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

Feed the Future Innovation Laboratory for Small Scale Irrigation

FINAL REPORT (2013-2018)

Submitted to USAID on Behalf of:

Norman Borlaug Institute for International Agriculture,
The Texas A&M University System (Lead Institution)

International Food Policy Research Institute (IFPRI)

International Livestock Research Institute (ILRI)

International Water Management Institute (IWMI)

North Carolina A&T State University (NCA&T)

Texas A&M AgriLife Research

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Acronyms

AE	Adult Equivalent
APEX	Agriculture Environment/Policy eXtender
AWM	Agricultural Water Management
BDU	Bahir Dar University
CA	Conservation Agriculture
CGIAR	Consultative Group on International Agriculture Research
CWR	Crop Water Requirement
EAC	ILSSI External Advisory Committee
FARMSIM	Farm Scale Nutrition and Economic Simulation Model
FEAST	Feed Assessments Tools
FGDs	Focus Group Discussions
FtF	Feed the Future
GIS	Geographic Information System
HDDS	Household Dietary Diversity Score
HICD	Human and Institutional Capacity Development
IDSS	Integrated Decision Support System
ILSSI	Feed the Future Innovation Laboratory for Small Scale Irrigation
INGENAES	Integrating Gender and Nutrition into Agricultural Extension Services
SNNPR	Southern Nations, Nationalities, and Peoples' Region of Ethiopia
SRI	System of Rice Intensification
SSA	Sub-Saharan Africa
SSI	Small Scale Irrigation
SUA	Sokoine University of Agriculture
SWAT	Soil and Water Assessment Tool
WASH	Water Sanitation and Hygiene
WDDS	Women's Dietary Diversity Score
WFD	Wetting Front Detector
WRM	Water Resource Management
WEAI	Women's Empowerment in Agriculture Index
WFD	Wetting Front Detectors
WLT	Water-Lifting Technologies
ZOI	FtF Zone of Influence

I. Executive Summary

The Feed the Future Innovation Laboratory for Small Scale Irrigation (ILSSI) is a cooperative agreement between USAID and Texas A&M AgriLife with a consortium of international partners. The geographic focus from 2013 to 2018 was Ethiopia, Ghana, and Tanzania. An external evaluation of the program found that ILSSI accomplished many of its objectives related to the following: 1) identify promising Small-Scale Irrigation (SSI) technologies, practices and strategies that have the potential to improve agricultural productivity, reduce farmer risks, improve nutritional quality and diversity, reduce poverty, and empower women farmers; 2) address the feasibility of SSI-related technologies and solutions; 3) develop farm-level recommendations, technologies, and strategies for improving access to irrigation technologies and related knowledge throughout SSA; and, 4) train agricultural and development students, educators, and professionals to analyze the farm- and watershed-level biophysical, economic, nutritional and labor implications.

ILSSI also contributed to advancing knowledge on farmer-led, small scale irrigation. Importantly, the project identified and mapped substantial areas for the three countries where SSI could be expanded sustainably without negative impact on water resource availability. SSI could have a substantial impact on agricultural growth, human well-being and poverty reduction for millions of smallholder farmers in those areas over the next ten years. Several pathways have been identified linking SSI and improved nutrition, particularly through increased income. While SSI can contribute to women's empowerment, project designers should follow guidance to reach women for equal access and benefit. The type of technology, crop choice and additional practices influence the benefits at household level, so project activities can be better targeted to meet aims. Constraints to adoption and water productivity were also identified, suggesting investments and interventions must be shaped to enable inclusive, broader access to SSI, in order to reach potential benefits for improved nutrition, income and agriculture-led economic growth.

