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

REPORT ON

Climate change, WATER RESOURCES, and irrigation sustainability

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FEED THE FUTURE INNOVATION LAB FOR SMALL SCALE IRRIGATION

Managing water resources sustainably for food security and climate adaptation

Small-scale irrigation enables farmers to adapt to climate change and build resilience. Water resources are currently underutilized in agricultural production in much of Sub-Saharan Africa, allowing significant scope for irrigation development.

Individual farmer investments have the potential to fill the gap in public investments and be [more cost-effective than large-scale irrigation](). However, this development primarily occurs outside of formal systems.

Water depletion and declining water quality in some areas of Africa and Southeast Asia suggest the need for careful planning and monitoring of small-scale irrigation to support resilience and avoid maladaptation. ILSSI research partners sought to support decision-makers to understand where and how water can be sustainably used by small-scale irrigators, employing and strengthening capacity for tools to manage competing demands and mitigate the risks to water security. Research partnerships also guided organizations and companies to deploy solar irrigation technologies based on biophysical and socio-economic suitability. **Working with farmers, water users, and extension services, the project aimed to improve on-farming water management practices and engage communities to help safeguard water resources.**

Improving livelihoods and adapting to climate change through farmer investments in small-scale irrigation

Across project countries, climate analyses show rising temperatures and evapotranspiration, changing rainfall patterns, and climate-influenced changes to hydrological systems. Across Ghana and Ethiopia, analyses expect long-term shifts in land suitable for irrigation, particularly for irrigation using surface water. Warmer temperatures and land use changes may interact to reduce water availability, such as in the Ndembera watershed. In the Blue Nile, seasonal rainfall change is expected to alter streamflow in major rivers. While each context varies, climate change is creating a need for irrigation and influencing water availability. In most areas, surface and groundwater resources should be used conjunctively and with good tools and practices for on-farm water management. **Treating rainfall and groundwater as an interconnected system can better support sustainable expansion of small-scale irrigation.**

Climate change is in part driving the need for supplemental and dry season irrigation. Application of the Integrated Decision Support System suite of models indicated sufficient water resources for smallholder farmers to sustainably expand irrigation in Ethiopia, Ghana, Tanzania, and in areas of Mali. Adding Agent-Based Models, studies showed adoption, probability, and outcomes within the environmental threshold in project countries, as shown in the table below.

