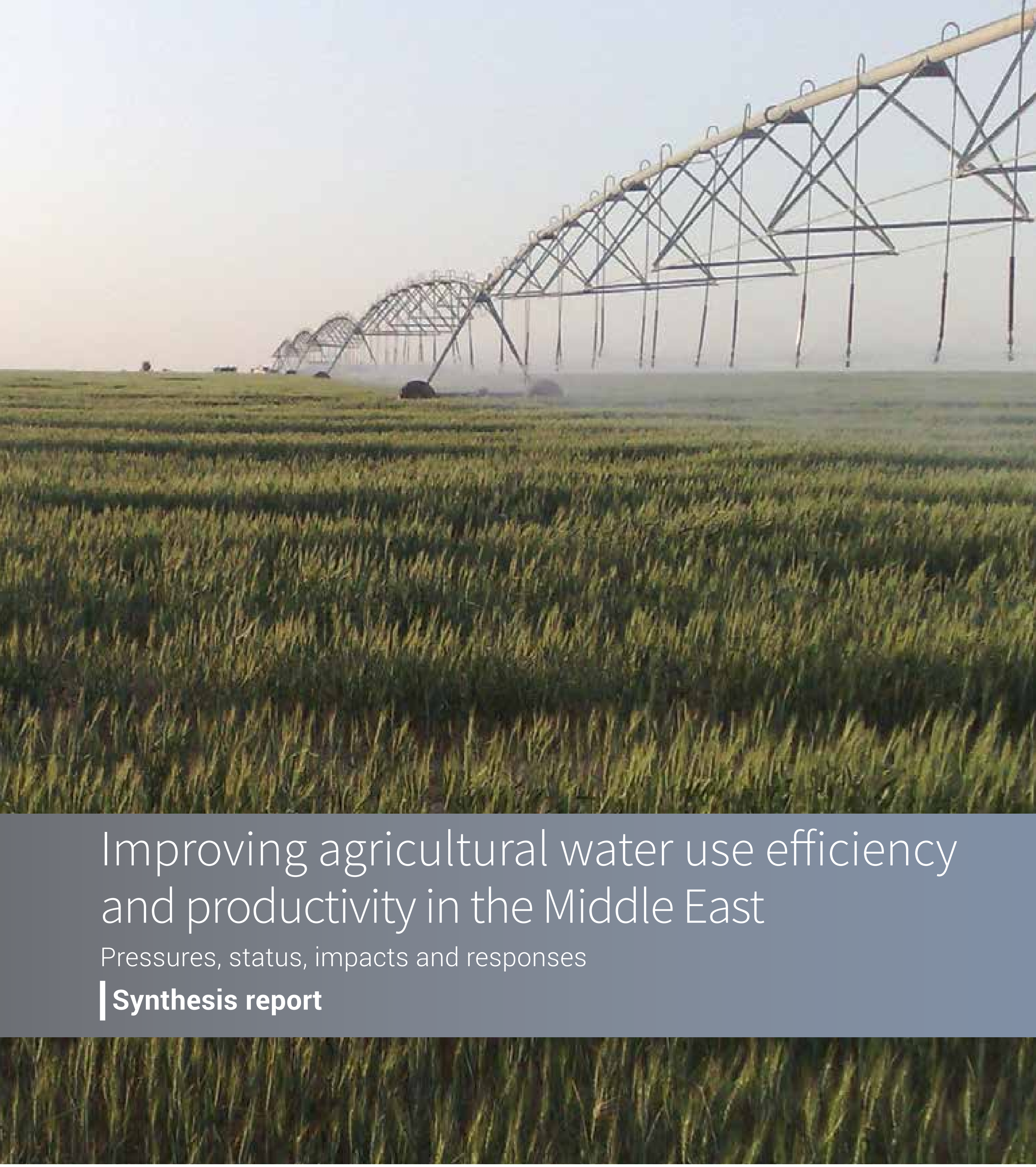

# Improving agricultural water use efficiency and productivity in the Middle East

## Pressures, status, impacts and responses

**Synthesis report**

Blue Peace
IN THE MIDDLE EAST

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## Pressures, status, impacts and responses

This report is a synthesis of the report, “Improving agricultural water use efficiency and productivity in the Middle East: Pressures, status, impacts and responses (ISBN: 978-625-8451-33-7)”, prepared as part of the project, "Disseminating Knowledge to Improve Agricultural Water Use Efficiency in the Middle East", under the umbrella of Blue Peace Middle East (BPME).

BPME is a regional initiative co-supported by the Swiss Agency for Development and Cooperation (SDC) and Turkish Water Institute (SUEN). SUEN functions as the Coordination Office of BPME since January 1st, 2019.



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## ABOUT BLUE PEACE IN THE MIDDLE EAST

The Blue Peace in the Middle East initiative is a structured and dynamic network of prominent institutions from partner countries in the region with the long-term vision of transforming water from a potential source of conflict into a potential instrument of cooperation and peace through concrete actions.

In partnership with Swiss Agency for Development and Cooperation (SDC), SUEN functions as the Coordination Office of the initiative as from January 1st, 2019.

Website: **www.bluepeacemiddleeast.org**

## ABOUT TURKISH WATER INSTITUTE (SUEN)

SUEN is a think tank established to develop water policies, provide consultation to decision makers, coordinate between organizations and institutions and enhance scientific research and strategic ideas with a focus on creating a common platform for water governance.

SUEN works in close cooperation with national and international water-related institutions on issues such as sustainable water management, development of water policies and capacity building to address local and global water issues.

Website: **www.suen.gov.tr**

# EXECUTIVE SUMMARY

This report is prepared under the umbrella of the “Blue Peace Middle East (BPME)" initiative. It focuses on water scarcity, the challenges this brings to irrigated agriculture, and the options available to improve water use efficiency (WUE) and, in turn, increase water productivity and crop production. The countries evaluated in this report include Iran, Iraq, Jordan, Lebanon, Syria and Turkey. Although Iran and Syria are not currently active members of BPME, given their location and relevance to this review, they are included in this study.

Irrigated agriculture plays a vital role in the economies, livelihoods and well-being of people living in the studied countries, but the sector is under severe pressure. More than 75% of available freshwater resources are already withdrawn for agriculture, mostly irrigation, exceeding 90% in some countries. Growing rural and urban populations, economic growth, improvements in lifestyle, and changing diets are driving water demand and have led the Food and Agriculture Organisation (FAO) to predict that if the world continues “business as usual”, the water demand for irrigation could double by 2050. Concerns also come from migration and rural employment, the impacts of climate change on water resources and agriculture, the damage that economic growth can inflict on the aquatic environment, and the challenges of coping with unexpected shocks, such as floods, droughts, and latterly COVID-19.

## Water scarcity radically changes everything about how we plan and manage water for irrigation

As water scarcity increases, irrigated agriculture has acquired a reputation for inefficiency. Reports suggest that as much as 50% of water withdrawals never reach the crops and are lost through seepage in canal systems and poor on-farm water management, creating further problems such as water-logging, salinity, and pollution. Thus, agriculture is seen as the main culprit of water scarcity and conversely the sector where efficiency improvements could release water for others to use. However, this is easily said but not easily achieved in practice. Water scarcity radically changes everything about how we plan and manage water for irrigation.

This report describes the significant challenges facing irrigation and the options available to improve performance. It follows a DPSIR approach (Driver-Pressure-State-Impact-Response) that briefly sets out the current state of water resources and agriculture in the region, the trends, drivers and pressures that impact and threaten them and the risks this creates. From this, appropriate responses/actions are recommended.

Getting water for irrigation right will be essential for sustainable and resilient food production. But the challenges are multi-faceted, and there is no simple “one size fits all” solution to the growing water scarcity problem. For this reason, this report offers a range of options available and possible solution pathways to enhance WUE, water productivity, and crop production in irrigated agriculture. Planners and policymakers are encouraged to select and bundle options into programmes and projects best suited to their local and national circumstances, priorities, and capabilities. These will most likely be a mix of technical and institutional options.

Although there are many differences, there are also similarities among the countries studied. Such synergies offer opportunities for collaboration on research, training, and sharing information for the benefit of all.

## State of water and agriculture

The state of water and agriculture across the countries studied establishes the serious concerns over water scarcity and its impacts on irrigated agriculture. Countries have much in common, such as increasing populations, reducing water availability per capita, a heavy dependency on freshwater to grow food, feed, and fibre and meet food security targets while recognising the need to sustain the natural aquatic environment on which the sustainability of natural resources depend. All report low levels of water productivity and WUE. However, the differences are striking as countries have adopted strategies that fit their unique natural resource endowments and socio-economic circumstances. Surface irrigation methods, for example, still dominate in countries with large irrigated areas such as Iran, Iraq, Syria, and Turkey. In contrast, hi-tech systems, such as sprinkler and drip irrigation, are more common in Jordan and Lebanon, where irrigated areas are much smaller and water is relatively scarce. It is no coincidence that Jordan and Lebanon quote the highest levels of on-farm WUE efficiency, which encourages others to switch to hi-tech methods. However, caution is needed. If the intention is to save water for others to use, investing in hi-tech systems alone may benefit some farmers but may not produce the desired water savings for others.

## Pressures and threats

Globally, the most prominent pressures and threats to irrigated farming come from water scarcity, deteriorating water quality, and salinity which degrades the quality of land and soils. Climate change is now ever-present and is responsible for changing temperatures and rainfall patterns and raising the severity and frequency of droughts.

A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis involving 156 national irrigation experts and a study of the published and grey literature confirmed that these global issues directly affect irrigation in the Middle East. The top threats identified included increasing salinity, growing populations, water scarcity impacts on food security and rural employment, and the mismatch between administrative and river basin boundaries in the implementation of basin-scale management of water resources. Jordan flagged treated wastewater as a critical alternative water source.

## Response options and actions

"Business as usual" will not be an option as global freshwater withdrawals for irrigation, already more than 70%, are predicted to double by 2050, creating unacceptable environmental disasters in many stressed river basins, increasing competition for resources, and causing new social challenges and conflicts over land and water. As the primary water user, it is incumbent on irrigated agriculture to use water resources wisely and reduce these problems.

