FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Improved Water Resources Management for Agricultural Systems

U.S. Government's Global Food Security Strategy Activity Design Guidance

This is one of several Activity Design Guidance documents for implementing the U.S. Government's Global Food Security Strategy. The full set of documents is at www.feedthefuture.gov and www.agrilinks.org.

Introduction

Sustainable, agriculture-led economic growth is critical to development and to reducing poverty, hunger, and malnutrition globally. Since all crops and livestock depend on water for their growth and production, water availability is often a limiting factor in agricultural production.[1] Water is also essential to many agriculture and livestock processes and value addition. Water for agricultural production comes from rainfall, surface water, groundwater, or a combination of these types.

Agriculture is highly sensitive to changes in water availability and water access, and conflicts over water also impact agriculture production. When compared to other water use sectors (such as municipal or industry), it becomes clear that globally, irrigated agriculture (small and large schemes combined) accounts for the majority of freshwater withdrawals.[2] Rising demands for irrigated water for agricultural production and the downstream impacts to water quality produce significant strain on water demand for other sectors. Climate change is increasing water stress in many places, making water availability less predictable, with more extreme rainfall and flooding in some areas, and more protracted, severe, or frequent drought in others. Changes in land use and unchecked ground and surface water pollution are degrading agricultural and pastoral lands and ecosystems and the services they provide, further reducing the quantity and quality of water available for many uses.

Water resources management (WRM) is key to the long-term viability of agriculture and global food production and processing, thus it is a Crosscutting Intermediate Result (CCIR) in the U.S. Government's Global Food Security Strategy (GFSS), CCIR 6: Improved water resources management. WRM is important to equitable water allocation, enhancing resilience to climate shocks, climate change, and other shocks and stresses, and addressing water scarcity. Achieving these objectives requires working at several levels, including at the community level, localized basin level, and national level to advance laws, policies, planning, and technical and social practices. Often, watersheds are shared among several countries, and international agreements must be considered in connection with large-scale projects. This work includes engaging in allocation processes; incentivizing and expanding access to profitable and efficient irrigation technologies; promoting on-farm soil, land, and water conservation practices; and supporting improved and equitable WRM within sustainable food production and processing systems.

According to the World Bank, "Irrigated agriculture is, on average, at least twice as productive per unit of land as rainfed agriculture, thereby allowing for more production intensification and crop diversification."[3] Due to double- and triple-cropping and higher yields on irrigated lands, WRM has been critical to preserving important ecosystems and lands that provide important contributions to climate resilience and biodiversity. However, many irrigation practices are inefficient—applying more water than required or applying water at the wrong time to be most efficiently used by crops are the two most common inefficient practices. Farmers need sound soil and water conservation practices in order to ensure

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sufficient soil moisture for crop growth and water availability at the right time during all cultivation stages. At the farm level, better land and water management strategies can enhance carbon storage in soils, thereby contributing to the mitigation of climate change while the additional carbon improves fertilizer efficiency and holds water for crop use. Successfully managing water quantity, quality, and timing, alongside other crop inputs, maximizes harvests and incomes at the farm level. These actions also benefit the wider catchment by improving land-water dynamics, such as rainfall runoff, infiltration, water consumption, and water quality; strengthening social cohesion and collective action; reducing levels of conflict; and improving resilience to climate variability and change. Thus, smallholder agricultural producers and their communities are central to WRM through on-farm water management, broader watershed management and natural resource management, and sustainable irrigation for increased crop and fodder production.

Locally led and inclusive development is vital for improving WRM for agricultural systems. It is important to capture the knowledge and experience of all participating household members and often marginalized groups within communities, not just the head of household or "community leaders." Additionally, people from various backgrounds engage in agriculture—from laboring on an hourly basis to renting a small field or owning a large farm. Many entry points mean that people in agriculture can be old or young, male or female, and wealthy or extremely poor. Marginalized groups experience uneven access to inputs and credit, disproportionate representation in group discussions and decision-making, spatial disadvantages (farms with poor soils or fields at the tail end of an irrigation system), and insecure land and water tenure. Inclusive institutions where stakeholders participate in decision-making about allocating water equitably and efficiently are important for strengthening inclusive development.