The specific research outputs of the initial phase of ILSSI include recommendations on integrated farming systems for SSI, equipment for delivering and managing irrigation water use, gaps in related infrastructure to support the use of irrigation by smallholder farmers (e.g. financial products, information services), and guidance on gender and nutrition. In Ethiopia, irrigated fodder emerged as a new and high potential value chain that could improve incomes and also animal nutrition and health. An integrated modelling system was strengthened to estimate outcomes and impacts of SSI at multiple levels of scale with 99 water resource assessments. In addition, ILSSI emphasized capacity development, training over 2000 producers, civil servants and private sector actors in SSI tools, practices and analytical methods. Hundreds of young and mid-career scientists participated in short- and long-term training on the Integrated Decision Support System (IDSS). More broadly, ILSSI supported over 100 young scientists and students to completed thesis papers toward degrees. ILSSI mobilized capacity development activities to increase demand for scientific evidence and analytical tools for improved decision-making while simultaneously developing the capacity of individuals and institutions to deliver research results. Notably, ILSSI held tailored IDSS trainings for the Ministry of Agriculture and Natural Resources and the Agricultural Transformation Agency in Ethiopia, which enabled the analytical methods developed in Phase 1 to be applied to national level suitability mapping methods to plan new SSI interventions.

During the next five-year phase of ILSSI, the project focus will shift to scaling research to support expansion of inclusive, sustainable use of SSI. Inter-related research will also be undertaken on SSI and related water resource management as it contributes to social and environmental resilience. The deep engagement and strong partnerships built in the first phase provides a solid foundation for future work and positive outcomes.

II. Introduction

The Cooperative Agreement for the Feed the Future Innovation Laboratory for Small Scale Irrigation (ILSSI) is led by the Norman Borlaug Institute for International Agriculture (BI) of the Texas A&M University System (TAMUS). Collaborative sub-contracted partners include organizations from the Consultative Group on International Agriculture Research (CGIAR), including The International Water Management Institute (IWMI), The International Livestock Research Institute (ILRI), and The International Food Policy Research Institute (IFPRI). Additionally, North Carolina A&T State University (NCA&T) also serves as a sub-contracted partner. The ILSSI approach is an integrated, collaborative initiative from planning to implementation and engagement. ILSSI research methods were inter-disciplinary and multi-method, including field studies, surveys, qualitative studies and systems level analysis in Ethiopia, Ghana, and Tanzania. The following report highlights the achievements of ILSSI from 2013 to 2018.

This final report provides a summary of achievements on the Feed the Future (FtF) indicators, as well key messages from research. The research results briefly describe important findings around a set of development relevant questions, including: outcomes of small scale irrigation (SSI) related to nutrition, income, and gender empowerment; high potential for SSI in project countries; opportunities and constraints to scaling SSI; challenges to and options for managing trade-offs; and observations for future policy and programming. This report identifies trends across countries, and highlights some results for each country, drawing on peer-reviewed publications and other knowledge products developed by ILSSI. Finally, the report provides an overview of the approach to and achievements toward impact, including capacity development – a central component of the project – as well as engagement, outreach and communications.

Photo: Irrigated leafy vegetables in the Kera Market, Ethiopia. *Photo Credit: Apollo Habtamu, ILRI*

III. Program Partners

A. Cooperative agreement partners

ILSSI is led by the Norman Borlaug Institute for International Agriculture (BI) of the Texas A&M University System (TAMUS), with collaborative sub-contracted partners from the Consultative Group on International Agriculture Research (CGIAR), including The International Water Management Institute (IWMI), The International Livestock Research Institute (ILRI), and The International Food Policy Research Institute (IFPRI), as well as North Carolina A&T State University (NCA&T). In addition, ILSSI sought to achieve goals through a strong set of complementary international and local partnerships coupled with continual, in-depth stakeholder engagement. A list of partners and stakeholder organizations for each project country is provided in Annex 1.

B. National sub-awardees

In addition to the core/sub-contracted partners, ILSSI established national and sub-national partnerships through sub-contracts with research institutions and development organizations in each project country (Annex 2). These partnerships within the project countries aimed to jointly implement research, human and institutional capacity development (HICD), and outreach. ILSSI directly engaged national research and development organizations in each of the selected FtF countries in sub-Saharan Africa (Ethiopia, Tanzania, and Ghana) to identify research priorities, share results, and advocate for the implementation of SSI-related research results.