Although this report initially reviews WUE as the primary metric to assess the state of irrigated agriculture, it also challenges the usefulness of this approach under water scarcity conditions. WUE values of 35% to 50%, reported across the region, suggest that only a small portion of withdrawals are usefully used by crops. This may be valid for individual farms, but so-called "losses" do not just disappear. Instead they return to the river basin and are often used by other farmers downstream.

Thus, WUE of individual farms may be only 50%, but the overall water used by crops in a river basin will be much higher. “Real” water savings are still possible as some losses are recoverable, but the savings are likely to be much less than originally anticipated. Switching to hi-tech solutions alone may not always produce water savings at scale.

To address water scarcity, this report focuses less on WUE as a metric to measure performance and more on practical and appropriate metrics that account for real water savings, improvements in water productivity (more crop per drop) and production, how water contributes to food security and people’s livelihoods and sustains the aquatic environment. New tools such as Water Accounting and Auditing (WA&A) combined with Remote Sensing (RS) are described that enable water resource planners to account for irrigation water use including return flows and real water savings. Systems are being developed to measure crop water use over large areas and enable irrigation managers to allocate and control water for irrigation.

Five main areas for action are recommended that can facilitate a transition towards efficient, reliable, and sustainable water irrigation management.

**Action area I:** concerns **good water governance** which is underpinned by strong formal and informal institutions and a workforce that is well informed on modern irrigation practices. Without this, technological and management innovations are unlikely to succeed. It requires a robust institutional framework to establish and implement good water policies, laws and regulations, and a strong administration to implement them.

Inclusive governance is also essential in recognising the symbiotic nature of water, land and soils and the need for coherent and integrated policies that enable the many land and water management objectives to be fulfilled. This requires multi-stakeholder engagement at all levels and across disciplines that will be critical to achieving integrated water resource management, a central plank in achieving the Sustainable Development Goal (SDG) 6 – the water goal. Introducing Water Stewardship in Agriculture (WSiA) is an integral part of good governance.

**Action area II:** is about **embracing innovative technologies** and management to address water scarcity and drought. There are myriad options available. These include modernising large-scale irrigation schemes, automating canal systems, transitioning towards participatory irrigation management and transferring responsibilities to Water User Associations (WUAs). New planning, design and evaluation technologies, such as water accounting and auditing, Information and Communication Technology (ICT) and automation, are helping to modernise existing schemes and inform new designs. Many activities beyond the farm also contribute to making wise use of limited water resources, including plant breeding to boost yields and tolerance to drought and salinity, adopting the principles of the circular economy, and reducing food losses and waste to improve resource use efficiency.

**Action area III:** concerns **implementing integrated solutions** at scale. Integrated approaches to resource use can help define critical resource thresholds and lead to beneficial outcomes when they are brought together in workable packages, including technical, institutional, governance, and financial support.

**Action area IV:** refers to **investing in long-term sustainability** in the irrigation sector. Irrigation can be costly, but the investment will need to be weighed against the cost of inaction and the impacts on water security, land and soil degradation and food insecurity. Internationally, investment is shifting from infrastructure solutions towards sustaining productivity and improving governance, integrating systems at scale, innovations in technology and management and strengthening the capacities of organisations, including water-user and producer organisations. The private sector should also be encouraged to engage in public-private investment, including farmers as investors rather than as recipients of aid.

**Action area V:** addresses the overwhelming need to enhance **cooperation across the region**. The Blue Peace Middle East initiative offers an excellent example of a regional platform that enables people from different nations to undertake joint research and training addressing water scarcity and reap the benefits of collaboration that shares problems and solutions. More is needed.

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## List of Boxes

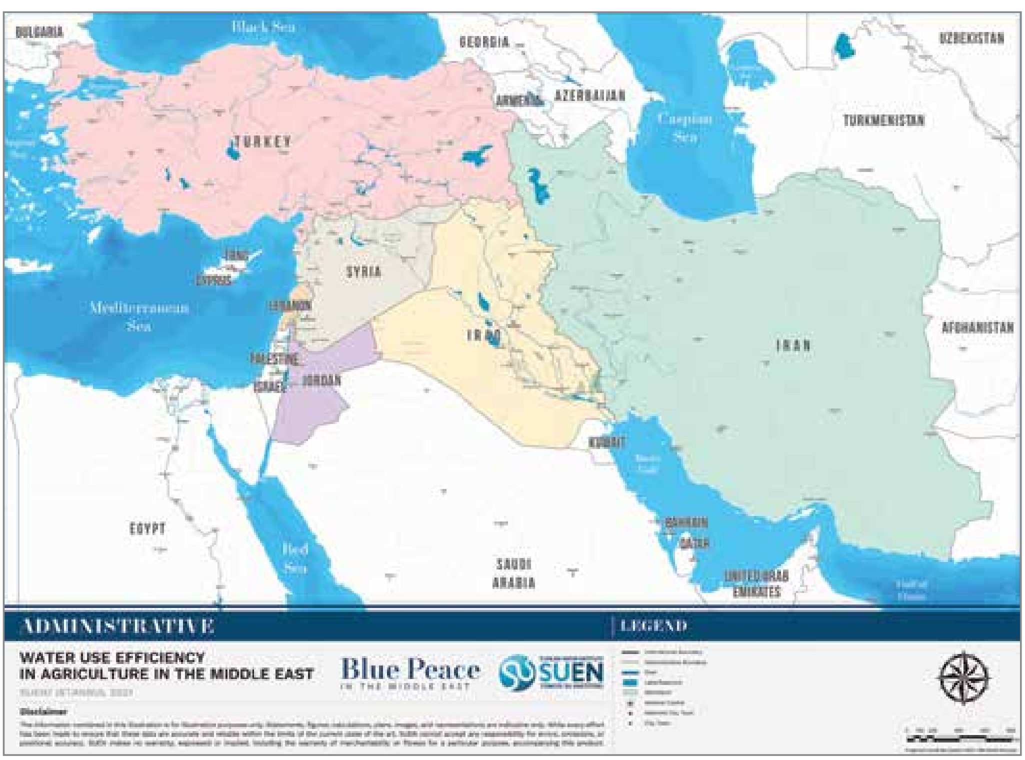
# 1 Setting the scene

This synthesis of the main report: *Improving agricultural water use efficiency and productivity in the Middle East* is prepared as part of the project, "Disseminating Knowledge to Improve Agricultural Water Use Efficiency in the Middle East", implemented under Blue Peace Middle East (BPME).

It focuses on water scarcity, the challenges this brings to irrigated agriculture, and the options available to improve water use efficiency (WUE) and, in turn, increase water productivity and crop production. The countries evaluated in this report include Iran, Iraq, Jordan, Lebanon, Syria and Turkey (Figure S1). Although Iran and Syria are not currently active members of BPME, given their location and relevance to this review, they are included in this study.

Irrigated agriculture plays a vital role in the economies, livelihoods and well-being of people living in the studied countries, but the sector is under severe pressure. More than 75% of available freshwater resources are already withdrawn for agriculture, primarily irrigation, exceeding 90% in some countries. Growing rural and urban populations, economic growth, improvements in lifestyle, and changing diets drive water demand.

**Figure S1** Countries evaluated in this study



# Water scarcity radically changes everything about planning and managing water for irrigation

They have led the Food and Agriculture Organisation (FAO) to predict that if the world continues "business as usual", the water demand for irrigation could double by 2050. Concerns also come from migration and rural employment, the impacts of climate change on water resources and agriculture, the damage that economic growth can inflict on the aquatic environment, and the challenges of coping with unexpected shocks, such as floods, droughts, and latterly COVID-19.

As water scarcity increases, irrigated agriculture has acquired a reputation for inefficiency. Reports suggest that as much as 50% of freshwater withdrawals never reach the crops and are lost through seepage in canal systems and poor on-farm water management, creating further problems such as water-logging, salinity, and pollution. Thus, on the one hand, agriculture is seen as the main culprit of water scarcity, and on the other, it is the sector where efficiency improvements could release water for others to use. However, this is easily said but is not easily achieved in practice like most complex problems.

## What this report says

Getting water for irrigation right will be essential for sustainable and resilient food production. But water scarcity radically changes everything about planning and managing water for irrigation. The challenges are multi-faceted, and there is no simple "one size fits all" solution to the growing water scarcity problem.

For this reason, this report offers a range of available options and possible solution pathways to enhance WUE, water productivity, and crop production in irrigated agriculture. Planners and policymakers are encouraged to select and bundle options into programmes and projects best suited to their local and national circumstances, priorities, and capabilities. These will most likely be a mix of technical and institutional options.

Although there are many differences, there are also similarities among the countries studied. Such synergies offer opportunities for collaboration on research, training, and sharing information for the benefit of all.

This synthesis first describes the current state and trends in water resources and irrigated agriculture in the region, the drivers and pressures that impact and threaten them, and the risks this creates. From this, appropriate responses and actions are recommended.

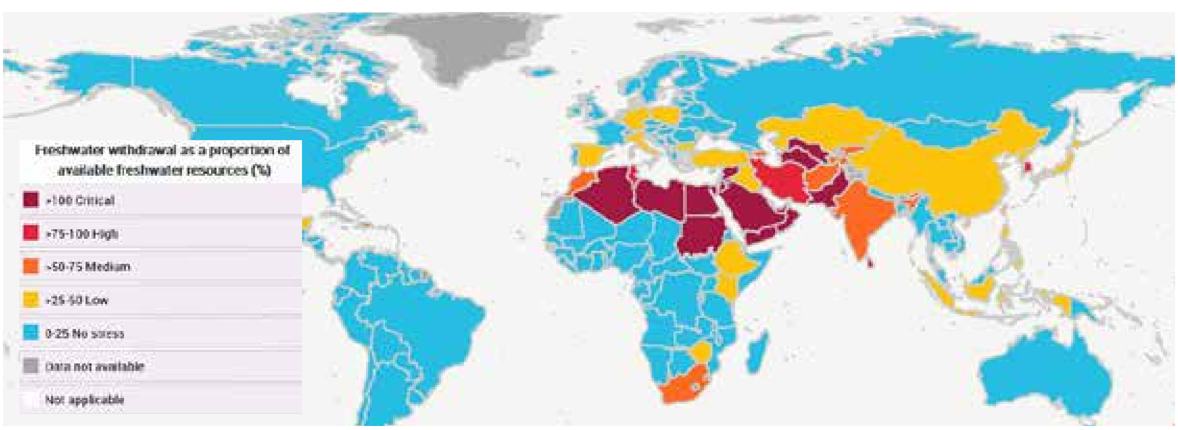
# 2 State of water and agriculture in the Middle East

**The state of water and agriculture across the countries studied establishes the serious concerns over water scarcity and its impacts on irrigated agriculture. Figure S2 highlights current levels of water stress measured at the national level by the Sustainable Development Goal (SDG) target 6.4.2.[1]**

The countries in this study have much in common: arid and semi-arid environments, increasing populations, reducing water availability per capita, a heavy dependency on freshwater to grow food, feed, and fibre and meet food security targets while recognising the need to sustain the natural aquatic environment on which the sustainability of natural resources depend. All report low levels of WUE and water productivity.