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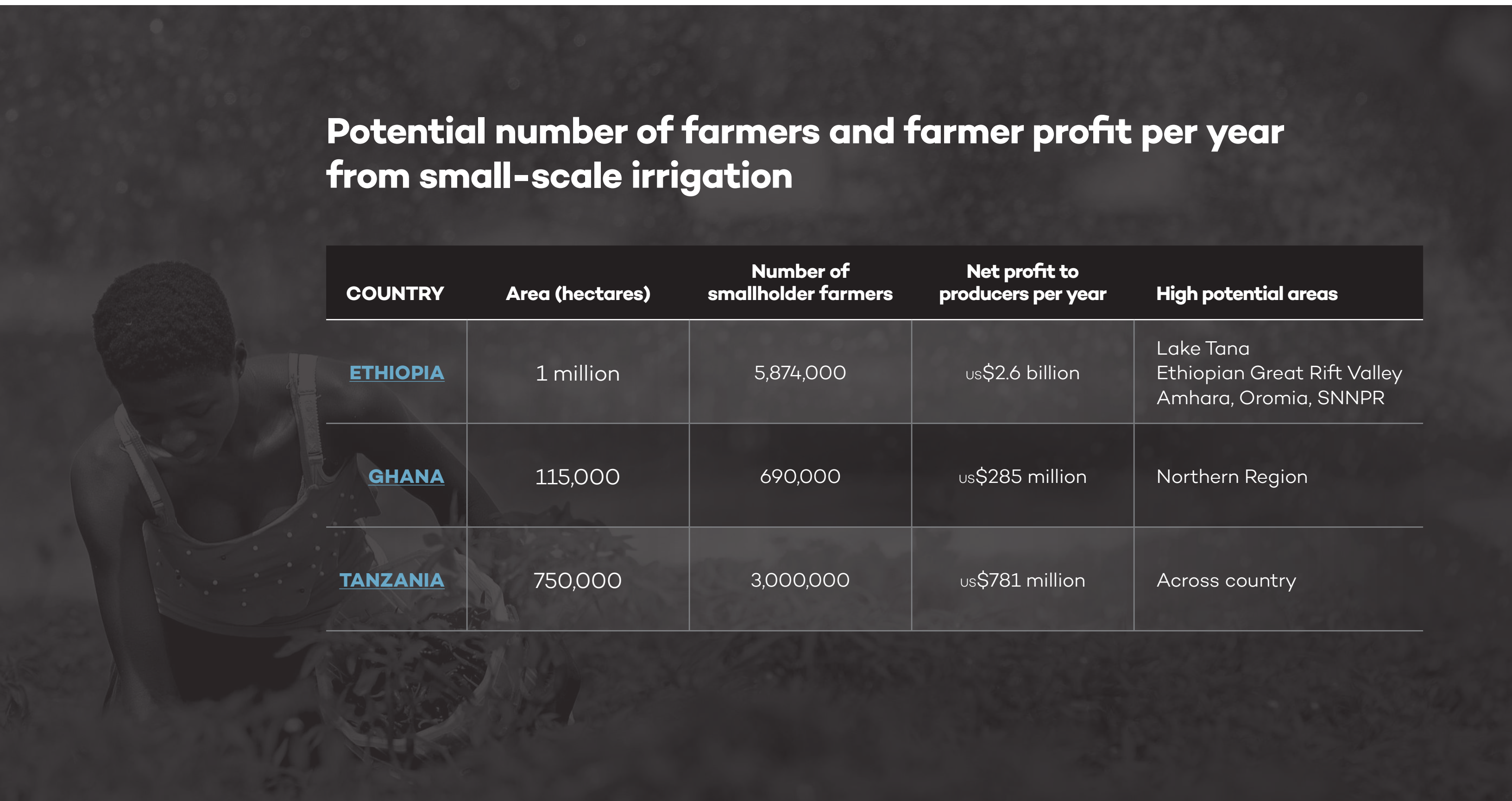
WATER RESOURCE ASSESSMENTS IN FEED THE FUTURE COUNTRIES



Potential number of farmers and farmer profit per year from small-scale irrigation

COUNTRY	Area (hectares)	Number of smallholder farmers	Net profit to producers per year	High potential areas
ETHIOPIA	1 million	5,874,000	US$2.6 billion	Lake Tana Ethiopian Great Rift Valley Amhara, Oromia, SNNPR
GHANA	115,000	690,000	US$285 million	Northern Region
TANZANIA	750,000	3,000,000	US$781 million	Across country

Farmers in Ghana dig ponds to store surface water for use alongside groundwater to bridge seasonal changes in water availability.

Understanding and managing groundwater as a valuable resource for small-scale irrigation

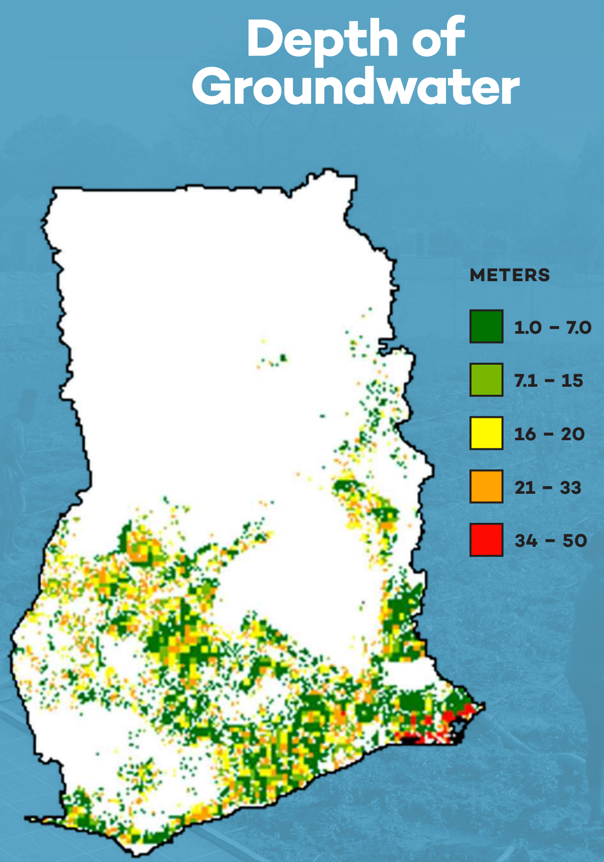
The boundaries for water supply at the current and expected rate of irrigation expansion need to be considered to avoid risk. Smallholders often tap into shallow groundwater using manual or mechanized pumps for multiple purposes, and increasingly, irrigation.