Livestock (both intensive production and pastoral), aquaculture, freshwater fisheries (managed and wild), and marine fisheries are, of course, important consumers and beneficiaries of water and WRM. Please look for additional guidance on WRM for these production systems in the GFSS Activity Design Guidance for Investing in Livestock and Animal Source Food Systems, the GFSS Activity Design Guidance for Sustainable Aquaculture Production Systems, and the GFSS Activity Design Guidance for Sustainable Fisheries Management.

Terminology and Context

Applied Water: Water that farmers use for their fields and crops.

Blue Water: Freshwater flows originating from runoff or percolation, contributing to freshwater lakes, dams, rivers, and aquifers. Soil moisture is considered blue water if it originates from blue water added through irrigation, as the result of hydrological events (e.g., flooding), or comes from springs or capillary rise.

Catchment, River Basin, or Watershed: An area of land that drains, or "sheds," water into a specific waterbody. Every body of water has a watershed. Watersheds channel runoff from rainfall and snowmelt into streams and rivers and, ultimately, into a reservoir and eventually an ocean. Watersheds or basins represent the unit of management for water resources. Watersheds can be divided into smaller units, usually based on tributaries, variously called watersheds, catchments, or subcatchments. A systems approach recognizes the upstream and downstream users in a catchment and socioeconomic context in which agricultural water sits.[4]

Landscape-Level Approaches: Landscape-level approaches are broadly defined as interventions that integrate technical solutions as well as policy and practice for multiple land and water uses within a given area, to ensure equitable and sustainable use of land and water resources while strengthening measures to mitigate and adapt to climate change. It represents an alternative approach that involves "joined-up" thinking between multiple stakeholders (often multidisciplinary) to best manage different land and water uses beyond field and farm to the landscape level.

Consumed Water: All water that is withdrawn but does not return to the catchment or aquifer as recoverable/reusable water. Water is consumed by evapotranspiration from crops, soil, other vegetation, and open water, and when water ends up in sinks, such as salty groundwater. Industry and power generation consume water through evaporative cooling, and water is even transported in and out of catchments via aqueducts, canals, pipes, trucks, and bottling. Consumed water is best analyzed at the basin scale.

Green Water: Precipitation that is stored as soil moisture and eventually transpired or evaporated.

Multiple-Use Water Services (MUS): MUSs are improved water management approaches designed to provide water for multiple uses to meet domestic and productive needs. MUS systems enable communities to allocate water resources, increase income from irrigation, and create economic and leadership opportunities for women and girls.

Resilience: The ability of people, households, communities, countries, and systems to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth. (See the GFSS Activity Design Guidance for Strengthened Resilience Among People and Systems.)

Water Productivity Ratio: Direct water productivity (in output unit per cubic meter) is calculated for a specific process, unit, or stage, including only the direct water consumed (see the "Consumed Water" definition). The goal of this metric is to identify potential improvements in direct water use per output unit of the system assessed as a means to track its performance.

Water Scarcity: Water scarcity occurs when demand for safe, usable water exceeds supply.[5]

Withdrawn Water: Water withdrawn from the ground or surface water. In centralized, larger-scale irrigation systems, withdrawals can also be measured as abstractions from the main intake.

Designing Activities

Interventions to improve WRM for agriculture and food systems can include work at the hydrological systems level (i.e., watershed, river basin, and aquifer) and the agricultural systems level (both rainfed and irrigated agricultural systems). In most contexts where the U.S. Agency for International Development (USAID) invests in food security programming, agricultural systems interventions may include: (1) assessment of relevant scale and sustainability of sources (e.g., watershed, landscape, groundwater, etc.) and planning of rainfed and irrigated systems; (2) governance and institutions; (3) on-farm water management and sustainable irrigation for crops, livestock, and aquaculture; and (4) markets, farm inputs, and private sector engagement.

