can play in tackling the water crisis is dominated by misunderstandings related to hydrology, economics and human behaviour.

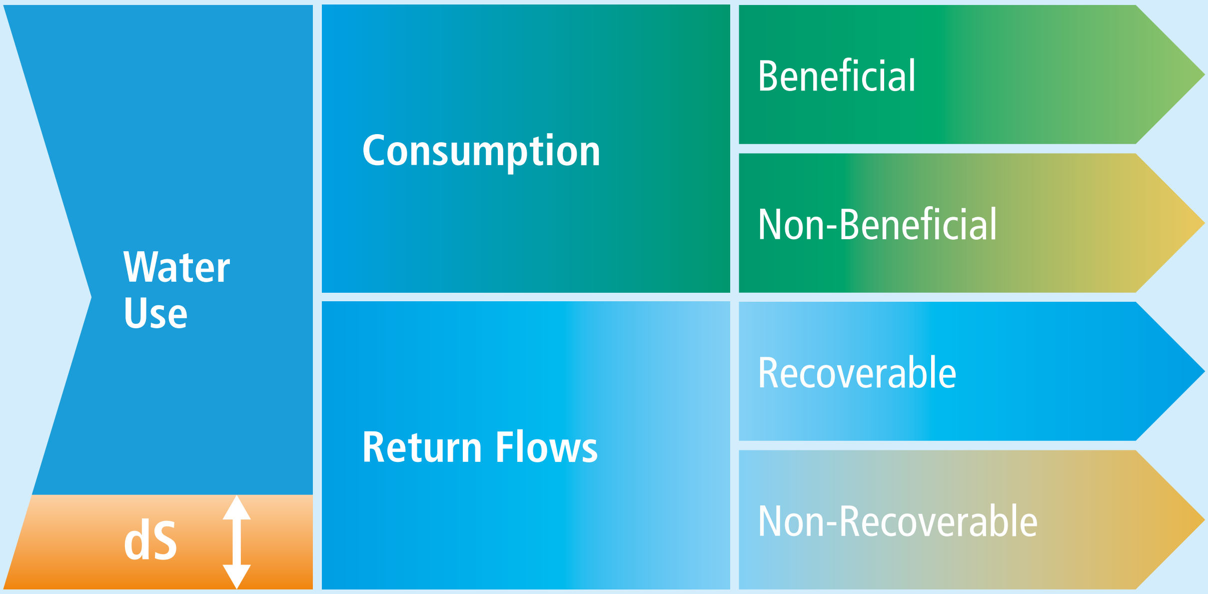
This policy brief is based on extensive work carried out by FAO and FutureWater under the Asia Pacific Water Scarcity Programme (WSP). It clearly explains the complexities associated with efforts to increase water-use efficiency and the importance of utilizing water accounting and a consistent use of terminology in developing water management interventions. A new tool is introduced that provides clear and practical guidelines on how to implement "real" water savings in agriculture by selecting suitable interventions that enhance crop water productivity.

Key definitions and terms

Follow the Water encourages water managers to consider that drainage, runoff and percolation to the groundwater are often not "losses", as this ignores the fact that this water is used by downstream users. So, claiming that a reduction in drainage, runoff and percolation at a field saves water is incorrect, as downstream reuse should be considered. Follow the Water utilizes the water-accounting terms below to communicate the categories of water flows in a system:

- **Water use** is the amount of water employed for a specific purpose (e.g. irrigation, energy, industrial process, domestic washing). Water can be consumed or returned to the system where it has been employed or stored.
- The consumption of water can be either **beneficial consumption** (e.g. crop transpiration) or **non-beneficial consumption** (e.g. soil evaporation).
- Water that is returned to the system (return flows) is either **recoverable return flow** (e.g. returned to a river or aquifer) or **non-recoverable return flow** (flowing to the sea, polluted, or returned to economically unviable sinks).
- **Water saved** is the amount of water resulting from a reduction in consumption and/or in the non-recoverable fraction of the return flows that can be made available for alternative uses.
- **Water saving** refers to the technologies, practices and measures (here called interventions) that result in the reduction in consumption and/or in non-recoverable fraction.
- **Apparent water savings** record reductions in water withdrawals but do not account for changes in water consumption.
- **Real water savings** record reductions in water consumption and non-recoverable return flows.
- **Water scarcity** is an excess of water demand over available supply.