However, there are also striking differences as countries have adopted strategies that fit their unique natural resource endowments and socio-economic circumstances. There are vast differences in the scale of irrigation among countries that influence the importance of irrigation to national Gross Domestic Product (GDP) and food security.

**Figure S2** Water stress by country




| Country | Iran | Iraq | Jordan | Lebanon | Syria | Turkey |
|---|---|---|---|---|---|---|
| Water stress (%) | 81.29 | 47.13 | 100.08 | 58.79 | 124.36 | 45.38 |

Source: FAO; UN Water, 2021

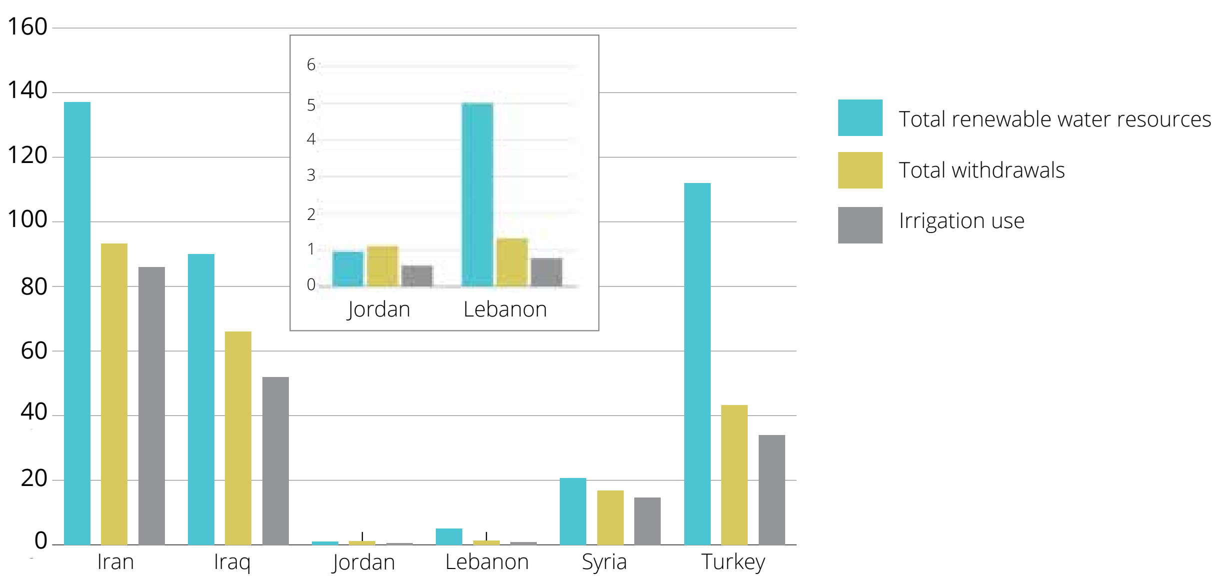
[1] SDG target 6.4.2 measures water stress at a national level as a ratio of freshwater withdrawals including environmental flows, to the available freshwater resources

Annual average rainfall differs significantly across the region from 111 mm in Jordan to just over 200 mm in Iran, Iraq and Syria, 660 mm in Lebanon and 580 mm in Turkey. However, average values mask the wetter areas where rainfed cropping is possible and the much drier arid areas where irrigation is essential for cropping[2].

All countries withdraw significant freshwater for agriculture, primarily because of irrigated agriculture and the high evaporative crop demand. Jordan uses 53% of total water withdrawals for irrigated agriculture, Lebanon 61%, and Iran, Iraq, Syria, and Turkey withdraw between 74% and 91% (Figure S3). Annual renewable water resources per capita vary considerably; the highest is in Iraq and Iran and lowest in Jordan at 97 $m^3$/capita, which is seriously below the recognised threshold of 1 000 $m^3$/capita. These values are likely to decrease as populations increase (Figure S4).

Surface water is the primary water resource used for irrigation in Iraq (90%) and Turkey (73%), whereas groundwater is more dominant in Iran (56%), Jordan (60%), Lebanon (50%) and Syria (53%). Wastewater provides a modest amount of water in Jordan (11%) and Lebanon (12%), but this is likely to increase in future.

**Figure S3** Annual total renewable water resources, total water withdrawals, and irrigation water use ($km^3$/yr)

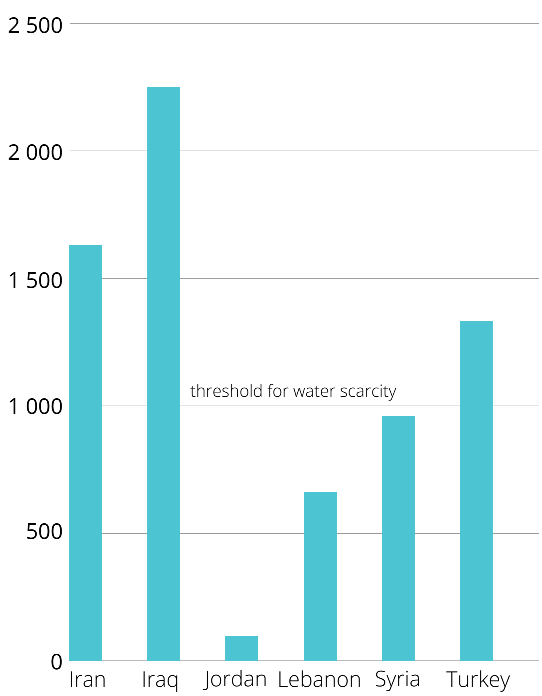



Source: FAO AQUASTAT

[2] Most data are from the internationally recognised FAO AQUASTAT database (FAO AQUASTAT, 2021), but some may be outdated for various reasons. Thus, data published by government and research organisations within countries complement AQUASTAT data. Although this has highlighted some inconsistencies, overall, they provide a helpful picture of water resources, irrigation, and trends.

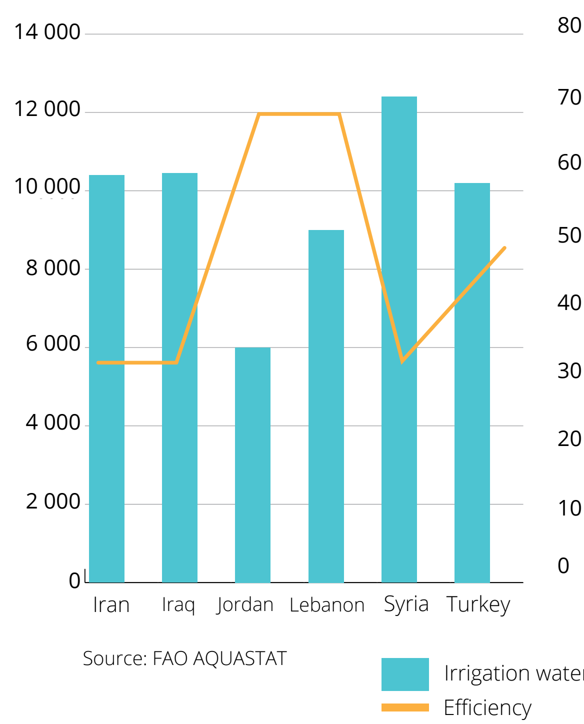
Across the region, WUE and water productivity are low and urgently need improvement to make the best use of available but limited resources. Irrigation water use averages between 6 000 m³/ha (in Jordan) and 12 400 m³/ha (in Syria) (Figure S5). WUE tends to be low in countries with high water use per hectare, 35% in Iran and Iraq and 50% in Turkey. WUE is much higher in Jordan (70%) and Lebanon (70%), where irrigation water use is lower and annual renewable water resources are limited.

**Figure S4** Annual renewable water resources (m³/capita)




Source: FAO AQUASTAT

**Figure S5** Irrigation water use (m³/ha) and average irrigation water use efficiency (%)

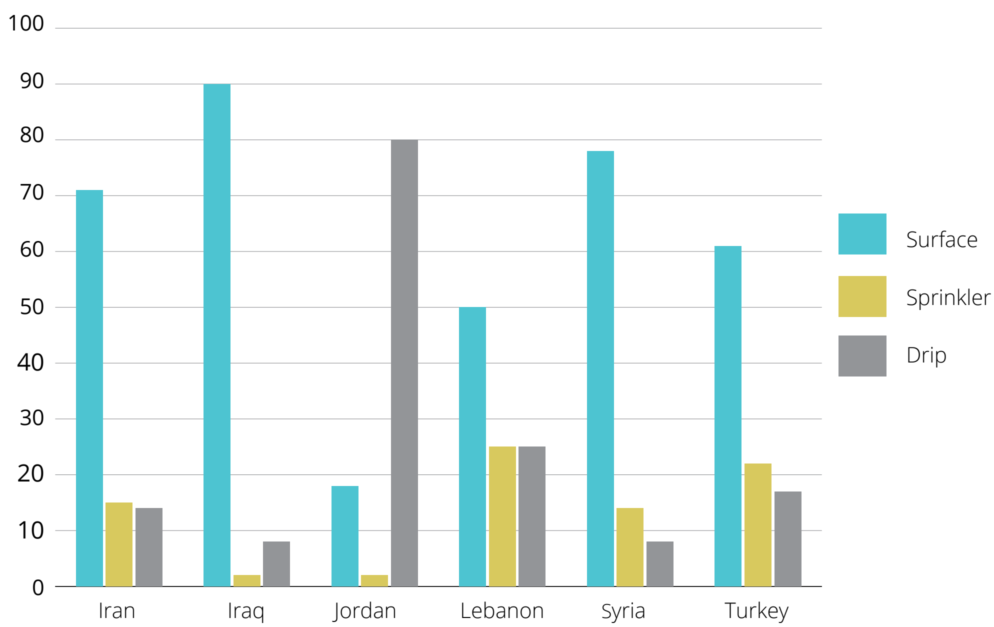



Source: FAO AQUASTAT

It is no coincidence that Jordan and Lebanon have the lowest water use per hectare, the highest WUE levels and the highest percentage of sprinkler and drip irrigation (Figure S6). This may lead some to assume that switching to hi-tech[3] systems is the answer to improving WUE. This makes sense for farmers looking to reduce water losses and increase crop production and income.