Assessment and Planning

Before interventions can go forward, it is important to undertake a situational analysis of water users and uses in the intervention area, as well as an intervention analysis. This includes an understanding of upstream water sources users and uses that (already or in the future) might impact the intervention site, as well as an understanding of downstream water sources users and uses that might be impacted by the intervention. It also includes an understanding of current and future climate change impacts on water sources in the area, as well as an understanding of other planned or potentially unplanned interventions that could affect water sources and users, such as urbanization, industrialization, de/reforestation, etc. Downstream and upstream areas might be located in other administrative units, including other countries.

Undertaking situation analysis includes an understanding of current de jure water management (water laws, irrigation policies, and priority in water use regulations) and de facto water uses and management (water rights structures, ground versus surface water dependence, and water quality). Any intervention needs to identify if current institutions, policies, and regulations (de jure and de facto) are supportive or would hinder the planned intervention and identify the changes needed. In some settings, community-level approaches will be the principal means for generating consensus on water resource governance.

Finally, the situation analysis would include an understanding of water demands in multiuser settings and actual or potential constraints to water access. Any intervention needs to also identify who would gain from the intervention and who would lose (e.g., an irrigation intervention might reduce water access to downstream domestic water users as a result of water quantity or water quality degradation).

A core component of any intervention analysis is the identification of water and related indicators that WRM aspects of the program or project would monitor. These include indicators that the intervention aims to directly impact and indicators to monitor other potential related impact, such as changes in crop, livestock, and fish diversification; changes in diets and nutrition of the population, directly or indirectly linked with the intervention; or indicators of changes in vegetation or downstream flows and groundwater levels.

Governance and Institutions

Water is a resource with multiple sources (groundwater, surface water, precipitation, etc.) and multiple users. Thus, it is important to take a systems approach or basin-level approach that is appropriate to the level and scope of the planned food security activity. Specific contexts determine how best to balance ensuring a sustainable supply with anticipated needs. This is accomplished using participatory planning, including all relevant users and their multiple needs, helping prevent or mitigate conflict among users. Governance of water resources is key to accountable, inclusive, and effective water management. Improved WRM at the appropriate scale can include engaging in water allocation processes, watershed protection, land and water tenure security, expanding access to profitable and efficient irrigation practices, and data analysis. See USAID's Water Resources Management Technical Brief and the GFSS Activity Design Guidance for Climate-Smart Agriculture and Food Systems for more guidance on governance and planning in watersheds and resource use efficiency in agriculture and food systems.

Engage in Water Allocation Processes. Responsible government entities, farmers, and other water users and stewards must work together and coordinate to ensure that water uses do not exceed the water available. There should be equity in distribution and allocation based on current and future needs, water availability, and quality of the water, while taking the responsibility of the agricultural sector on water use into consideration. The significance of multiple water uses and users is not only about competition, but also about inter-user benefits. For example, wetlands, rangelands, pastures, forests, and natural vegetation can act as natural water reservoirs during droughts and buffers during floods. Similarly, water allocation for crop and fodder production should be calculated at the landscape or basin level.

As larger numbers of farmers invest in farmer-led irrigation systems,[6] it is even more important to engage farmers to raise awareness and build knowledge to support improved WRM and formal or customary laws and regulations that reduce unsustainable water abstraction from both surface and groundwater sources.[7] According to the latest estimates from the Food and Agriculture Organization of the United Nations (FAO), women account for an average of 43 percent of the agricultural labor force in developing countries, but in spite of this, water policies related to agriculture continue to wrongly assume that farmers are men, thus marginalizing women in WRM. Therefore, programs should work with relevant government entities to enable women's access to water rights, regardless of land ownership, by strengthening women's leadership in water policy and decision-making spheres and supporting their membership in water user organizations.[8] In many farmer-led settings where no water user associations exist, water use or allocation agreements should be explored and promoted at the community level.