IV. Goals and Objectives

ILSSI seeks to contribute to the overarching FtF goal of reducing global poverty and hunger. Advancement toward inclusive agricultural sector growth and improved nutritional status is aided through the knowledge and information generated by ILSSI on SSI in sub-Saharan Africa (SSA). ILSSI's impact pathway/theory of change aligned with the FtF goals as depicted in Annex 3. More specifically, ILSSI's objectives were to:

1. identify promising SSI technologies, practices and strategies that have the potential to: improve agricultural productivity; reduce farmer risks; improve nutritional quality and diversity; reduce poverty; and empower women farmers.
2. address the feasibility of SSI-related technologies and solutions.
3. develop farm-level recommendations, technologies, and strategies for improving access to irrigation technologies and related knowledge throughout SSA.
4. train agricultural and development students, educators, and professionals to analyze the farm- and watershed-level biophysical, economic, nutritional and labor implications of these technologies and strategies.

In addition, recognizing that women are important food producers and that reducing gender inequality is critical to achieving global food security and with guidance from FtF and subject matter experts, ILSSI integrated a gender responsive approach to research design and implementation. In this regard, ILSSI sought to expand on the limited research-based evidence on the links between irrigation and gender on issues related to production, resources, income, leadership and time. The irrigation-nutrition-gender linkages were also central to identifying the potential impact pathways linking irrigation with gender and positive nutrition outcomes in Africa.

V. Overview of Activities

A. Countries and sites

ILSSI's primary project countries included Ethiopia, Ghana and Tanzania, all of which had shown promise for SSI in previous studies. Specific field sites were chosen based on FtF Zones of Influence (ZOI), stakeholder consultations at project start-up, availability of historical data and complementary project data, and scores on a set of criteria related to potential for developing small scale, farmer-led irrigation. The sites for each country are outlined in Table 1.

Table 1. ILSSI sites across all project countries

Country	Region/State	District	Village
Ethiopia	Amhara	Dangila	Dangishita
Ethiopia	Amhara	Bahir Dar Zuria	Robit
Ethiopia	SNNPR	Lemo	Lemo
Ghana	Northern	Savelugu	Bihinaayili
Ghana	Northern	Savelugu	Duko
Ghana	Upper East	Nabdam	Zanlerigu
Tanzania	Morogoro	Mvomero	Mkindo
Tanzania	Morogoro	Kilosa	Rudewa
Tanzania	Manyara	Babati Urban District	Babati

B. Components and methodological approaches

ILSSI integrated methodological approaches with the primary methods including 1) application of a suite of analytical models (the Integrated Decision Support System [IDSS]), 2) implementation of quantitative baseline and endline household and intrahousehold surveys, 3) experimental and demonstration field plots, and 4) implementation of field tests, bringing action research to farmers' own fields on SSI technologies, water management practices (such as conservation agriculture), and SSI in value chains (such as fodder). ILSSI used qualitative methods to identify greater detail on socio-economic relationships that influence decision-making by farm households. These methods were used iteratively to analyze data collected through surveys and field studies, as shown in Figure 1.

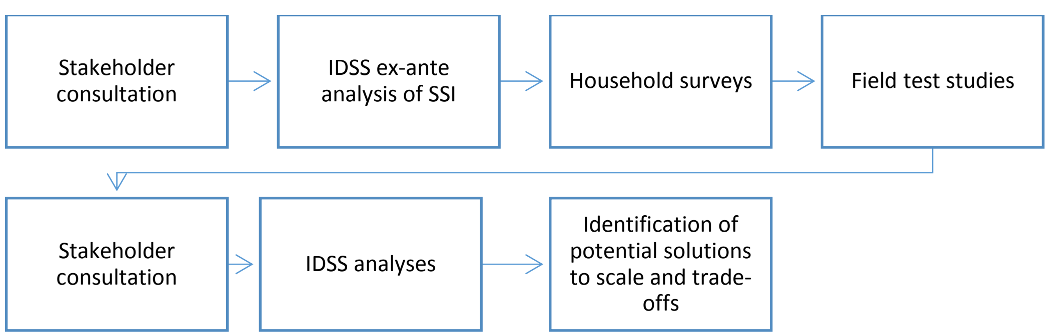


Figure 1. ILSSI integrated methodological approach

C. Research activities

While ILSSI integrated methods and shared data, cooperative agreement partners served a specific role in different types of research activities. Key research activities included field level pilots and data collection, surveys and systems level modeling; a list of activities across countries is provided in Annex 4.