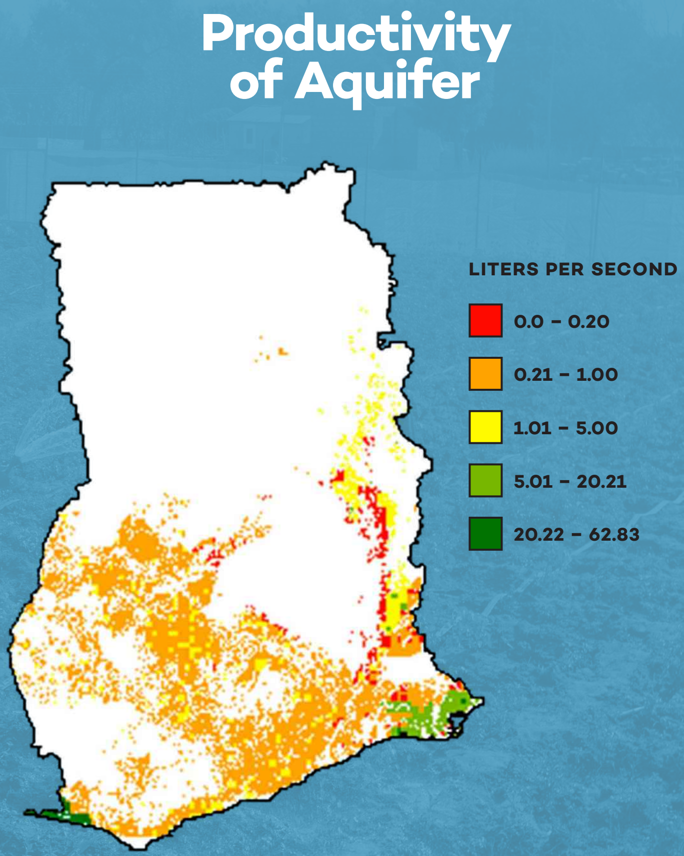
Groundwater can provide higher reliability than surface water during drought and variable weather, but seasonal variation can pose short- and long-term risks.

ILSSI partners assessed spatial variation in groundwater depth, storage, and aquifer productivity to identify irrigated land potential for different crops under current and climate change conditions. For example, one study found that shallow groundwater in Ethiopia is sufficient to irrigate only about 10% of suitable land. Studies showed that conjunctive use of groundwater and surface water — and more water storage — will be needed to irrigate vegetables sustainably across several basins, such as the Lake Tana Basin.

Millions of smallholder farmers live in hilly and highland areas, so ILSSI partners sought to fill information gaps about shallow groundwater on sloping lands. In the Ethiopian Highlands, water levels in shallow wells fluctuate across locations and seasons.

Most wells can only provide irrigation inputs during the initial months of the long dry season, except for wells at valley bottoms. ILSSI partners identified suitable water and soil management approaches to facilitate groundwater recharge for irrigation into the dry season. For example, farmers can use the berken plow and intercrop with pigeon pea to break up the hard crust formed below the surface of some soils in the Ethiopian Highlands to increase groundwater recharge for irrigation. Such measures also reduce rainwater runoff, limit soil disturbance and increase soil moisture, making carefully planned, small-scale irrigation possible in the dry season. At the same time, **ILSSI partners examined groundwater use for multiple purposes, highlighting the salience of adaptive community and watershed-level governance of conjunctive water use.**





Source: Effect of climate change on land suitability for surface irrigation and irrigation potential of the shallow groundwater in Ghana, Computers and Electronics in Agriculture