Improve Watershed Protection. In some contexts, interventions and practices to improve protection of watersheds can be designed by integrating diverse funding sources in support of participatory planning processes to enhance agricultural productivity, sustainability, and resilience by improving water quality, quantity, and flow, while reducing vulnerability to flooding, drought, and chronic water insecurity. Interventions may include restoration of degraded watershed lands, adoption of sustainable land use practices and the use of nature-based solutions. Protecting watersheds from agriculture-based pollution, and solutions to protect them, must be at the community level with support from farmers and livestock producers. While frequently underused, green infrastructure and improved land use practices can offer lasting, cost-effective improvements, with multiple cobenefits for water resources, food security, climate change adaptation, communities, and ecosystems. For example, natural solutions in agroforestry systems can close their canopies earlier, reducing both evaporation from the soil surface and surface runoff; however, such community-based solutions must be locally led with extensive support and agreement from participating communities.

Increase Resilience to Shocks and Stressors. Agricultural WRM is vital to improving resilience, especially to climate threats. Given the increasing threat and impact of compounded shocks, including climate and weather, conflict, rural-urban migration, and others, it is important that implementing partners consider future impacts and the adaptations and transformative changes that will be needed within WRM systems. This may include understanding groundwater flows, understanding increasing demands given urbanization and changing land uses, etc. Seasonality, slopes, and soils are also important considerations. Drought can bring in new technical practices, institutions, and agreements that can be carried forward once the drought breaks. Interventions must not only address how and what individual farmers change, but how to enact group agreements impacting watersheds and subcatchments, as well as collective action at the governance and social levels, so that changes are adopted in the long term.

Strengthen Cooperation and Reduce Conflict over Water. Water insecurity can create or exacerbate tensions that generate fragility within communities and countries and across borders. Policy interventions that improve water resources for one scale or group of users can bring risks, conflicts, and externalities for other users. The greater competition for water resources often raises questions: who will get the water and how will allocations be decided? Conflict will often grow between farmers, pastoralists, and herders, between farms and cities, and between those upstream and those downstream. Therefore, it is important that programs and implementing partners utilize conflict-sensitive approaches and bring together and build the capacity of and trust between stakeholders to establish or improve governance processes in order to prevent the escalation of a water conflict. Tools such as the Conflict Assessment Framework, the Water and Conflict Toolkit, and the Land and Conflict Toolkit, can be leveraged to integrate conflict analysis and Do No Harm principles in program design and to identify linkages between water, conflict, and proposed USAID activities.

Review Land and Water Tenure.[9] Existing water rights, tenure arrangements, usage agreements, or compacts may need to be carefully reviewed considering climate change and evolving water uses. In many contexts where food security projects are active but where governance is not prioritized by governments, community approaches and agreements are necessary. Past water availability and usage calculations typically assumed relatively constant water availability from year to year and did not foresee advances in irrigation technology, increased demand from other sectors, or climate change-induced rainfall changes. Past agreements may have also underestimated the amount of water needed in hydrologic systems for healthy ecosystems.

Expand Access to Profitable and Efficient Irrigation Practices. One of the most complicated and contentious topics in WRM for agricultural systems is how to reduce net water consumption in irrigation so that: (1) "conserved" resources can be allocated to other users in the river basin, including healthy ecosystems, and (2) crop production levels are maintained or increased. A basic policy that seeks to improve WRM by creating more productive capacity from the same amount of water might create economic, legal, or behavioral incentives that drive up efficiency. However, this type of policy will be incomplete and possibly flawed if the means to achieve, and consequences of, higher irrigation efficiency are not fully managed (e.g., if higher efficiency drives up unsustainable water consumption, negatively affects sensitive ecosystems, or accelerates soil/land degradation from inadequate drainage).