Led by Texas A & M researchers, ILSSI refined and applied the IDSS to assess the holistic impacts of SSI on agricultural production, environmental sustainability and household income (Clarke et al. 2016; Worqlul et al 2018). The IDSS includes the Soil and Water Assessment Tool (SWAT), Agriculture Environment/Policy eXtender (APEX), and Farm Scale Nutrition and Economic Simulation Model (FARMSIM). The SWAT model helps to assess the impact of intensifying SSI on production and environmental sustainability at the watershed or national scale. The APEX model analyzes the production and environmental impacts of different farming systems at the field to small watershed scale. The FARMSIM model evaluates the impacts of different agricultural technologies on household income and nutrition. The models are integrated at multiple points. Data collected through pilot studies in farmers' fields, from representative groups of households in each site, and through surveys, enabled validation of the IDSS results.

Another ILSSI research activity was scaling analysis at the national level. IFPRI and Texas A&M developed an upscaling framework (described in Worqlul et al. 2017), which integrates several modeling tools and biophysical and socioeconomic data to provide spatially disaggregated, quantitative estimates of SSI development potential in the three study countries. The key components of the framework include: 1) Pre-suitability analysis using Geographic Information System (GIS) spatial data analysis tools; 2) Agent-based modeling for irrigation expansion simulation, simulating the process of irrigation technology diffusion. Economic and water balance considerations are also introduced into the simulation to refine initial estimates generated in the pre-suitability analysis, and to determine the likely potential scale and pattern of SSI development across the nation; 3) SWAT modelling; and 4) Economic analysis of irrigation and crop production costs and benefits.

A central component of ILSSI was the collection of two rounds of household survey data (baseline and endline) in each of the countries' study and control sites, which was led by IFPRI. The data collected were then used to assess the determinants of SSI adoption, the links between SSI and nutrition, and the links between irrigation and gender. The data also provided an input into the modeling work led by Texas A&M University. The household survey covered a variety of topics including crop and livestock inputs, production and practices (including both irrigating and non-irrigating households), income sources, consumption, household and women's dietary diversity, child health diet, and feeding practices, household food security, and anthropometry.

IFPRI also led research related to SSI and gender. The IFPRI survey included a modified version of the Women's Empowerment in Agriculture Index (WEAI)[1] to measure the relationship between women's empowerment and irrigation and how women's empowerment influences nutrition outcomes, particularly: decision-making roles on irrigated food and cash crops; codes for irrigated and non-irrigated crops, productive assets, access to extension on irrigation methods, and time spent irrigating. Data was analyzed related to men's and women's perceptions of the technologies that ILSSI field tested in project countries. Additionally, IFPRI collected data at the community level in each country while the surveys were

[1] The WEAI is a survey-based tool, asked of both the main male and female decisionmakers in a household, to determine the level of inclusion of women in domains important to the agricultural sector. These domains of empowerment relate to decision-making about agricultural production, access to and control over productive and natural resources, control over income and expenditures, leadership and time burden. See: http://weai.ifpri.info/

implemented. IFPRI and IWMI collected qualitative data through Focus Group Discussions (FGDs) on men's and women's roles related to different SSI technologies and intra-household decision-making.

Field level studies, led by IWMI, enabled evaluation of the trade-offs of agricultural water management (AWM) technologies, tools and practices. IWMI implemented the field studies as action research, piloting technologies, tools and practices in the 'real world' conditions in partnership with farmers on their own plots. IWMI tested multiple water lifting technologies (WLT) (solar, manual and mechanized pumps), irrigation scheduling tools (e.g. wetting front detector [WFD]), and irrigated agronomic practices in farmer fields. Analysis was conducted related to the biophysical suitability and sustainability, and economic feasibility; results were used to propose business models for promising technologies. As the project matured, stakeholders and researchers recognized constraints to adoption and scaling of SSI, which led to qualitative and quantitative research on access to credit and the SSI technology market supply chain.