Figure 1: Simplified water accounting system known as "Follow the Water", with dS representing delta (i.e. change) of water stored.



Source: Van Opstal, J., Droogers, P., Kaune, A., Steduto, P. & Perry, C. 2021. *Guidance on realizing real water savings with crop water productivity interventions.* Wageningen. FAO and FutureWater, doi: 10. 4060/cb3844en. Ruane, J., & Food and Agriculture Organization of the United Nations (FAO). 2013. *Coping with water scarcity: An action framework for agriculture and food security.* Rome.

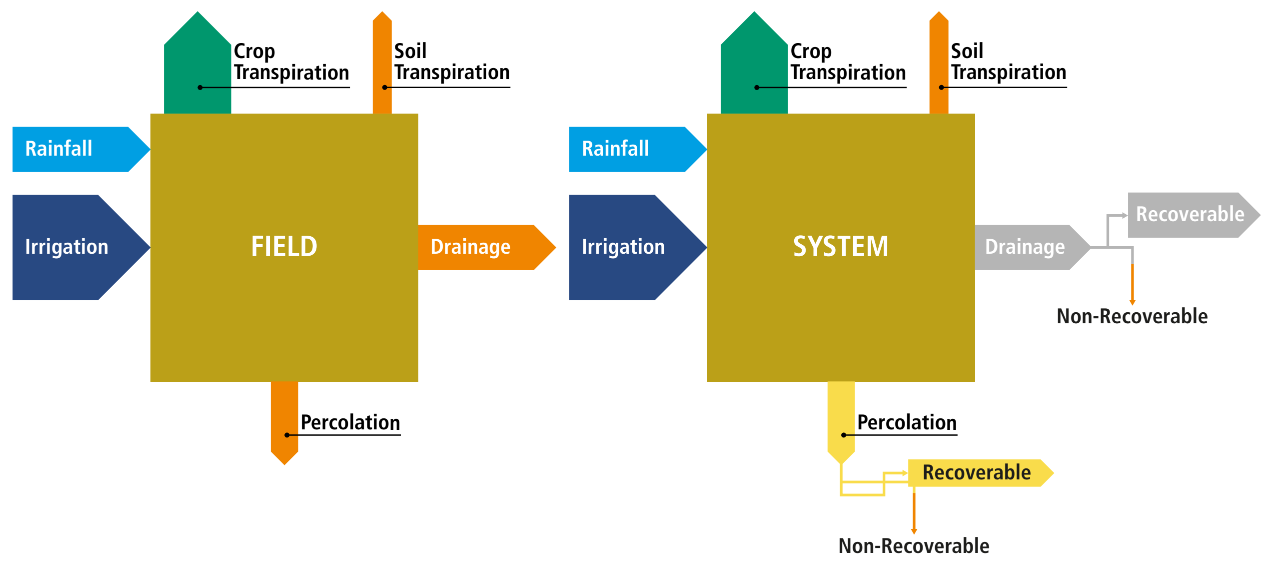
2. Water-use efficiency and water savings

A commonly held misconception is that increasing water-use efficiency always equals water savings. However, by definition, increasing water-use efficiency (put simply: water consumed as a proportion of water diverted at source) *increases* the proportion of water delivered that is consumed. In addition to this basic hydrological fact, farmers who become more efficient (by making new investments) will logically seek to increase their yields and income further – for example, by intensifying increasing cropped area or intensity. This will increase water consumption even further. The idea that increasing water-use efficiency will always lead to water savings is a myth. The reality is best characterised by the Jevons Paradox, a widely known paradox in environmental economics that documents how increased efficiency most commonly leads to *increased* demand and overall consumption. This paradox is present in a wide range of resource efficiency issues, including energy, traffic and water (Polimeni *et al*., 2007).