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CASE STUDY

Farmers in Ghana are turning to irrigation to adapt to climate change but face varied groundwater availability

In Ghana, decreased rainfall leaves insufficient water for rain-fed production to meet crop requirements, for example, in cocoa. While southern Ghana has the highest potential for surface water irrigation, many farmers in northern Ghana are beginning to pump shallow groundwater to irrigate vegetables and other crops. Water quality is often suitable for irrigation in northern Ghana. However, one study highlighted that shallow groundwater availability varies significantly, and some areas have insufficient shallow groundwater to meet crop water requirements. **Study results suggest urgency for climate adaptation and mitigation measures at different scales, including improved on-farm practices such as conservation agriculture and solar pumps for water lifting.**

2.3 MILLION HECTARES

LAND SUITABLE FOR SOLAR IRRIGATION IN GHANA USING SURFACE WATER AND GROUNDWATER ≤ 25 METERS

Source: Solar Photovoltaic Technology for Small-scale Irrigation in Ghana: Suitability Mapping and Business Models

Accurate water availability information is critical for the sustainable expansion of small-scale irrigation in a changing climate.

CASE STUDY 2

Supporting solar pump scaling as a climate-smart technology in Sub-Saharan Africa through suitability maps

More smallholder farmers are gaining access to solar pumps for irrigation through markets and development projects. ILSSI partners developed a multi-criteria analysis framework to map out the suitability of solar pumps in Ethiopia, Ghana, and Mali using biophysical and socio-economic factors. Several initiatives then supported expansion of the maps into an interactive online tool. As a result, companies and projects in Ghana, Ethiopia, Mali, Rwanda, and other countries have applied the maps to target potential pump users better and refine market strategies.

CASE STUDY 3

Using multiple tools to guide solar irrigation development in Mali

In Mali, Ségou and Sikasso have some of the largest areas suitable for solar-powered irrigation. Using water accounting plus (WA+), solar suitability mapping, remote sensing, and hydrologic modeling-based datasets, a study found about 145,000 and 655,000 ha of land suitable for solar irrigation in Ségou and Sikasso, respectively. However, it also showed that supplemental irrigation from groundwater is essential to avoid crop failures. Groundwater resources are available to provide supplemental irrigation and meet most of the crop water requirements during the dry season for an area of about 270,000 ha in Sikasso and about 80,000 ha in Ségou. To ensure sustainability, investment in solar irrigation should verify water availability and use and provide smallholder irrigators with guidelines on water management.

Strengthening production and productivity through improved water management tools, technologies, and practices

Small-scale irrigation expansion is led mainly by farmers within the market and outside public programs. Farmers lack access to production information for their own plots about localized crop-water requirements, suitability of land and water quality, risks to the water supply, and ways to mitigate potential depletion. Many public agencies lack the capacity to provide information to farmers. They do not have field-to-basin scale data to guide farmer practice, monitor water use and availability, and plan and regulate water use to prevent scarcity.

Field tests and model analyses showed that conservation agriculture practices can enhance on-farm water use compared to current farmer practices, improving soil health and reducing negative environmental impacts.

ILSSI project partners analyzed approaches to improve field-level agricultural water management. **Farmers benefit from increased crop yields, reduced yield variability, increased profit from agricultural activities, and enhanced nutrition.** For example, comparing conservation agriculture to conventional tillage, one site in Ethiopia saw 26% reduced soil evaporation and 35% higher yield in onion. In both Ethiopia and Ghana, conservation agriculture with drip irrigation reduced water use by 18-45% and increased crop yield. However, farmers indicated numerous challenges to apply these practices, such as a shortage of mulch and labor, so more options are needed.