Among the technologies field tested was conservation agriculture (CA), which was led by NCAT. Local farmers were trained and supported for the implementation of conservation practices and drip irrigation. Successful implementation of field operations and data collection activities were hindered by many local and uncontrolled challenges; nonetheless, at least five or more seasons of data were collected on crop yield, water use, and land and labor management, among others, were used in building a farm-scale APEX model specific to local field conditions.

ILRI led studies on a promising irrigated value chain – fodder - in all three project countries. The main targets of the irrigated value chain studies were to: 1) improve on meat and milk production for improved nutrition though better feeding; 2) evaluate forages as cash crop to improve income and employment opportunities; and 3) employ irrigated forage production to support diversification, intensification and sustainability. At the outset of the project, farmers in study areas did not allocate land and water to irrigated forage, requiring a a stepwise approach to field level studies, notably 1) Stakeholder engagement, 2) Community engagement, 3) Rapid diagnosis, 4) Pilot interventions and field analysis. The main research activities carried out through these steps were to: 1) assess and target areas where irrigated forage may play a role because of high feed demand using interactive and demand driven feed assessments tools (FEAST), 2) test key annual and perennial grass and legume forages for forage yields and fodder quality and optimize their agronomic management and depart essential training to farmers, extension officers and researchers, 3) survey fodder markets for demand for forages and forage price-quality relationships; and 4) explore multi-purpose use of forages for soil improvement, direct food production and water management. Though irrigated fodder was not practiced generally in any of the study areas, introduction by ILSSI led to evidence of the potential, as well as changed farmer practices and emerging opportunities for commercial fodder production.

D. Integrated approach to impact: Engagement, outreach and capacity development

ILSSI considers continuous engagement and national partnerships the foundation to ensuring relevant research and effective use of results. Engagement is an iterative process that includes activities at multiple levels related to human and institutional capacity development (HICD), outreach to policy and decision-makers at multiple levels, co-researching and publishing with technical experts and planners, as well as general communications to share results of research. Relationships with institutions responsible for SSI policy and investment were particularly targeted. ILSSI also utilized an External Advisory Committee (EAC), which provided oversight on research design, process and preliminary results, and acted as champions for the project with national stakeholders. The integrated approach is represented in Figure 2. Results and achievements across the engagement activities are discussed in the next section below.