However, it does not always make sense for water resources planners looking for "real" water savings within a river basin and allocating saved water to other users. Understanding this paradox is critical to saving water and making judicious investments in hi-tech irrigation systems (see section 4.2).

**Figure S6** Irrigation methods (% of total)




Source: FAO AQUASTAT

[3] Hi-tech refers to any technical intervention designed to improve water delivery to farmers, examples include sprinkler and drip irrigation

# 3 Pressures and risks to irrigated agriculture

**Globally, the most prominent pressures and threats to irrigated farming come from water scarcity, deteriorating water quality, and salinity which degrades the quality of land and soils. Climate change is now ever-present and is responsible for changing temperatures and rainfall patterns and increasing the severity and frequency of droughts.**

A SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis involving 156 national irrigation experts and studies of available published and grey literature confirmed that these global issues directly affect irrigation in the Middle East.

Although there are many differences across the region, several common **strengths** were recognised. But high on the list of **weaknesses** were the need to improve legislation for agricultural water use and concerns about the dominance of surface irrigation in some countries, though not in Jordan and Lebanon, where hi-tech systems are widely used. Turkey has also been investing in hi-tech over the past decade. Concerns also were expressed about the lack of volumetric water measurement. This is a global problem that needs special attention. If you cannot measure water flowing into farms, you cannot possibly manage it properly, which can be a significant source of inefficiency.

**Opportunities** included building resilience in irrigation to support food security and mitigating and adapting to climate change. These issues are well known, but there is little evidence of resilience planning to date in many countries.

## If you cannot measure water flowing into farms, you cannot manage it

High on the list of **threats** was increasing salinity, growing population, their impacts on future water and food security, and the mismatch between basin boundaries and territorial organisations and administrative zones, which can cause confusion among planners, duplicate efforts, and result in multiple allocations of the same water. Jordan flagged the low use of treated wastewater as a critical alternative water source. Over-abstraction from river basins when water is scarce is a constant threat, particularly groundwater, which is already in crisis, and there is little or no control over its exploitation.

## High on the list of threats was increasing salinity

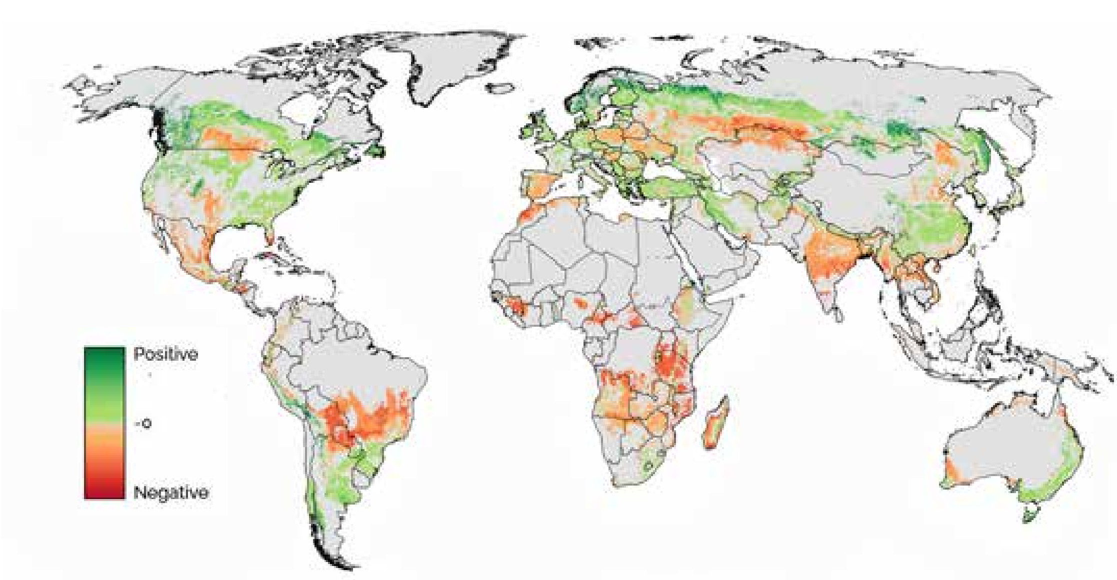
## 3.1 Climate change

Globally, climate change brings additional risks to agricultural production and other ecosystem services, particularly in countries where economic growth is needed most. Rising temperatures and changes in the hydrological cycle amplify the frequency and severity of extreme flood and drought events. Evidence shows that weather systems are causing significant shifts in agricultural production, cropping patterns, and crop yields. Figure S7, for example, illustrated potential shifts in land suitability for rainfed wheat up to the 2080s (FAO, 2021a).

Climate change is expected to alter crop yields and water availability in the Middle East, by how much is not known (Waha ***et al.***, 2017). However, a model study based on a set of plausible changes in crop yields and water scarcity offers an indication (though not a prediction) of what may happen in economic terms (Taheripour ***et al.,*** 2020). For crop yields, the scenario models a 5% reduction in yields for irrigated wheat and corn, 10% reduction for rainfed crops, 5% improvements in yields for oil crops (rainfed and irrigated), no change in yields for vegetables, and a 20% reduction in the water supply. The analysis also assumed "business as usual" with no change in WUE. Based on these assumptions, the possible impact on GDP of increasing water scarcity is illustrated in Figure S8.

All the countries appear to suffer losses under increasing scarcity. However, the most significant losses are expected in Iran and Turkey, countries with substantial agricultural sectors contributing 19.6% and 6.6% respectively to GDP. The 20% water loss scenario also indicates that Syria would experience the most significant fall in GDP. Agriculture is likely to suffer most under climate change, but other sectors of the economy will also be adversely affected (Figure S9). This study suggests that increasing water scarcity may render capital idle in agriculture and other sectors, forcing a shift away from producing agricultural products.

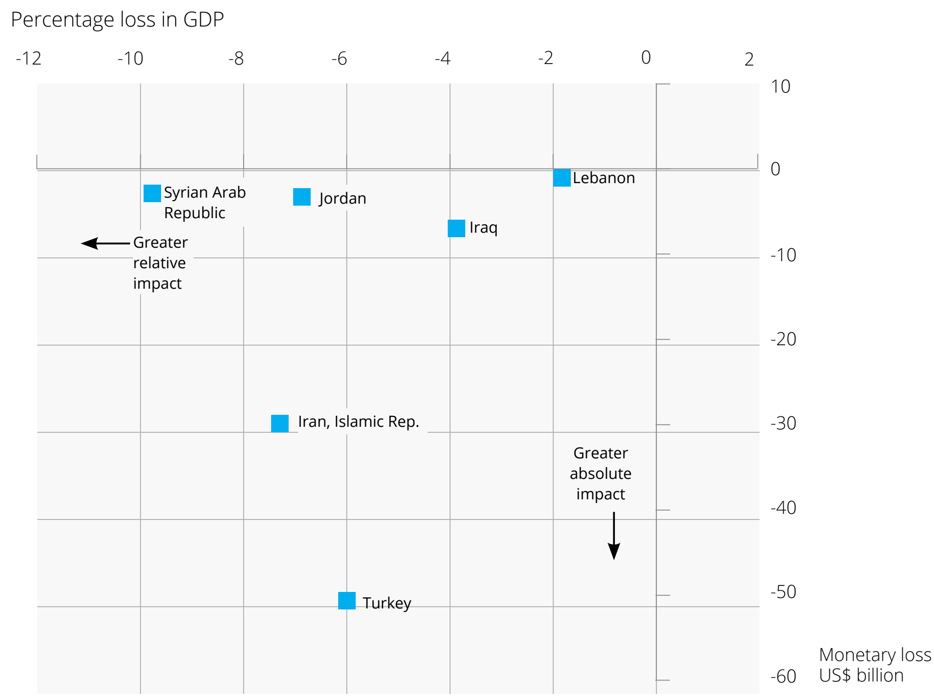
**Figure S7** Land suitability shifts for rainfed wheat up to 2080s (RCP 8.5)




RCP 8.5 is the Representative Concentration Pathway is a greenhouse gas concentration trajectory for the "business as usual" climate future scenario.