The issue is even more pervasive with water, because the "lost" water that is "saved" is often being used downstream (Figure 2). In the quest for greater efficiency, it is important to take a broad view at basin level to properly recognize the contribution that return flows (misleadingly called "losses") can make to the productivity of other users, including downstream farmers and the environment (Ruane et al., 2013). The simple fact that agricultural use of water becomes more efficient does not mean that water is "saved".

Real water savings can only be achieved if the amount of water supplied is reduced accordingly and reallocated elsewhere via a water allocation system. A critical point here is that no *comprehensive* and *enforceable* water allocation systems exist in the developing or middle-income countries of Asia. Currently, therefore, there is no constraint on water consumed in newly "efficient" locations. This generally means that efforts to increase water-use efficiency will increase water consumption and reduce return flows, depriving downstream users (including ecosystems) of water that they had accessed in the past.

Figure 2: Diagrammatic representation of water-use components using the "Follow the Water" principle, where drainage and percolation at the field/farm scale are part of recoverable flows that can be used as irrigation input for downstream users.



Source: Van Opstal, J., Droogers, P., Kaune, A., Steduto, P. & Perry, C. 2021. *Guidance on realizing real water savings with crop water productivity interventions*. Wageningen. FAO and FutureWater, doi: 10. 4060/cb3844en.

Note: The scientific interest in the potential perverse impacts of increasing water-use efficiency and the need to identify real water savings have grown rapidly and there is now a robust body of evidence. Additional links have been provided at the end of this policy brief for further reading.

The importance of water accounting

No intervention in the water cycle can be properly assessed without a clear understanding of the hydrological cycle and sound water accounting. The main purpose of water accounting is to help societies understand their water endowment: how much water there is, where it is, how it is used, and whether current patterns of use are sustainable. Water accounting can be a one-off activity designed to achieve a specific purpose; however, it should also increasingly be part of a long-term monitoring and evaluation programme aimed at improving sustainable water resources management. Information collected during water accounting is typically very varied and addresses a range of societal, technical and governance issues.

Source: Ruane, J., & Food and Agriculture Organization of the United Nations (FAO). 2013. *Coping with water scarcity: An action framework for agriculture and food security.* Rome.

3. The REal WAter Savings (REWAS) tool

These issues make it clear that there is an urgent need to develop and use simple and pragmatic tools that can evaluate the **impact of field-scale crop-water interventions at larger scales** – more specifically, tools that can allow the results from the widely used field scale models, such as Cropwat and AquaCrop, to be assessed on their basin-scale water savings. Although many basin-scale hydrological models exist, FAO and FutureWater identified a clear need for a more straightforward analysis tool that converts field-scale results into a first-order basin-scale impact on real water savings.

In this context, the REal WAter Savings (REWAS) tool was developed to overcome misconceptions with respect to water savings and to provide easy templates to help inform water savings interventions. REWAS is developed in Microsoft Excel to enhance usability, reach, transparency, and transferability of data input and output. Input data can be obtained from studies, field trials, measurements, ground observations or remote sensing (Van Opstal *et al.*, 2021; Kaune *et al.*, 2020; Droogers *et al.*, 2020). REWAS output is based on proven concepts of water accounting, and the appropriate water terminology, as promoted by FAO globally (Ruane *et al.*, 2013).

The tool calculates outputs for field and basin level to compare apparent water savings and real water savings. An example of the output format is provided in Table 1; note that through intermediate calculations, the field output units of water and crop production are converted from mm to MCM (mega cubic metres) and from kg/ha to Mkg (mega kilograms), respectively. All calculations are explained step by step in the REWAS Training Manual. Multiple scenarios can be entered for comparison of real water savings at the system level.