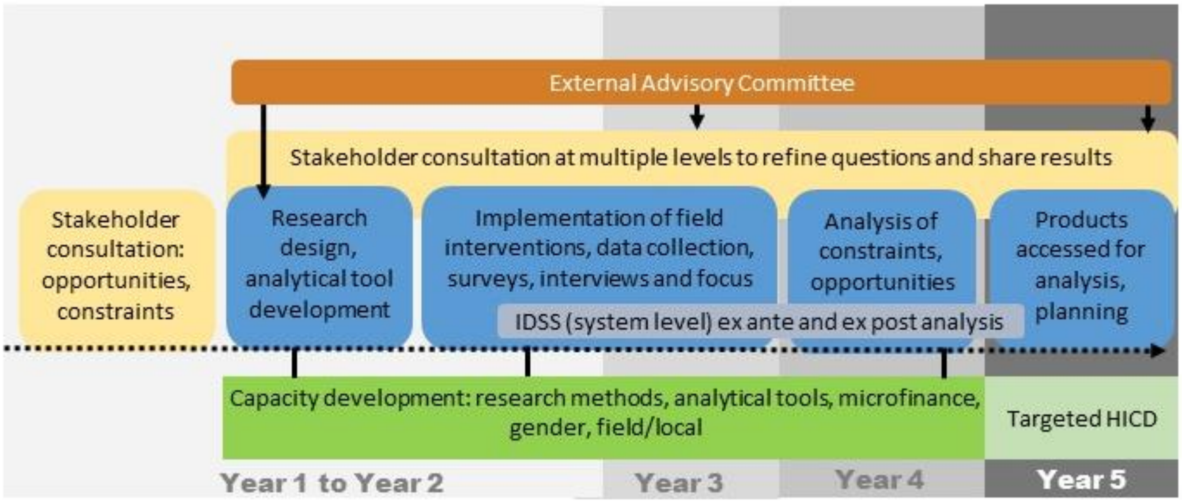


Figure 2. ILSSI engagement approach to impact

VI. Achievements

A. Achievements on Feed the Future indicators

ILSSI exceeded targets on all FtF indictors (Table 2). The number of short-term and long-term trainees reflected the high demand by national stakeholders for both the analytical tools and methods, as well as the technologies and practices under research and development. The number of water resource sustainability assessments contributed to national knowledge on available, potential and at-risk resources, which will serve as a resource for planning and future monitoring and evaluation. ILSSI also contributed to both policy analysis, as well as knowledge and information for evidence-based decision making on policy. The overall achievements represent the high value placed on water resources and the importance given to SSI by governments and investors.

Table 2. Feed the Future indicators: ILSSI five year achievement

Indicator No.	Description	Total
EG.3.1-12	Number of agricultural and nutritional **enabling environment policies** analyzed, consulted on, drafted or revised, approved and implemented with USG assistance	17
EG.3.2-1	Number of individuals who have received USG-supported short-term agricultural sector productivity or food security training	2247
EG.3.2-2	Number of individuals who have received USG-supported degree-granting non-nutrition-related food security training	109

EG.3.2-7	Number of technologies, practices, and approaches under various phases of research, development, and uptake as a result of USG assistance	141
EG.3.2-24	Number of **individuals in the agriculture system** who have applied improved management practices or technologies with USG assistance	624
EG.3.2-x41	Number of water resources sustainability assessments undertaken	99

B. Key messages from research

SSI is highly context-specific, both environmentally and socio-economically; ILSSI identified key trends and issues across all project countries. Research findings around key development questions that relate to FtF goals were grouped together. The overarching messages are briefly described here, while more detailed results can be found in separate reports, publications, and knowledge products detailed in Annex 5.

1. What contribution can SSI make to agricultural growth and human livelihoods, particularly nutrition and income?

Key Message: SSI can have a positive impact on nutrition and income, and therefore, support achievement of goals related to agricultural growth and improved human nutrition and livelihoods.

a. Irrigation-Nutrition Linkages

Interventions that aim to increase water availability for agriculture hold great potential for improving nutrition through increasing food production, generating income, enhancing water access and sanitation and hygiene conditions, and through strengthening women's empowerment. Under ILSSI, IFPRI developed four pathways that link irrigation positively with food security, nutrition and health outcomes (Domènech 2015). To illustrate these pathways, IFPRI adapted an agriculture-nutrition conceptual framework to include irrigation (Figure 3). Irrigation enters the framework as a productive asset in which **SSI enables the transformation of agricultural livelihoods through pathways of food production, agricultural income, water supply, and women's empowerment**, which can ultimately lead to changes in child and maternal nutritional outcomes.