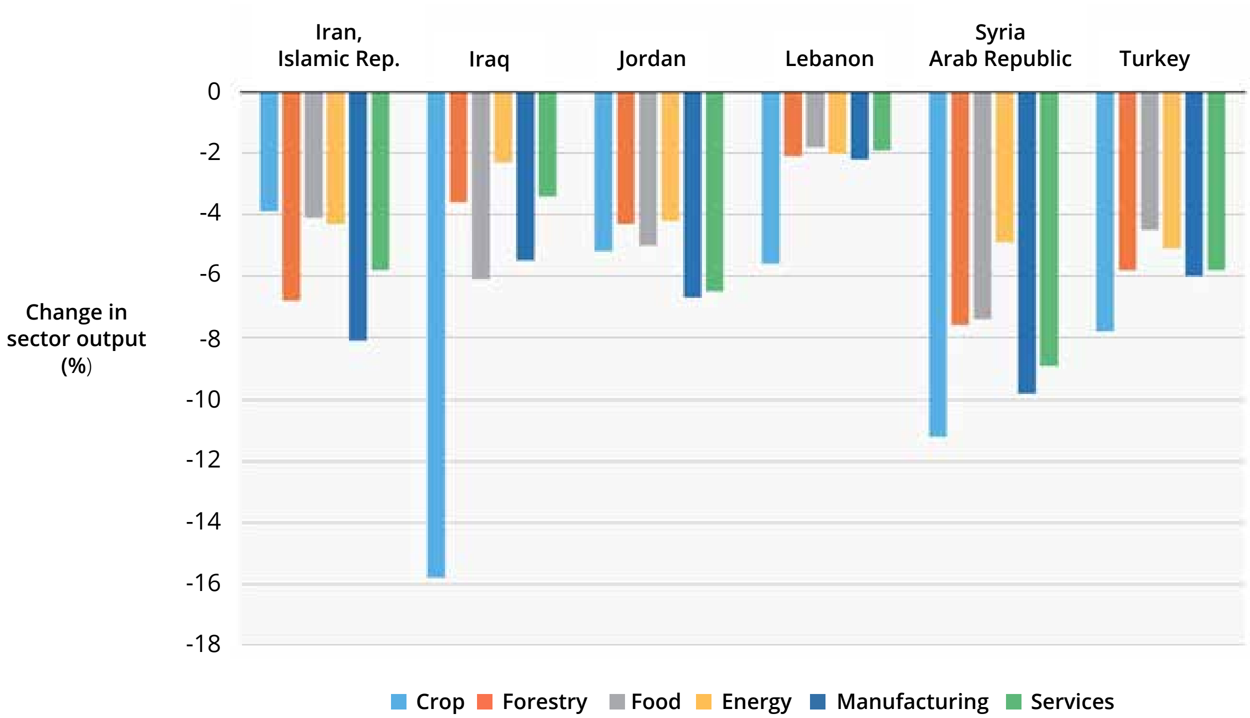
Source: FAO, 2021a

**Figure S8** Impacts of climate change-induced water scarcity and crop yield changes on GDP




Source: Taheripour *et al.*, 2020

**Figure S9** Impacts of climate change-induced water scarcity and crop yield on sectoral outputs




Source: Taheripour *et al.*, 2020

## 3.2 Water scarcity

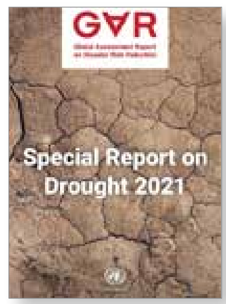
Water has always been scarce and variable in the Middle East, primarily because of natural aridity but increasingly because of drought. Most countries have already exploited their available water resources. Many river basins have passed the sustainable level of water withdrawals and will experience major constraints in maintaining and expanding agricultural production in the future (Taheripour *et al.,* 2020).

Water scarcity is a persistent and worsening problem globally, mainly where water resources are exploited for irrigation. Climate change predictions expect evapotranspiration rates to increase with a knock-on effect on withdrawals and water stress. FAO predicts that by 2050 crop water requirements will rise by 17% under "business as usual" conditions and by almost 30% when accounting for climate change, including likely increases in areas irrigated. If the current WUE (as a ratio of crop water use to water withdrawals) remains about 50%, climate change could double withdrawals by 2050 (FAO, 2021a). In most countries, such increases are unsustainable, and the need to raise water productivity and reduce water wastage is present and urgent.

Groundwater use for irrigation is already in crisis in most countries, yet all the signs point to increasing use for irrigation as farmers switch from reduced or regulated surface supplies (USGS, 2018). Groundwater is attractive for irrigators who are close to shallow aquifers. It offers a convenient, reliable, flexible, and primarily unregulated supply close to farms. Advantages for farmers are many, but they are outweighed by the more significant long-term problems of over-exploitation where there is no administrative control over the resource.

Current patterns of exploitation present long-term risks for sustainable water supply and agricultural production. Poor water quality from saline intrusion and contamination from excess fertiliser applications also limit options to increase groundwater use in many accessible shallow aquifers (FAO, 2021a).

## 3.3 Droughts increase water scarcity




"*Droughts are among the most complex and severe climate-related hazards encountered, with wideranging and cascading impacts across societies, ecosystems, and economies. They recur, can last from a few weeks to several years, and affect large areas and populations worldwide. Droughts have occurred throughout history, due to natural climate variability* " (UNDRR, 2021).

Droughts are natural phenomena that threaten every country in both summer and winter. In developing countries, droughts can impact livelihoods and result in severe undernutrition and death from starvation. In the developed world, the impacts are mainly on economic growth, livelihoods, and the natural environment.

In the Middle East, which is primarily arid and semi-arid, it is essential to distinguish between drought and the 'normal' lack of rainfall that is a feature of aridity. In simple terms, drought can exacerbate water scarcity, but it is temporary and comes to an end. In contrast, aridity does not. It is a permanent state with little or no rainfall to support vegetation. Planning to cope with aridity and drought has many facets in common, but there are also significant differences.

Droughts are temporary and come to an end. In contrast, aridity does not.

Droughts are unpredictable, and most countries lack early warning systems, which often leads to crises requiring emergency intervention to provide essential water and food supplies.

Dealing with drought is different to water scarcity. Approaching drought as a risk to be managed is a process that is gaining recognition internationally though very few countries have taken the steps needed to minimise drought impacts (WMO; GWP, 2017). Indeed, one of the biggest obstacles to effective drought planning is apathy. When there is good rainfall, other problems take priority and drought is forgotten – until the next one comes along, which it surely will (Box S1).

**Box S1 The "hydro-illogical cycle" of drought**

The "hydro-illogical cycle" describes the pathway through a drought in much the same way as the more familiar "hydrological cycle" sets out the pathway of water. Drought slowly becomes visible and this leads to concern and then to panic. Rain usually brings relief and then apathy sets in as people relax and refocuses their attention on the many other pressing issues of the day. That is until the next drought...


WMO; GWP, 2014

## 3.4 Shocks

Shocks are increasingly prevalent, including severe floods and droughts and pandemics such as COVID-19, for which most countries were unprepared. They tend to divert attention away from long-term development priorities. COVID-19 notably exposed threats to global food systems.

The World Bank estimates this has pushed many millions into extreme poverty (Lakner *et al.,* 2021). FAO's ***The State of food security and nutrition 2021 report*** highlights food insecurity and estimates the effects will last for many years to come (FAO; IFAD; UNICEF; WHO, 2021). Projections show the global number of undernourished people in 2030 will be around 660 million, in part due to the lasting effects of the COVID-19 pandemic on global food security. These events need to be part of future planning and investments to overcome the vulnerabilities they have exposed. Planning for future shocks and long-term development have many common features and offer win-win benefits.

## 3.5 Land and soil degradation

Healthy soils play a crucial role in improving water productivity and crop production. However, concerns are growing worldwide about degrading soil resources. The desire to produce more with existing and limited resources is exhausting soils and impacting soil health.

According to the FAO report, *The Status of the World's Soil Resources Report* (FAO-ITPS, 2015), most of the world's soil resources are in poor or very poor condition; 33% are moderate to highly degraded and subject to ten main threats leading to soil degradation: soil erosion, organic carbon loss, nutrient imbalance, soil acidification, contamination, waterlogging, soil compaction, soil sealing, salinisation, and loss of soil biodiversity.

Most of the problems are human-induced and potentially reversible, and as such, land degradation due to erosion, salinisation and pollution is high on the global agenda alongside water scarcity. Yet it is rarely addressed on the ground until cropland soils are degraded and compromise crop productivity.

Risks of soil salinisation have long been a problem in irrigation in arid and semi-arid areas, where salts build up in the surface soil through evaporation and reusing wastewater for irrigation (Sjoerd *et al.*, 2017). Globally, more than 1 100 million ha are affected; 60% are saline, 26% are sodic, and 14% are saline-sodic.

Estimates of irrigated salt-affected soils vary widely between 20% and 50% of irrigated land. The FAO Global Soils Partnership has prioritised soil salinity mapping to identify the scale of the problem in each region and the required investment in remedial measures (FAO, 2021a).

The combination of water scarcity for irrigation and land degradation means that soil and water conservation must be a development priority (FAO, 2021a).

# 4 Response options and actions when water is scarce

**The challenges facing irrigation are complex and multi-faceted, so there are no single-purpose solutions to the problems of inefficiency and low productivity.**

All the countries studied have similar water scarcity problems, but each has its own unique set of natural resource endowments, socio-economic circumstances, and governance arrangements for investing and managing water resources. As such, this chapter cannot offer specific solutions. However, it can highlight tried and tested options for decision-makers to select and package them to produce strategic actions that enhance efficiency and productivity. In doing so, the overall aim is to contribute to a nation's food security and well-being while sustaining and protecting the natural environment on which future production depends.

Water scarcity radically changes many aspects of planning and management, including irrigation. In response, this chapter first describes how irrigation professionals rethink how they plan and modernise irrigation systems and measure and monitor performance. Second, it offers a range of technical and institutional options to improve the performance of both large irrigation systems and on-farm irrigation practices.

Water scarcity radically changes everything about planning and managing water for irrigation

Some options that can influence irrigation performance and save water lie beyond the farm gate, such as plant breeding and reducing food losses and waste on farms and in supply chains from "field to fork". This implies that every citizen needs to know how much water they use.

This is the advent of "water stewardship". For farmers, this is about Water Stewardship in Agriculture (WSiA).

## 4.1 Rethinking irrigation design and assessing performance

Although irrigation has been practised in the Middle East for many centuries, the science of irrigation is relatively new and was established in the 1970s. The "classical" thinking about WUE[4] guided designers and water managers and served irrigation well. Water was plentiful, demand was low, and planning new schemes and withdrawals was done in silos, with little or no thought given to the impact on existing withdrawals in a river basin.

Today, we face different circumstances. Water scarcity means that planning new water projects and modernising old ones in isolation is no longer an option. Integrated approaches are essential to using limited water resources among abstractors.

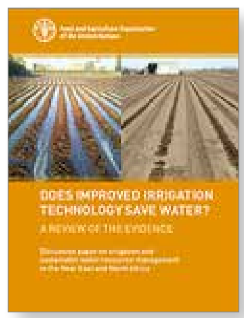
[4] Classical WUE is a ratio of crop water use (evapotranspiration) to the amount of water withdrawn from a source.

Although this report initially reviews WUE as the primary metric to assess the state of resources, it also challenges the usefulness of this approach under water scarcity conditions. WUE values of 35% to 50%, reported across the region, suggested crops usefully use only a small portion of withdrawals, and much is wasted. However, irrigation engineers and water resource planners are now asking: *where do the water losses go*? They do not disappear. Some may be truly lost as water percolates into deep aquifers or drains into the desert or the sea. But much remains in the river basin and is frequently used by others downstream. Already farmers in the lower parts of a river basin exploit these *return flows*. Although WUE measured on individual farms or schemes maybe only 35% to 50% and at face value are unacceptable, when considered at the river basin level the WUE will be much higher as one person's losses become another person's source of supply. Scale matters when quoting WUE values. Most people are now familiar with reusing sewage effluent for irrigation, so why do we not account for and reuse water lost from farms?