Use of Data and Analysis. Some resources and inputs are readily measurable. Farmers can easily determine their farm area in square meters or hectares, their total production in weight or number of bags harvested, their yields in weight or number of bags per harvested area, and the income generated. However, other components of the system, particularly those related to water use, such as performance ratios, are notoriously difficult to measure. Supporting water and related weather- and climate-monitoring and information systems and developing capacity to analyze and use data for decision-making are important interventions to promote improved WRM for agricultural, livestock, and aquaculture production systems. An important factor to consider is that data collection, storage, and use is highly context sensitive—designing such interventions must consider the motto, "Nothing for us without us," as some communities are highly sensitive to any centralized data collection.

Consider MUSs. Planning for new or upgrading existing irrigation systems should include consideration for MUSs. MUSs provide water to serve multiple uses, commonly irrigation and domestic use, but could also include uses for postharvest processing and livestock. Since most irrigation schemes occur at the watershed level, MUS is best considered at the governance, policy, and planning stages. MUSs enable communities to allocate water resources, increase income from irrigation, and create economic and leadership opportunities for women and girls.

Use Landscape-Level Approaches for WRM. The landscape-based approach is increasingly recognized as an effective way to address challenges in WRM for improved food security, enhanced environmental integrity, and adaptation to climate change. Farmers are often caught at a crossroads with the question, "What would it take to transform rural areas into resilient, sustainable, equitable, and economically vibrant communities?" This requires a landscape approach bringing multisectoral solutions. Most agricultural systems are intertwined with natural resources, such as fallow land, grazing/rangelands, valleys with water flow, and forests. These agricultural systems form the basis for the livelihoods of rural communities who depend almost exclusively on these natural resources. Many factors, such as population rise, climate shocks, land use changes, decline in cropland fertility, and increase in livestock populations, have resulted in growing pressure on water resources. Given these changing pressures, water resources are often overexploited and degraded, and consequently decline in their quality and productivity. This often affects ecosystems and economic prosperity for societies at large. Thus, for a better outcome at the farm level, there is a need to integrate landscape-based approaches into water management.

Illustrative WRM Policy, Planning, and Practices Interventions
● Developing economic, technical, and institutional incentives for water conservation that enable or underpin water reallocations, such as improving land tenure security and payment for ecosystem services. ● Promoting appropriate governance or informal user agreements appropriate to the scale of the activity. These should align with broader GFSS objectives relating to poverty, malnutrition, resilience, sustainable and efficient natural resource use, and equity, including for marginalized and underserved groups. ● Improving data collection, information sharing, and decision-support tools that enhance WRM and resilience while ensuring that such activities are used for equitable WRM plans and are not used to further marginalize any groups or households.

- Integrating water-monitoring practices that gauge water balance, availability, and quality.
- Supporting watershed conservation and restoration efforts that improve water quality and retention and strengthen natural systems and ecosystem services to support food systems and productivity.
- Identify current informal and formal agreements among farmers underpinning community expectations of individual water withdrawals.

On-Farm Water Management and Sustainable Irrigation

On-farm programming should support farmers to strategically design and increase the efficiency of affordable irrigation systems, including intentional design for MUSs. Effective WRM for on-farm water management mitigates environmental costs and risks of both large- and small-scale irrigation. Other activities include addressing land degradation, salinization, and erosion; loss of ecological stream flows; pollution; destruction of natural habitats and livelihoods; and waterborne diseases.

Technologies and Practices to Reduce Field Applications of Water. Many approaches exist to reduce the amount of water applied to crops and fields: irrigation scheduling, field-edge/infield control of water, sprinkler or drip irrigation, and soil moisture meters. Innovative technologies and practices, such as drip irrigation; small, affordable pumps; and small-scale water harvesting and storage, can boost the irrigated area and productivity of small-scale farmers. Certain considerations and tradeoffs, however, must be considered. Discriminatory norms and practices, along with a lack of access to land, credit, and markets, are huge barriers to farmer adoption of improved technologies and practices and should be addressed.