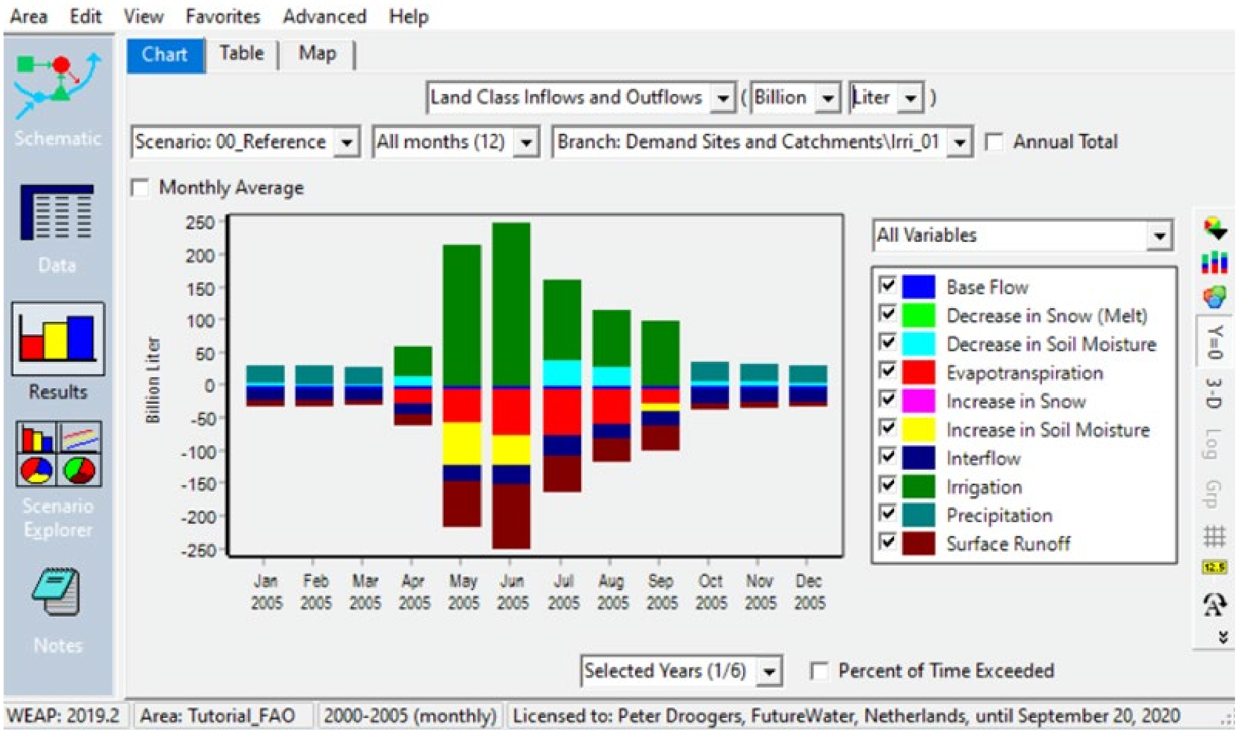
Table 1: Example of REWAS water savings calculation output. Numbers are derived from a case study in Iran. (Islamic Republic of)

RESULTS			
		Scenario	
		Reference	Intervention A
RESULTS FIELD			
Consumption, beneficial BC	(mm)	382	185
Consumption, non-beneficial NBC	(mm)	65	50
Return flows	(mm)	174	26
Storage change CS	(mm)	0.0	0.0
Water Productivity WP	(kg/m³)	1.19	1.36
Apparent Water Savings FWS	(mm)	-	163
Percentage of Apparent Water Savings %FWS	**(%)**	**-**	**26%**
RESULTS SYSTEM			
Consumption, beneficial BC	(MCM)	19.1	9.3
Consumption, non-beneficial NBC	(MCM)	3.3	2.5
Return flows, recoverable RF	(MCM)	6.1	0.9
Return flows, non-recoverable NRF	(MCM)	2.6	0.4
Storage change CS	(MCM)	0.0	0.0
Water Productivity WP	(kg/m³)	1.19	1.36
Real Water Savings RWS	(MCM)	-	3.0
Percentage of Apparent Water Savings %FWS	**(%)**	**-**	**10%**

Source: Droogers, P., Kaune, A., Van Opstal, J., Steduto, P. & Perry, C. 2020. Guidance on Realizing Real Water Savings with Crop Water Productivity Interventions. Wageningen, Netherlands. FutureWater Report 198. FutureWater. https://www.futurewater.nl/wp-content/uploads/2020/05/FAO_Guidance_v07.pdf.