"Real" water savings are still possible on farms and schemes. However, the savings are likely to be much less than originally anticipated. Not all return flows are useful as high levels of salinity and residues from fertiliser and pesticides degrade them. Nonetheless, return flows are vitally important when assessing WUE within a river basin.

There is still much confusion over the meaning of WUE. Decision-makers, scientists, water professionals, and farmers often use the same vocabulary to discuss water management issues. However, each may have a different meaning that can lead to misunderstandings, and in some cases, expensive mistakes. Myths about water that misrepresent facts and basic science are commonplace. A common language and understanding are essential for sensible discussions, decision-making and investment (Perry, 2007).

## 4.2 Does switching to hi-tech make sense?




Improving WUE is usually the reason for switching from surface irrigation to sprinkler and drip systems. However, water scarcity is challenging this logic.

In 2017 FAO published *Does Improved irrigation technology save water?* (Perry and Steduto, 2017). A quote from this publication: " … *introducing hi-tech irrigation [sprinkler and drip] in the absence of controls on water allocations will usually make the situation worse: [water] consumption per unit area increases, the area irrigated increases, and farmers will tend to pump more water from ever-deeper sources."* This statement seems paradoxical. However, experiences reported worldwide are showing this to be true.

Research findings show that farmers become more willing to invest in hi-tech irrigation to reduce losses when water is scarce.

We are familiar with reusing treated wastewater for irrigation, so why do we not reuse water lost from farms?

However, they tend to use the water they save to increase their production and water productivity rather than release it for others to use. The main impact is fewer return flows and less water available downstream.

There are many examples where policymakers subsidise switching to hi-tech, expecting farmers to save water and release it for others to use, only to find those benefits do not materialise. In some cases, water consumption increases with little gain in water productivity (Yu *et al.,* 2021). See examples of this in Box S2.

Answering the question: *does switching to hi-tech make sense?*

**Yes** – for farmers. They are likely to invest in hi-tech systems to reduce water losses when water is scarce, providing they can retain the water they save to increase their production.

**No** – when water is scarce, and the government subsidises hi-tech investment on farms intending to claw back the saved water for others to use. Experience worldwide shows claw-back only happens when irrigation managers use flow measuring devices and legally enforceable farm quotas to limit abstraction. Such measures are unlikely to appeal to farmers who see little benefit in investing in hi-tech systems, even with subsidies.

**Box S2 Investing in hi-tech on farms does not always produce water savings**

**In Montana and Wyoming in the USA**, in 2012, a legal case in the US demonstrated the severe and unexpected impacts of increasing irrigation WUE to reduce water losses (return flows). The Yellowstone river basin in the US is nearly equally divided between Montana and Wyoming, and in 1950 the two states agreed to apportion the available water for irrigation and other purposes. However, following a severe drought between 2000 and 2006, Wyoming invested in sprinkler and drip irrigation to increase irrigation WUE to use their limited water allocation better. But Montana had long benefited from the inefficiencies (return flows) in Wyoming. The impact of increasing WUE was to reduce the return flows to the detriment of Montana. Montana alleged sprinklers increased WUE in Wyoming from 65% to 90%, reducing return flows from 35% to only 10%. Montana argued that Wyoming should have imposed administrative requirements to offset these adverse effects on Montana. The court held that such improvements were permitted under the Yellowstone river agreement. This was a landmark ruling, and a recognition of the importance of return flows in assessing water availability.

Source: MacDonnell, 2012

**In India** the government promoted drip irrigation, including paying up to 75% of the costs to conserve groundwater. In the absence of regulations to limit abstraction, farmers reacted by intensifying production, shortening fallow periods, and expanding the irrigated area between 40 - 67%. The result was an increase in abstraction rather than water saving.

Source: Birkenholtz, 2017

**In Nepal,** a river basin study reported irrigation water losses 75% and recommended the investment to recover and reuse the water. However, further analysis of the basin found that 80% of the "losses" were return flows, which were recovered and used by irrigators downstream. The original study focused only on the amount of water diverted for irrigation and the amount used by the crops. The results showed that real water saving in the river basin was only 6%.

Source: Kaune *et al.,* 2020

## 4.3 From water use efficiency to water productivity

Irrigation professionals are now turning away from measuring WUE, towards more useful metrics that account for real water savings, improvements in WP, increased crop production and nutrition in foods, water's contribution to food security and people's livelihoods, and sustaining the aquatic environment (Box S3).

## 4.4 Options to save water and increase productivity

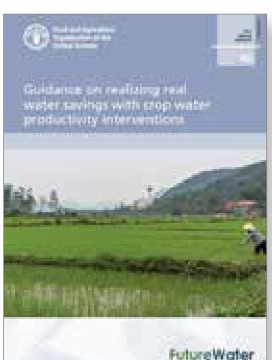
### 4.4.1 Adopting water accounting and remote sensing

New tools such as Water Accounting and Auditing (WA&A) combined with Remote Sensing (RS) enable water resource planners and decision-makers to better understand and quantify the significant water volumes that irrigated agriculture needs, and irrigation managers to improve control over water allocations to farmers.

In its simplest form, WA&A is a hydrological water balance of inputs and outputs. It can help determine how much is available and allocated to ensure the taps do not run dry. But WA&A is much more than this. It is essential to understand the hydrological cycle, but WA&A goes much further. It includes accounting for spatial and seasonal variations in rainfall and the less predictable extremes of floods and droughts. It takes account of medium and long-term changes in demand from all water users: communities, farming, energy, industry, and the environment, and informs water infrastructure investment for pumping, storage, and planning for climate change.

Assessing agricultural water demand is fraught with difficulties because of the many technical and political uncertainties that affect water requirements for home food production. Agriculture needs to negotiate a fair share of available resources. To do this it must and answer that critical question: *How much water does agriculture need, now and in the future?*

**Box S3 Water productivity is replacing water use efficiency on farms**




Water productivity (WP) offers a simple, direct and unambiguous link between water and the benefits of irrigation in terms of production, yield, economic value, and connections with food security.

Water productivity refers to the ratio of physical production (in terms of biomass or crop yield) or, in some instances, the economic value of production (gross or net value of the product) relative to water use (water withdrawn, applied, or consumed). This is expressed in kilograms per cubic metre (kg/m$^3$) or US dollars per cubic metre (US$/m$^3$) and focuses attention on achieving more crop per drop.

FAO's *Guidance on realising real water savings with crop water productivity interventions* offers an intervention framework for water savings based on water management practices, soil and land management and agronomy, following an extensive search and analysis of available literature.

Source: Van Opstal *et al.*, 2021

## If agriculture is to produce water management plans, an evidence base is needed to assess current water use and forecast demands; WA&A and RS can help

This is a difficult one, but one that needs an answer for governments to plan for future water and food security. However, most developing countries do not have a water management plan for agriculture even though it is the largest water user. Another critical issue is that most countries do not have the physical infrastructure or the administrative systems to manage and monitor water withdrawals on a volumetric basis.

WA&A and RS can help to resolve this situation. RS does not require extensive monitoring networks and field data collection. It can identify and map cropped areas, measure evapotranspiration, and provide data on actual water consumed as an input into WA&A. The accuracy of RS data enables water consumption in river basins, irrigation schemes, and even individual farms within schemes to be measured. Recent studies in Jordan and Lebanon illustrate the benefits of this approach. However, operationalising this system highlighted a lack of institutional and human resource capacity to support this sophisticated technology (World Bank, 2020). FAO in the Near East and North Africa region, in collaboration with IHE-Delft in the Netherlands, has introduced regional training programmes to overcome these human capacity constraints (FAO, 2021b).

### 4.4.2 Modernising irrigation schemes

Modernisation can help to improve the overall performance of large irrigation schemes. It can give managers much greater control over water allocations and provide more reliable, timely, and adequate water services to farmers, including the options to limit supplies in times of shortage. An additional benefit is reduced water wastage in the distribution system.

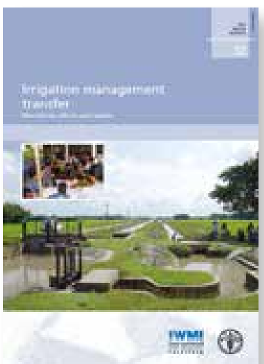
Modernisation is not just about saving water and improving water control. FAO coined modernisation as *"a process of technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes combined with institutional reforms, to improve resource utilisation (water, labour, economic, and environmental) and water delivery to farms"* (FAO, 2007a).

Implicit in modernisation is a shift from traditional supply-driven irrigation to demand-driven irrigation and introducing the concept of providing irrigation services to farmers (FAO, 2007a). Modernising irrigation involves two essential and complementary components. The first is upgrading technologies, the "hardware" that goes beyond rehabilitation, as this only replaces what is already there. This is the visible part of a system and involves installing networks and control structures, automation, lining canals, constructing reservoirs, and installing modern information systems to improve management and control. More than 90% of irrigation in the region uses surface irrigation methods, and most technology upgrading needs to simplify canal management and improve surface irrigation performance.

Modernisation is often misunderstood and is associated only with high-tech solutions or costly automation. However, Horst argues that modernisation can be achieved using simple technologies and more sophisticated options. Both are worthy options and have the same objective in mind: to find manageable technological solutions that replace manually

Implicit in modernisation is a shift from traditional supply-driven to demand-driven irrigation and providing irrigation services to farmers

adjustable control gates that have proved so challenging to manage properly (Horst, 1998).




Modernising irrigation management is about the "software". It is mostly invisible but is an essential complement to the "hardware" improvements in irrigation infrastructure. It involves upgrading irrigation management and supporting institutional structures to provide irrigation services appropriate to modern farming. Key elements include irrigation management transfer and participatory irrigation management that brings irrigation managers and farmers together to supply services to farmers, usually through Water User Associations (WUAs) (FAO, 2007b).

### 4.4.3 Modernising irrigation on farms

Although saving water is a priority for governments and irrigation scheme managers, it is not usually a priority for irrigating farmers who are more concerned about saving money and maximising profits. Farmers are often more concerned about irrigation costs, the financial benefits of crop yield and quality, and resilience to water scarcity. An indirect benefit of addressing these concerns is often water savings which can benefit the river basin and other users.