21%

INCREASE IN CROP YIELD COMPARED TO CONVENTIONAL TILLAGE AT AN ETHIOPIAN SITE

44%

REDUCTION IN WATER USE COMPARED TO CONVENTIONAL TILLAGE AT AN ETHIOPIAN SITE

4 CASE STUDY

Learning tools enable farmers to improve on-farm water management

For farmers, irrigation learning tools showed promise to support farmers in adapting to climate change and managing water use in some areas. Tools such as wetting front detector systems enable farmers to achieve higher water productivity, increased yields, and improvements in the quality of produce. In Dangishta, Ethiopia, learning tools resulted in doubling onion yields for farmers using manual water lifting devices and 21% crop yield increases, and water use reduction by up to 44% for farmers using motorized pumps. **Solutions must be flexible, bundling technologies and practices that fit local conditions.**

5 CASE STUDY

To achieve health and nutrition goals, consider water quality

Intensified production poses risks to water quality, especially under irrigation. Sub-Saharan Africa is expected to experience the highest decline in water quality than any other region in the coming years. Continent-scale modeling using data on fertilizer and water indicated areas with high risks to water quality, which may be indicative of risks from pesticides. A field study in Ethiopia confirmed the presence of agrochemicals in surface water bodies and groundwater. Many households rely on these same water sources for household uses.

Studies have also pointed to gaps in local and national guidelines, regulatory systems, and testing and monitoring. Public agencies and water users need information about water quality, particularly related to agricultural intensification. In some cases, new guidance is needed for allowable levels of chemicals in water bodies, which will, in turn, require strengthened institutional capacity for monitoring and enforcement.

Wetting front detectors enable farmers in Ethiopia to learn how to manage water on-field for better yields and quality.

Governing shared water resources by the community contributes to improved water use practices

Managing water resources to ensure sustainability must occur at multiple scales and levels — from farmer learning tools and conservation practices for on-farm management to watershed and basin-scale irrigation planning and monitoring. In addition, community-level information and knowledge support adaptability and resilience. ILSSI project partners implemented experiential games that can improve farmer understanding of groundwater-related interdependences. Interventions in Ethiopia and Ghana facilitated discussions around water use practices, and norms, then assessed the impact of the games on participants' understanding. ILSSI also supported a South-South learning exchange between Ethiopia and Ghana to share experiences and explore entry points to scale the process to more communities.

KEY POINT:

Smallholders are investing in irrigation with resilience and food security benefits. Policy, planning, and monitoring need to keep pace.

Smallholders are investing in irrigation equipment and trying out new practices to respond to changes in markets and rainfed systems, increasing production in dry seasons. Evidence shows the benefits to farmers: climate change adaptation, increased incomes, and improved resilience. Water resources are sufficient to significantly expand small-scale irrigation within environmental boundaries in most African countries.

However, water systems are also highly contextual. **Sustainable management will require vastly increased capacity for localized analysis, planning, and monitoring of water availability and quality.**

As farmers continue to independently expand their investments in small-scale irrigation, they need support to learn to better manage water on-field for improved produce supply and income. Farm-level efforts should be linked to scaling community governance approaches. The growing number of companies in irrigation equipment supply may also play a role. Across scales, sectors, and actors, initiatives need to be coordinated and complementary to ensure resilience of people and prevent risks to water resources from farm and landscape to watershed, aquifer, and basin scales.

CONTRIBUTORS

FATI AZIZ

Post-doctoral Fellow, Department of Ecosystem Science and Management, Texas A & M University.

YARED BAYISSA

Assistant Research Scientist, Texas A & M University.

YIHUN T. DILE

Assistant Research Scientist, Spatial Sciences Laboratory, Texas A & M University at the time of research. Currently a data scientist in the private sector.

CLAUDIA RINGLER

Deputy Division Director of the Environment and Production Technology Division at the International Food Policy Research Institute and the CGIAR Research Program on Water, Land and Ecosystems.

PETRA SCHMITTER

Principal Researcher, International Water Management Institute.

RAGHAVAN SRINIVASAN

Regents Fellow Professor, Director of the Texas A & M AgriLife Blackland Research & Extension Center, professor in the Departments of Ecology and Conservation Biology and Biological and Agricultural Engineering at Texas A & M University.

Seifu Tilahun

Professor of Hydrology, Civil and Water Resources Department, Bahir Dar Institute of Technology, Bahir Dar University. (Currently with the International Water Management Institute).

Abeyou Worqlul

Associate Research Scientist, Blackland Research & Extension Center, Texas A & M University at the time of research. Currently with the International Center for Agricultural Research in the Dry Areas, ICARDA.

Hua Xie

Research Fellow, Environment and Production Technology Division, IFPRI.

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