Incentives to Reduce Field Applications. Combining soil moisture learning tools and training on crop water recommendations, farmers see that they can reduce labor time for water while increasing production and quality, leading to increased income. These effects may take several seasons to be fully appreciated. For example, farmers who have to pump water using their own fuel or paid-for electricity start to economize on fuel and water. Irrigators in southern Tanzania who agreed to a small levy on land area to be irrigated also started to economize on water. Solar pumping may also be an option; however, for farmer-owned systems, this may encourage over withdrawal since the resource has already been paid for. In other settings, higher energy prices often increase the costs of pumping water, applying fertilizers, and transporting products. Interventions should ensure that female farmers are able to participate equally and equitably. Farmers also respond to intra-farmer competition for water in their irrigation system, for example, accepting that in rotational systems, they should take their "turn" and pass the water to the next farmer within a strict timetable. In practice, this can lead to perverse incentives because farmers fear their next turn will not come.

Crop and Water Productivity. Water use efficiency efforts should reduce water applied to crops and fields per unit area while maintaining, or even increasing, crop yields. This requires farmers to boost crop productivity (the ratio of crop biomass per water unit consumed). Practices include: mild deficit irrigation, using shorter-season or drought-resistant varieties, not irrigating infertile soil patches, and better crop husbandry (via fertilizer, better weeding, land preparation, pest control, etc.). A key intervention can be increasing access to newer, more water-efficient crop varieties. However, consequences of these practices and technologies, such as increased labor requirements or timing of labor availability, should be analyzed with any intervention.

Good, Cost-Effective Soil and Land Management. Soil and land management also plays a vital role in the water requirements of crops—soil conservation practices that build healthy, rich soils also function to store water for crops to access in the short term and allow roots to penetrate into deeper, more water-abundant soil layers. Inadequate or increasingly erratic rainfall is often compounded by inappropriate tillage practices and a lack of soil vegetation cover. Many soils become degraded and infertile due to the leaching of nutrients, erosion by water and wind, and salinization, making farmers unable to obtain maximum potential yields. These negative impacts can be reduced by introducing good physical soil and water conservation practices. Better soil and land management practices can provide win-win solutions and increase water productivity, reduce surface runoff through modified tillage practices, increase soil organic matter, improve soil structure, replenish soil nutrients, increase water infiltration and water use efficiency, conserve soil moisture, and increase efficiency of nutrient uptake by crops. Nature-based solutions and green infrastructure, such as tree cover, planting between shrubs, building bunds and contour ridges to capture rainwater and slow runoff, increasing soil carbon, and others, should be considered, where appropriate. However, the quantity of biomass inputs needed to improve soil health and soil water storage may be unrealistic in resource-constrained environments. Labor-intensive interventions, such as surface mulching or large-scale organic soil amendments, may result in a larger labor burden, particularly on women, and reduce the available forage for livestock.

Infrastructure Influences. Physical infrastructure often mediates how farmers receive water and apply water in their fields; physical design also affects whether they are able to reduce their applications. For example, a paddy rice farmer in the middle of a 300-hectare (ha) rice system with few canals who receives her water from a neighbor's fields has little control over timing, rates, location, and depths of flow. A farmer with an irrigation system for two 1-ha farms, each fed by a channel and gate, has greater control (e.g., she can switch off her water when it is not needed).

Sustainable Intensification Assessment Framework (SIAF). This framework can be used to evaluate the potential of an innovation by considering the impact on overall farm productivity, economics (including profitability, stability, production, and market risks), environment, social and human condition, resilience, ability, and means, as well as access to products and services that enable farmers to adopt innovations. Successful cases of using the SIAF are evident in sub-Saharan Africa. For example, the tool is now being used by the Zambian government as a mechanism for technology validation and clearance to roll out agricultural technologies as farming interventions within the country.