Modernisation requires "hardware" improvements on farms, such as control systems that simplify canal management and provide farmers with flexible and reliable water supplies. Reliability creates confidence in managers and farmers, enabling them to switch off water supplies when irrigation ends.

Where appropriate, farmers can also consider switching from gravity fed to pressurised sprinkler and drip irrigation to improve control over water application. Installing drainage can help to remove excess water and control salinity.

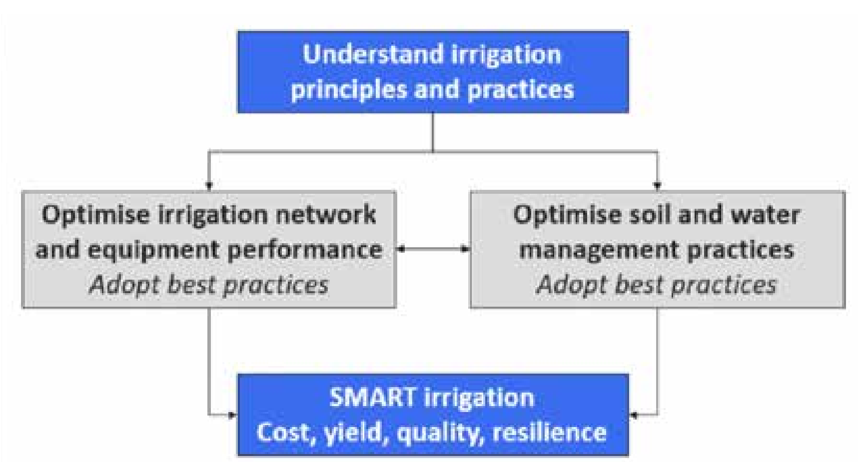
Understanding and applying best practices can help to ensure that farmers become water stewards in agriculture. Famers need encouragement to adopt best practices, including ranking irrigation highly within farm management activities, understanding the interactions between soils, crops, and water, scheduling irrigation, using objective monitoring tools, and remaining open to new ideas, such as solar pumps for renewable energy. Benchmarking also helps farmers improve performance and, together with WUAs, can provide opportunities for farmers to work together to share ideas, compare performance, and transfer knowledge.

From a farmer perspective, there are many aspects of their irrigation system and farm management to consider, and the importance of each will depend on the local circumstances. Farmers should consider efficiency as a goal to be achieved by taking a holistic approach to improving all aspects of on-farm irrigation, rather than calculating WUE, which is often confusing and has little meaning in practice. This approach is the *pathway* to farm irrigation efficiency (Figure S10). Assessing performance in this way also points out that the path is not a one-off procedure or measurement. Instead, it is an ongoing process of iteration and improvement over the life of the farm irrigation system (Knox *et al.*, 2009)

## Saving water is a priority for governments and irrigation scheme managers; it is not usually a priority for farmers

Optimising the various components of an on-farm system leads to SMART (Sustainable, Managed, Accountable, Responsible, and Trusted) irrigation and to an operating level that is practical and appropriate to local circumstances not just in terms of water use but also cost, yield, quality, and resilience.

**Figure S10** A pathway to improving farm irrigation performance




Source: SUEN, 2020

# Farmers should think about efficiency as a goal to be achieved by taking a holistic approach to improving all aspects of on-farm irrigation

Although there is growing interest in switching from surface methods to hi-tech sprinkler and drip methods, surface methods still dominate world agriculture, accounting for about 90% of the irrigated land area (Figure S11). Surface irrigation still dominates irrigation in Iran, Iraq, Syria, and Turkey and will continue to play a significant role in the future. Thus, it is incumbent on policymakers to ensure that irrigation managers and farmers follow pathways to improve surface irrigation methods. There are many ways of improving the performance of basins, borders, and furrows but much depends on local circumstances (SUEN, 2020). WUE can be increased by evaluating, diagnosing problems and improving farm irrigation practices. Other options include installing low-pressure pipe delivery systems and automatic regulators on canals (Figure S12). Much can be done to improve surface irrigation before switching to hi-tech irrigation, which may not bring the expected benefits that equipment suppliers promise. Farmers can increase on-farm WUE by reducing water losses, but they cannot reduce crop water needs (evapotranspiration) which remain the same whichever method is used to apply water.

Switching large areas to sprinklers and drip technologies can be costly and bring new problems to the farm as well as solving old ones. They require upgraded management skills to operate the systems and adequate and reliable maintenance facilities, including spare parts. Disposing of large quantities of PVC drip tubing can also create serious environmental problems.

**Figure S11** Surface, sprinkler and drip irrigation methods used on farms

**Figure S12** Typical automatic gate and pipe systems to control water flow onto farms



**Water storage** is an ideal asset for balancing supply and demand, managing uncertainties and variability, and building resilience to climate change. On irrigation schemes, overnight storage allows farmers to continuously take water from a canal system and irrigate their crops according to crop water needs rather than a fixed water schedule determined by scheme managers. The current silo approach to storage needs rethinking, and a more integrated approach adopted. There are many different kinds of storage, natural and built, that can come together to provide multiple socio-economic benefits (GWP; IWMI, 2021).

**Rainwater harvesting** links rainfed agriculture and supplemental irrigation. It offers opportunities for improving water productivity in dry regions and can boost yields 2-3 fold over rainfed production, especially when combined with minimum-tillage methods that enhance water conservation (Oweis, 2016). *"Water Harvesting – Guidelines to Good Practice"* provides comprehensive and practical advice covering a wide range of flood, macro and micro catchment, and rooftop/courtyard water harvesting techniques (WOCAT, 2013).

**Healthy soils** play a key role in improving water productivity and crop production. Managing soil salinity involves reducing evaporation from the soil surface by controlling water applications to meet crop demand and providing a leaching fraction to maintain an acceptable salt balance in the soil. Some countries now accept saline drainage water and adopt bio-saline agriculture with selected salt-tolerant crops and appropriate cropping patterns and management practices. *A handbook for saline soil management* (FAO, 2018) provides innovative methods and technologies for ameliorating salt-affected soils.

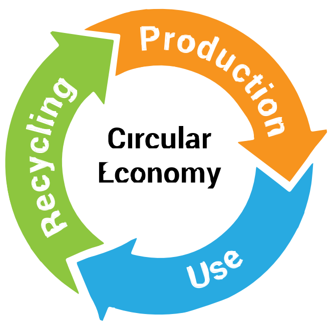
### 4.4.4 Do water charges improve performance?

Economists see irrigation as an obvious case for introducing volumetric water pricing to reduce over-consumption and enhance efficiency, but in reality, the issue is far from simple. A study commissioned by the FAO focused on applying charging tools and the practical lessons drawn from documented case study experience (FAO, 2004). The study concluded that the effect of volumetric water charging on water saving was minimal, as current prices tended to be well below the levels that farmers considered water saving was a significant financial consideration. Additionally the cost of installing measuring devices and administering a measuring and charging system for many thousands of small farmers would be prohibitive.

FAO suggests that introducing a water charging policy is likely to be part of a larger package of measures designed to provide good irrigation services for which farmers are willing to pay. Broadly, two types of intervention can restrict and reduce water consumption – pricing and some form of constraint on demand through rationing or a quota system. No country relies on pricing alone to balance supply and demand (Perry, 2018).

## 4.5 Options beyond the farm gate

Many activities beyond the farm also contribute the making wise use of limited water resources. Some are discussed briefly.

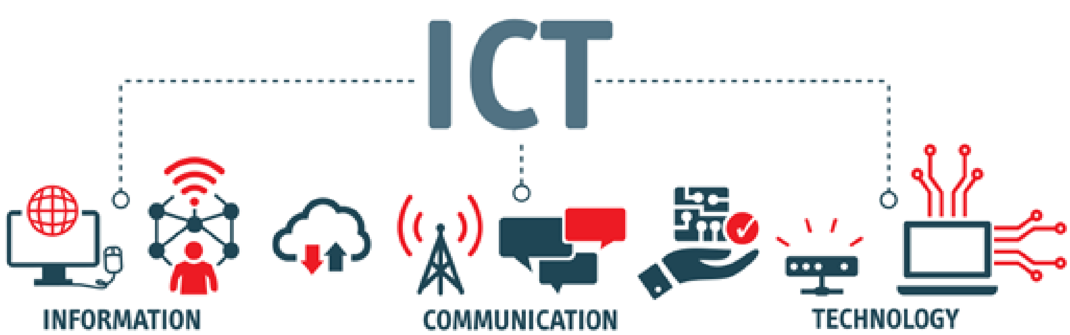



**Circular economy** benefits are just as applicable to agricultural water management as the broader land-use and food systems. This approach creates opportunities to use non-conventional waters that might otherwise go to waste, such as saline and brackish water. Wastewater remains a largely untapped resource because the capacity to treat waste from cities is often inadequate. Wastewater must be safe to reuse and is a requirement of SDG 6 to halve the proportion of untreated wastewater by 2030. One constraint is monitoring water quality, and a requirement to increase and improve data collection.

**Reducing food losses and waste (FLW)** can increase food security, lower production costs, reduce pressures on natural resources and improve environmental sustainability. The SDG Target 12.3 calls for halving global food waste per capita at the retail and consumer levels and reducing food losses along production and supply chains by 2030 (UN, 2015). Globally, FLW accounts for 24% of total freshwater withdrawn for food crop production, 23% of cropland area and 23% of fertiliser use (Kummu *et al.,* 2012). Halving FLW would provide enough food for approximately 1 billion people.

Globally, food losses and waste accounts for 24% of total freshwater withdrawn for food crop production

**Using ICT and big data** can help improve productivity, manage associated environmental risks, and ensure sustainable land and water management. Recent advances in Information and Communication Technologies (ICTs), Big Data Science, Earth Observation Systems (EOS), Open-Access (OA), Artificial Intelligence (AI), Machine Learning (ML), and Cloud Computing Platforms (CCP), along with Smartphone-enabled Citizen Science (SCS), have increasingly made Big-Data analytics much smarter and more useful for agricultural planning and management.