REWAS allows the calculation of real water savings that result from field interventions (e.g. drip irrigation, canal lining, field levelling). Basin-scale hydrological models such as the Water Evaluation and Planning tool (WEAP) enable users to undertake scenario evaluation and planning based on multiple water uses along a river course, using a combination of spatial links between nodes to estimate demand and supply. Bar charts display demand and supply components for each successive month above or below the zero axis; the cumulative amounts for each should match to avoid shortages or water scarcity. The model allows for realistic irrigation demands based on weather conditions, crop status and soil characteristics; an example of a model output for a node of interest is provided in Figure 3.

Figure 3: WEAP land class inflows and outflows by month.



Source: Droogers, P., Kaune, A., Van Opstal, J., Steduto, P. & Perry, C. 2020. Guidance on Realizing Real Water Savings with Crop Water Productivity Interventions. Wageningen, Netherlands. FutureWater Report 198. FutureWater. https://www.futurewater.nl/wp-content/uploads/2020/05/FAO_Guidance_v07.pdf.

Finally, practical guidelines on achieving those real water savings have been provided in the REWAS Guidance Document. The Guidance Document groups water savings interventions into three categories: water management; soil and land management; and agronomy (Table 2). A key finding is that **real water savings are most often found in agronomy interventions (as opposed to water or land interventions)**. A full inventory of the interventions, and their impact on water management and productivity, can be found in the REWAS Guidance Document.

Table 2: Water savings categories.

THEME	CATEGORY	INTERVENTION
Water	On-field irrigation methods	Border/furrow irrigation
		Sprinkler irrigation
		Drip irrigation
		Sub-surface irrigation
	On-field irrigation management	Supplemental irrigation
		Regulated deficit irrigation
		Surge irrigation
		Alternate wetting and drying
	Irrigation infrastructure	Canal lining
		Pipes
	Moisture recycling	Greenhouse
		Hydroponics

Table 2: Water Savings Categories (continued).

THEME	CATEGORY	INTERVENTION
Soil and Land	Tillage Soil and Land	Zero tillage
		Tillage
	Land grading	Field levelling
		Terracing
		Block-end or soil bunds
Agronomy	Supplements	Fertilizers
		Growth enhancers
	Crop selection	Crop rotation
		Cultivars: high yields
		Cultivars: short duration
		Cultivars: rooting depth
		Timing of planting/sowing
		Planting density
	Coverage	Mulching
		Shading
		Weed control
		Cover crops
	Disease control	Pesticides
		Biological
	Salinity management	Leaching
		Salt-tolerant crop types

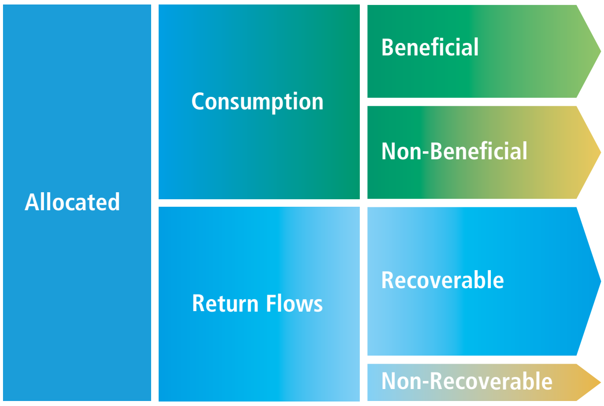
Sources: Droogers, P., Kaune, A., Van Opstal, J., Steduto, P. & Perry, C. 2020. Guidance on Realizing Real Water Savings with Crop Water Productivity Interventions. Wageningen, Netherlands. FutureWater Report 198. FutureWater. https://www.futurewater.nl/wp-content/uploads/2020/05/FAO_Guidance_v07.pdf. Kaune, A., Droogers, P., Van Opstal, J., Steduto, P. & Perry, C. 2020. REWAS REal WAter Savings tool: Technical Document. Wageningen, Netherlands. FutureWater Report 200. FutureWater. https://www.futurewater.nl/wp-content/uploads/2020/06/FAO_REWAS_v08.pdf. Van Opstal, J., Droogers, P., Kaune, A., Steduto, P. & Perry, C. 2021. Guidance on realizing real water savings with crop water productivity interventions. Wageningen. FAO and FutureWater, doi: 10. 4060/cb3844en.