Irrigation Management Plans. The Mapping Systems and Services for Canal Operation Techniques (MASSCOTE)[10] toolkit provides structured procedures for developing a strategic approach for irrigation management on canal/gravity irrigation systems. In most contexts of food security programs, gravity/canal systems are absent, and private sector irrigation equipment is more prevalent. Most private sector companies selling irrigation equipment (pumps, etc.) offer basic templates for calculating water needs and guiding on-farm management.

Water Management for Livestock and Aquaculture. There is no question that the livestock sector utilizes a great deal of water and land (41 percent of total agricultural water, 35 percent of total cropland, 20 percent of blue water, and many times as much green water), mostly to produce feed.[11] Livestock systems, therefore, need to be fully integrated into agricultural water use approaches.[12] Similarly, freshwater aquaculture has influent and effluent requirements that need to be integrated into the surrounding landscape and neighboring water needs.

<table>
<tr><th colspan="2">Illustrative On Farm Water Management and Sustainable Irrigation Interventions</th></tr>
<tr><th>On-farm practices in both rainfed and irrigated agriculture and soils</th><th>On-farm practices in irrigated agriculture and soils</th></tr>
<tr><td>● Improve rainwater infiltration and in-situ soil moisture conservation via land preparation practices (e.g., contour plowing and ridges).
● Improve rainwater harvesting (e.g., via ex-situ rooftop, surface ponds, and aquifer recharge).
● Increase soil water holding capacity by managing organic matter, crop rotation, and deeper-rooted</td><td>Note: All practices on the left apply to irrigated farming, in addition to this list.
● Empower farmer groups to maintain, operate, and monitor irrigation systems.
● Locate sources of water, including mixing with treated wastewater and aquaculture effluent.
● Support farmers with information about efficient</td></tr>
</table>

plants. ● Reduce off-season evaporation through use of cover crops and mulches. ● Work with rainfall timing via adjusting planting dates in sowing windows. ● Carefully select crops and varieties for agroecological conditions and climate. ● Improve indicators farmers use to monitor WRM and their crop/water productivity. ● Intersperse native shrubs and trees among crops, tapping into deeper soil and drawing water up for crops. ● Reduce runoff of agrichemicals into streams and rivers through training on integrated pest management and appropriate fertilizer application.	irrigation technologies and practices. ● Map areas, flows, and times in distribution networks, allowing bottlenecks in the under- or over-supply of distributed water to be identified and adjusted. ● Gray water and treated water, often not appropriate for horticulture crops, can be used on irrigated fodder. ● Integrated agriculture-aquaculture can diversify farm production and provide cobenefits to both fish and crop production (e.g., tilapia raised in rice ponds).[13]

Markets, Farm Inputs, and Private Sector Engagement

Access to markets can have a crucial influence on the management of agricultural water. Collaborating and encouraging irrigation practices in areas where there is no access for farmers to sell their produce will likely lead to net loss for farmers. Access to high water-saving technologies such as drip irrigation, as well as services such as maintenance, can influence the adoption of the technology in different contexts. The less the profitability farmers gain from selling the produce, the higher the likelihood of using low-cost technologies, such as using terraces for better soil and water conservation or using calabash bowl[14] or rope and washer[15] to irrigate—which makes it hard to scale due to the high labor use and many other factors.

Farm inputs, such as fertilizers and mechanization are critical in adopting farming practices that influence farmers' decisions on which WRM practice they might pursue. "Efficient irrigation reduces the amount of fertilizer needed per plant, as nutrients can be dissolved in the irrigation water for uniform application, reduced waste, and lower labor input."[16] Mechanization practices, such as Zero Tillage, save water by increasing the amount of pore spaces between the soils.[17]