## 4.6 Good water governance

FAO defines governance as the formal and informal rules, organisations, and processes through which public and private actors articulate their interests and make and implement decisions. Governance issues arise in various public and private settings, from local communities, farms and cooperatives, business organisations, and large-scale enterprises, to local, regional, national, and international contexts. Good water governance is essential for building capable and informed institutions and organisations that respond to change and are open and transparent. However, achieving this with clear development objectives and commitment is still one of agriculture's most significant challenges for most developing countries (UN, 2018). Large irrigation schemes built last century, for example, paid little attention to governance and instead focused on supply-driven, infrastructure-led solutions that ignored the interconnections within a river basin as decision-makers devised responses to individual problems. Change is needed.

Many governance functions lie with the government and include formulating policy, developing legal frameworks, planning, coordination, funding and finance, capacity development, data acquisition and monitoring and regulation.

**Water Stewardship in Agriculture (WSiA):** WSiA is an integral part of good water governance. It is another step in collective stakeholder engagement that can bring a farming perspective to water resources planning and management and instil a sense of ownership among farmers for their actions as water users when pursuing objectives of increasing water productivity and profitability. Farmers need encouragement to become water stewards and share joint responsibility for water resources rather than just be thought of as abstractors (World Bank, 2020).

**Capacity development:** Strong formal and informal institutions and human resources underpin good water governance. In 2004 FAO highlighted a consensus among policymakers in the developing world that a lack of capacity was constraining development in irrigation agriculture (Kay and Renault, 2004). Countries in the Middle East have a long tradition of irrigation, and government organisations have a legacy of knowledge and experience in irrigated agriculture. Despite the conflicts in parts of the region over the past two decades, it is anticipated that the corporate memory of these organisations is still strong. However, for some countries, the questions focus on how to modernise existing systems, develop human capacity and institutional structures and deliver changing services to farmers. For others, there may be an urgent need to re-build capacity curtailed by years of turmoil. Thus, countries across the region will have different priorities and capacity needs. Strategies to develop capacity as outlined in SUEN, 2020.

## 4.7 An integrated approach

Although this study focuses on irrigation, it cannot ignore that irrigated farming is an integral part of water management within a river basin. Water scarcity is now driving water and water-using sectors to cooperate and take an integrated approach to basin water planning and management. This aligns with the call for integration in the UN-Water Goal (SDG 6), in which agriculture and irrigation must play a significant role (UN, 2018). However, agriculture has work to do in putting its own house in order. It is a highly fragmented industry, primarily organised around commodities rather than resources and is a complex mix of rainfed and irrigated cropping. Irrigation also suffers from fragmentation as engineers have traditionally focused on infrastructure while agronomists have concentrated on cropping. A more enlightened approach is needed that builds links not just between engineering and agronomy but among the many disciplines that can influence improvements in WUE and water productivity. It is hoped that this study will help develop those essential links for the benefit of all water users.

Photo Rubiconwater, Australia

# 5 Conclusions and policy recommendations

"Business as usual" will not be an option as global freshwater withdrawals for irrigation, already more than 70%, are predicted to double by 2050, creating unacceptable environmental disasters in many stressed river basins, increasing competition for resources, and causing new social challenges and conflicts over land and water. As the primary water user, it is incumbent on irrigated agriculture to use water resources wisely and reduce these problems. There is an urgent need to design a future for sustainable agriculture and food production that is coherent and inclusive, is climate-smart and protects the environment.

To address water scarcity, this report focuses less on water use efficiency as a metric to measure performance and more on practical and appropriate metrics that account for real water savings, improvements in water productivity (more crop per drop) and production, how water contributes to food security and people's livelihoods and sustains the aquatic environment. New tools such as Water Accounting and Auditing (WA&A) combined with Remote Sensing (RS) are described that enable water resource planners to account for irrigation water use including return flows and real water savings. Systems are being developed to measure crop water use over large areas and enable irrigation managers to allocate and control water for irrigation.

There are five main areas recommended for action that would facilitate a transition towards efficient, reliable, and sustainable land and water management in irrigation.

**Action area I: the need for good governance.** Good water governance is underpinned by strong formal and informal institutions and a workforce that is well informed on modern irrigation practices.  Without this, technological and management innovations are unlikely to succeed. It requires a robust institutional framework to establish and implement good water policies, laws and regulations, and a strong administration to implement them.

Inclusive governance is also essential in recognising the symbiotic nature of water, land and soils and the need for coherent and integrated policies that bring land and water management objectives together, resources to be fairly distributed, and mechanisms agreed to avoid conflict over resource allocation. This extends to transboundary resources, where water use across national boundaries is a dominant issue.

Inclusive governance also recognises the need for multi-stakeholder engagement at all levels and across disciplines that will be critical to achieving integrated land and water management, a central plank in achieving SDG 6: the “water goal”. Holistic approaches to change will be essential to improve resource allocation and management, provide better control over water supplies and improve service quality in terms of precise, timely, and reliable water delivery. Introducing Water Stewardship in Agriculture (WSiA) is an integral part of good governance. It could play a central role in helping irrigation agencies and individual farmers and farmer groups, such as Water User Associations (WUAs), to understand and adjust to the significant changes that limited water allocations bring.

**Action area II: embracing innovative technologies and management** to address water scarcity and drought and tackle problem soils. There are myriad options available. These include modernising large-scale irrigation schemes, automating canal systems, transitioning towards participatory irrigation management and transferring management responsibilities to WUAs. New planning, design and evaluation technologies, such as Water Accounting and Auditing (WA&A) and Remote Sensing (RS), Information & Communication Technologies (ICT) and automation, are helping to modernise existing schemes and inform new designs. Attention is shifting from ill-defined metrics, such as water use efficiency (WUE), and focusing on increasing water productivity (WP), making real water savings and meeting farmer demand for more flexible and reliable water supplies. Water resources planning needs a well-defined language to avoid confusion among the various water and water-using organisations and the many disciplines involved in water management.

Water storage offers a buffer for managing climate uncertainty and variability, addressing differences in supply and demand, and building resilience to climate change. A shift is needed from conventional infrastructure-led storage to multi-purpose storage, integrating natural and built storage and exploiting surface and groundwater conjunctive use.

Modernising irrigation on farms must include surface irrigation and canal systems, which accounts for about 90% of the irrigated land area in the Middle East and switching to hi-tech systems. The main objective must be to make real water savings that others can use productively.

Drought should no longer be considered an unexpected natural disaster requiring emergency assistance that wastes valuable resources and does not help build resilience. A risk-based approach can lessen drought impacts. This is a “three-pillar” approach that requires investment in monitoring and early warning systems, studies to assess vulnerability to drought and actions to reduce adverse impacts.

Farmers benefit from the rapid spread of ICT and mobile phone technologies into agriculture. RS services, cloud-based computing and open access to data and information on crops, natural resources, climatic conditions, inputs and markets already benefit farmers by integrating them into digitally innovative agri-food systems. However, care is needed to avoid a “digital divide” among those with different access levels.

Options are also available beyond the farmgate that can contribute to making wise use of limited water resources. Circular economy principles, widely used in the food sector, are now being applied to agricultural water management, including non-conventional waters that might otherwise go to waste, saline and brackish water, agricultural drainage, and domestic and industrial wastewater effluents.

Adapting crops to climate change will be vital as temperature and rainfall patterns shift cropping to new areas. Since 2000, progress in breeding crop varieties traits has been good. These are important to boost yields, tolerance to drought, waterlogging and salinity. Genetically modified crops offer many benefits but continue to be the subject of a long-running debate regarding risks to biodiversity and human and environmental health.

The consequences of continued salinity build-up in soils in arid climates are worrying. However, options are available to deal with salinity issues, and drainage of salt-affected soils will be vital to secure future food security in arid and semi-arid environments.

**Action area III: implementing integrated solutions at scale.** Integrated approaches to resource use can help define critical resource thresholds and lead to beneficial outcomes when they are wrapped up in workable packages, including technical, institutional, governance, and financial support. Rigorous integrated planning for water and land resources is a crucial step involving all stakeholders rather than a traditional top-down approach. Water accounting will prove to be an invaluable tool to provide evidence for allocating and controlling water resources. Many examples are emerging of the success of this approach in terms of sustainable resource use, meeting food production targets while protecting valuable ecosystems on which everything else depends.

**Action area IV: investing in long-term sustainability.** Irrigation can be costly, but the investment will need to be weighed against the cost of inaction and the impacts on water security, land and soil degradation and food insecurity.

Internationally, investment is shifting from infrastructure solutions towards sustaining productivity and improving governance, integrating systems at scale, innovations in technology and management and strengthening the capacities of organisations, including water-user and producer organisations.

Through public-private partnership models, governments can encourage the private sector to complement public funding and investment from development banks and environmental funds. Farmers and local communities are also beginning to recognise the importance of investment. In situations where there is stable and good water governance, they too can become critical investors in sustaining their livelihoods.

**Action area V: working together for common solutions**. Working together has been the subject of much research by Elinor Ostrom (a Nobel prize winner) on governing common resources such as land and water in irrigation systems (Ostrom, 1993). She demonstrated that when people come together in a common cause, they can share and manage resources sustainably. She established the ingredients for effective collaboration, including a shared dependence on irrigation, common threats, key individuals that can motivate group work, and people who have a long-term view of what needs to be done. The Blue Peace in the Middle East (BPME) is an excellent example of a platform that follows these principles to promote collaboration across the water sectors among BPME countries.

Although the countries in this study must adapt potential solutions to their unique natural resource base, environmental and socio-economic circumstances, they do not need to face some challenges alone as they have much in common. They are all concerned about water scarcity, land and soil degradation, soil and water pollution, and sustainable food security as populations increase and climate change threatens resource availability. They also have much in common, including shared culture, customs and habits that can enable people to work together for common solutions and reap the benefits of scale. These are essential ingredients that set the foundations for effective and mutually beneficial collaboration.

Experiences in collaboration within the European Union of funded joint research have shown significant benefits. They encourage collaboration among many young professionals working in different countries and environments across Europe. This is not just about building and sharing technical knowledge. It is also about making social capital (trust and friendship) among different nationalities and disciplines. This is the important but invisible benefit of collaboration and should prove a valuable asset from the BPME initiative. Collaboration takes time and resources and produces benefits that are not easily expressed in physical and monetary terms. However, they can be compared with the costs of non-cooperation and the benefits foregone, which are often much greater.

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