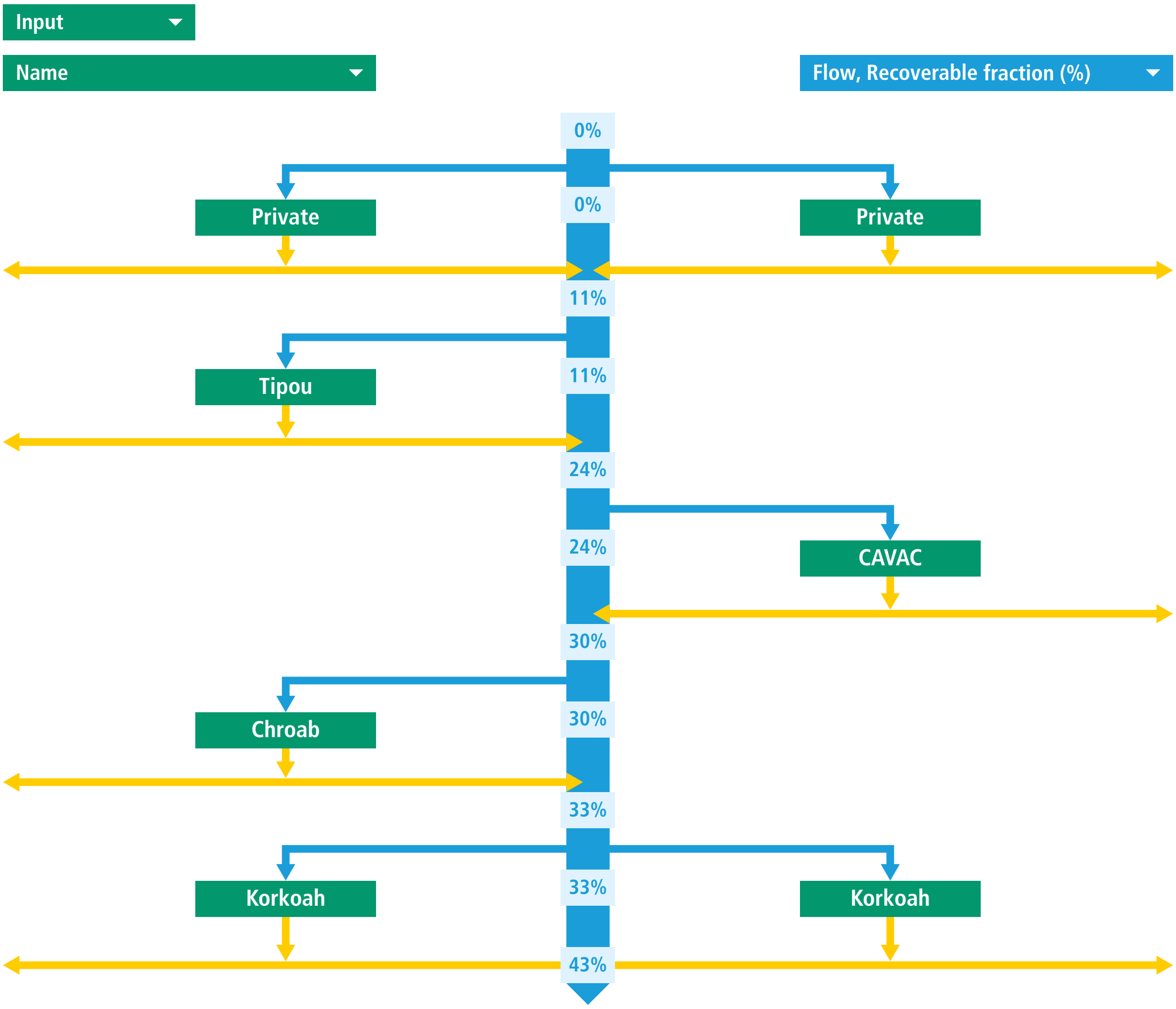
In sum, each of the interventions have benefits and limitations and need to be considered in a context-specific strategy, depending on available resources, capacity, government support and farmer contexts. Most importantly, these interventions are designed to achieve water savings at the field or farm level, and **many of these will significantly reduce recoverable return flows further downstream.** Therefore, the only way that these interventions will actually save water at basin scale (and make it available for other uses) is if there is a cap on overall water use and the amount of water supplied is reduced in parallel with efficiency improvements so that only the same net consumption occurs. It is important to note that this is usually unacceptable to farmers, especially if they have invested significantly in water-saving infrastructure, and it is therefore politically difficult. The net effect is that water savings interventions result in increasing water use, and real water savings at a larger spatial scale are much lower, or even negative, than at the field or farm scale.