Engaging the private sector is increasingly becoming critical for sustainability of research for development and scaling of technologies. "From companies to small scale farmers, the private sector is co-creating, co-funding and co-managing irrigation related business."[18] In addition, the private sector provides extension services and financing for agricultural projects that have water-related investments. The private sector, driven by profits as well as by development partners, is increasingly pursuing inclusiveness—such as with approaches to reach more women and resource-poor farmers, for example, by refining credit scoring and assessment tools and market segmentation to be more gender responsive.[19] Private sector partners have also been partners in scaling of technologies through local service providers—where, for example, a farmer in a community can provide irrigation and other associated services, such as tilling and harvesting, for a very reasonable fee from individual farmers or a community of farmers.[20]

Illustrative Markets, Inputs, and Private Sector Engagement Interventions
● Supporting sustained investment into WRM to support food systems by strengthening public finance and developing private sector and civil society partnerships. ● Sponsoring or developing training programs to teach youth how to install and maintain various irrigation systems and technologies.

Programming in Practice

West Africa: The SERVIR Activity trained representatives from West African hydrological and agro-meteorological services to develop seasonal forecasts, allowing farmers to anticipate and better prepare for wet and dry years. Seasonal forecasting is one of the best adaptation strategies to climate variability and climate change in West Africa. By developing and disseminating information characterizing the rainy season before it starts, farmers and other stakeholders can adapt their cropping systems and value chains to make better use of rainfall.

Guatemala: Under the Western Highlands Integrated Program (WHIP), five critical water recharge areas were reforested by coffee farmers and local governments using local tree species, and they prepared long-term management plans. The Buena Milpa Activity (through the International Maize and Wheat Improvement Center (CIMMYT)) improved soil and water conservation practices through green mulching. MasRiego (through the Horticulture Innovation Lab at UC Davis) promoted drip irrigation to commercial farmers and youth production groups—producers and technology providers were supported to provide finance and training, resulting in high-value horticulture producers switching from overhead spray irrigation to drip irrigation and expanding production.

Malawi: The Malawi Agriculture Diversification Activity (AgDiv) promoted drip irrigation to a wide variety of producers. AgDiv facilitated the financing, sales, delivery, installation, maintenance, and producer training of drip irrigation kits. This resulted in higher numbers of women than men adopting the technology for the promoted crops, primarily for orange fleshed sweet potato; however, more men than women adopted drip irrigation to produce other crops (such as Irish potato, paprika, and chilies).

Bangladesh: The Feed the Future Bangladesh Cereal Systems Initiative for South Asia—Mechanization and Extension Activity (CSISA-MEA) supports smallholder farmers to affordably access cost- and resource-saving sowing, irrigation, harvesting, and other types of machinery. It is a follow-on activity from the CSISA—Mechanization and Irrigation (CSISA-MI), which taught producers how to sustainably intensify and diversify agricultural production through surface water irrigation to increase household income. CSISA-MI promoted axial flow pumps (AFPs), highly efficient irrigation machines, into local markets by building public-private partnerships that addressed key components of the supply chain.[21]

Ethiopia: The Feed the Future Innovation Lab for Small Scale Irrigation (ILSSI) focuses on generating evidence for effective expansion and inclusive access to small-scale irrigation, while boosting social and ecological resilience. ILSSI has had great success in scaling irrigated fodder in Bahir Dar, Ethiopia, as there was a demand for livestock feed due to the expansion of dairy farming in the peri-urban and urban areas. Farmers allocated plots of land ranging between 50 and 140 square meters (m^2) per household for Napier grass production. The continued farmer participation and strong collaboration with local partners meant that more farmers adopted the practice, reaching 400 farmers by 2018, and with many households allocating as much as 1,000 m^2 for irrigated fodder.[22] The adoption rate is continuing at an increasing rate.

Funding

To holistically improve WRM that supports GFSS goals, it may be advantageous to integrate multiple U.S. Government investments. Feed the Future funding is necessarily focused on GFSS goals, but additional resources that relate to water (including water directive, biodiversity, democracy and governance, and climate change adaptation and mitigation funds) may also help advance GFSS goals through sustainable WRM. See the Water Resources Management Technical Brief for more information.

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