The main objective of the REWAS Tool is to evaluate the impact of **field-scale crop-water interventions on larger scales.** The **interaction between irrigation schemes** (blocks), with a focus on Return Flows, can be analysed by the recently developed Follow the Water Tool (FtW). The same principles and terminology as used for the REWAS tool have been followed. Again, a user-friendly interface has been developed making FtW extremely suitable for training and awareness rising. FtW makes use of so-called virtual tracers to tracing Recoverable Flows between irrigation blocks.

Figure 4: Screenshot of the Follow the Water tool to explore interactions between irrigation schemes with a focus on Return Flows under various irrigation types.

INTERVENTION	MCM	m^3/s	%
Inflow	290.3	14.000	
Demand	248.7	11.994	
Delivered	248.7	11.994	
Shortage	0.0	0.000	0%
Consumed Beneficial		2.998	25%
Consumed Non-Beneficial		2.998	25%
Return Flow Recoverable		4.797	40%
Return Flow Non-Recoverable		1.199	10%





Source: FAO & FutureWater. 2019. Real Water Saving (Rewas_v. 8). Bangkok. FAO

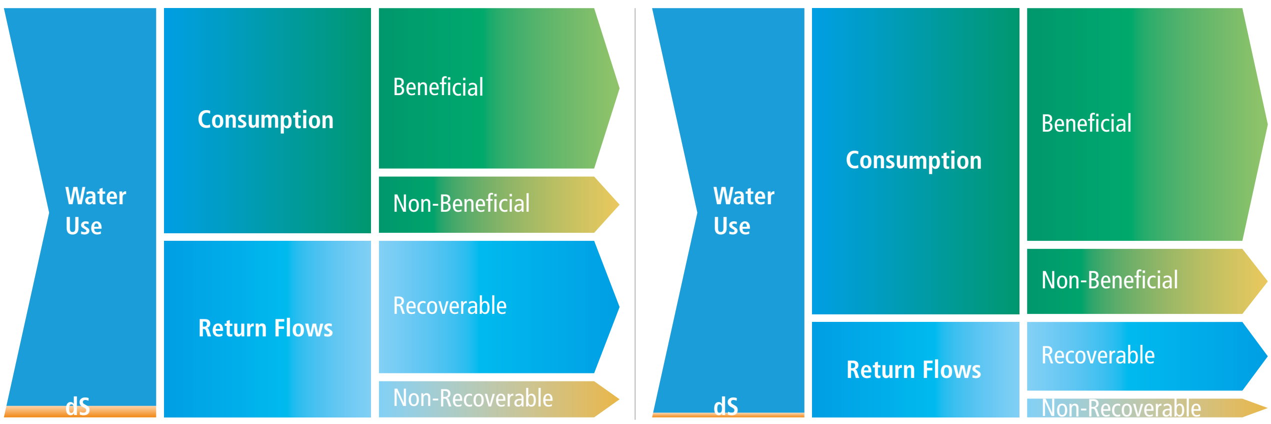
4. Applying REWAS in practice: A case study

Iran is a typical example of a water-scarce country with large agricultural output. Even though water savings measures have been promoted and implemented for decades, water scarcity has continued to worsen and is now more pronounced than ever before. In a quest to better understand why significant "water savings" investments have not reduced water stress, the country is in the process of embracing the REWAS approach.

The Shiraz region is an important wheat-producing area in the country that faces enormous water stress. As the region receives on average just 360 mm of rainfall per year, all crops are irrigated. It is "common knowledge" that irrigation efficiencies vary from 40 percent for surface irrigation systems to 80 percent for drip systems (Raeisi *et al.*, 2019). In an attempt to "save water" and make more water available for downstream wetlands, policy-makers have been promoting drip irrigation under the expectation that drip irrigation saves more water than traditional irrigation systems. However, in practice, transition from surface to drip irrigation did not result in the expected water savings or benefits to other users. The REWAS tool was used to analyse the real impact of this conversion from surface irrigation to drip. Figure 4 shows that under surface irrigation a substantial amount of "lost" water was in fact recoverable return flow that was either being used by downstream users or contributing to the water needs of the wetlands.

Changing to drip irrigation reduced the return flows and, strikingly, consumption *increased* from 598 mm to 655 mm. Obviously, this increased water consumption by the crop results in higher yields for farmers who adopted drip technology, but no water was saved. The REWAS analysis demonstrates that the reduction in irrigation application of 255 mm did not result in water savings at basin scale, and the impact on the wetlands was to further reduce water flow. As a consequence of the REWAS analysis, other interventions need to be considered by Iran, including agronomic interventions and even a reduction in cropping area.

Figure 5: "Follow the Water" graphs for surface irrigation (left) and drip irrigation (right) fields in the Shiraz region. Introducing drip irrigation increases consumption. It also reduces return flows substantially, but those were to a large extent recoverable.



Source: FAO & FutureWater. 2019. Real Water Saving (Rewas_v. 8). Bangkok. FAO

5. Conclusions

Increased demand for food and increased uncertainty of precipitation underlie the importance of accurate water accounting at multiple spatial scales to understand where savings can be made and how systems can be optimized under different scenarios. The REWAS tool has been developed by FAO and FutureWater to calculate real water savings at the basin scale, taking into account return flows that are used elsewhere. The tool is designed to assist decision-makers who intend to increase water efficiency to obtain a more accurate estimate of real water savings that can be achieved. The REWAS Guidance Document can be used to determine interventions that might lead to real water savings. The REWAS tool itself helps to explain that water-saving is an intervention that results in incremental water being made available for an alternative beneficial use. The use of these tools will assist decision-makers in investing in water-planning based on robust water accounting practices.

REWAS training has been provided in eight countries reaching over 150 participants from governments, NGOs, research institutions and related organizations. The REWAS tool and manual can be obtained free of charge from https://www.futurewater.eu/projects/training-package-for-water-productivity-and-real-water-savings/.

The complementary Follow the Water was made available in December 2022.

To learn more about the REWAS tool and approach, an eLearning is available on the *FAO elearning Academy*.

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Next Generation Water Management Policy Briefs Collection

This Briefing Collection has been developed to inform policymakers of new and improved approaches to different aspects of water resources management for agriculture and food security across Asia and the Pacific. Each brief promotes cutting-edge approaches in water management that are being developed and implemented by FAO and its key technical partners. Content for this Briefing Collection draws from two major programmes led by FAO's Regional Office for Asia and the Pacific:

Asia Pacific Water Scarcity Programme (WSP): The WSP aims to bring agricultural water use to within sustainable limits and prepare the agriculture sector for a productive future with less water. The WSP is assessing the scope of water scarcity in the region, evaluating effective management response options (primarily water accounting and allocation), supporting improvements in governance, and assisting partner countries to implement adaptive water management in the agriculture sector using appropriate and newly developed tools and methodologies. The WSP is also establishing a regional cooperative platform to enable countries to share solutions and experiences, in addition to ensuring national engagement at the highest political level.

Next Generation Irrigation and Water Management Programme (NextGen): NextGen draws on global best practices to accelerate the modernization of irrigation systems and water management practices in Asia and the Pacific. NextGen aims to ensure a bioeconomy that balances economic value and social welfare with environmental sustainability. The programme addresses cross-cutting issues in irrigation and water management, such as irrigation performance, food security, eco-system health, gender equality, fisheries, and aquatic biodiversity. In this way, NextGen promotes the implementation of integrated and evidence-based policies and practices in micro and macro environments, using technological, organizational and social innovations. NextGen is undertaken in collaboration with the Australian Water Partnership, supported by the Australian Department of Foreign Affairs and Trade (DFAT).

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