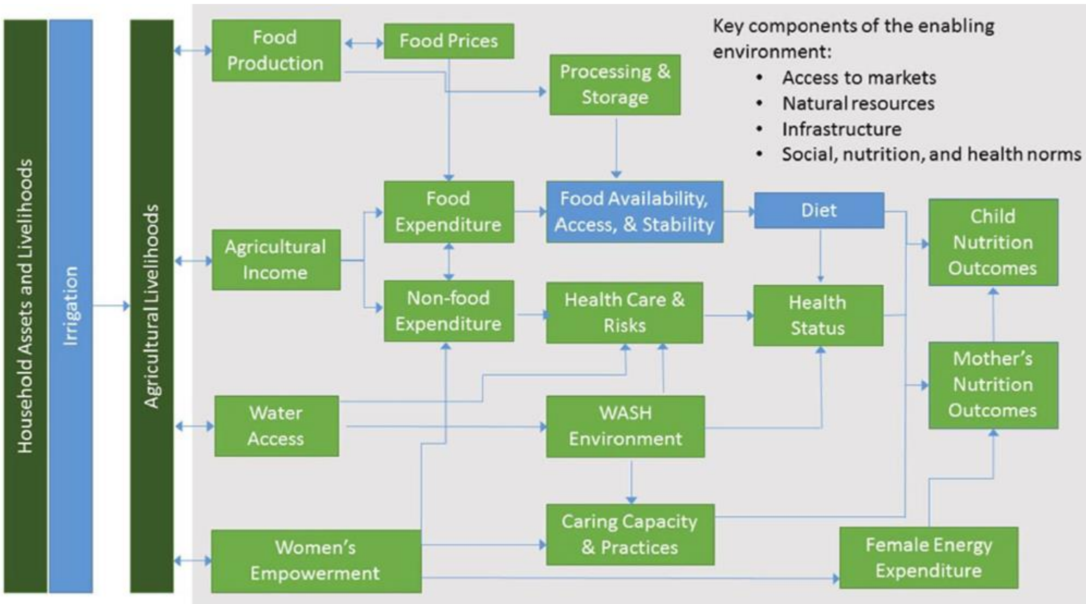


Figure 3. Pathways from irrigation to nutrition

b. Irrigation--Income linkages: Income and other livelihood benefits of SSI

The IDSS analysis also found a strong **linkage between improved farm profitability and nutrition** through the use of SSI technologies, including the application of adequate fertilizers to cultivate high value vegetables and fodder. In general, low-investment cost irrigation tools (e.g. pulley) had a higher benefit cost ratio, but a lower profit amount, when compared to labor saving technologies. More specific to nutrition, results from an IDSS analysis generally align with the results from the surveys. Nutrient intake available were sufficient for calories, proteins, iron and vitamin, but not for fat and calcium in most of the studied sites. Significant increase in nutrients (e.g. calcium) however, was obtained with the use of profits (increased income) to purchase supplemental food items (e.g. milk, eggs and meat).

Text Box 1. World Bank uptake of irrigation-nutrition linkage information

As a result of the ILSSI project, the World Bank sought IFPRI's support in developing and expanding guidance for World Bank Task Managers leading irrigation, irrigation-WASH (Water Supply, Sanitation and Hygiene) and water resources management (WRM) projects. As a result, IFPRI developed a guidance note drawing on the work done under ILSSI to present a conceptual framework and set of indicators that can be used to promote and track nutrition sensitive irrigation and WRM interventions.

The overall goal of the initiative is to ensure that World Bank irrigation activities are implemented in a nutrition-sensitive fashion. The objectives of the guidance are to summarize the evidence on irrigation-nutrition linkages; to sensitize irrigation managers to nutrition outcomes; and identify indicators on nutrition that can be measured as part of irrigation development projects.

The guidance is currently under development and meetings will be carried out with specific project leaders over the next few months. A larger convening of project leaders is currently being planned during the World Bank's Water Week.

Field level results further indicated **SSI is profitable for farmers in most scenarios**, as represented in Table 3. Nearly all WLT can be economically feasible assuming high value crops. ILSSI identified the cost of labor, including household labor, as significant to the overall costs of irrigating. **Some crop-technology combinations show higher potential for strong profit and household income, and other**

for household consumption increases. Technology payback period ranged between less than 6 months (i.e., one or two cropping seasons) and up to 3 years. One important observation from the economic studies was that profitability decreases when family labor is measured and included in costs at local labor rates.

Table 3. Summary of economic feasibility of water lifting technologies

Country and site	TZ – Mkindo, Rudewa	TZ - Mkindo, Rudewa	ETH Adami Tulu	ETH Robit	ETH Robit	ETH Dangila – (*family labor cost incl*)	ETH Dangila – (*family labor cost excl*)	GH – Bihinaayili	GH – Zanlerigu, home garden	GH - Zanlerigu
Technology	MP	MP	MP	Pulley	Pulley	Pulley	Pulley	MP	RWH	MP
Irrigated Crop	Tomato	Eggplant	Cabbage	Fodder	Tomato	Onion	Onion	Corchorus	Pigeonpea	Onion, Amaranth
Profit-ability	+	++	++	-	+	-	+	+/++	-	+/++
Internal rate of return (IRR)	163%	281%	40%	-35%	185%	-	30%	47%	-	45%
Payback period for credit (years)	0.6	0.36	2	-	0.6	-	2.4	2.5	-	1.6

MP: Motorized pump RWH: Rainwater harvested (rooftop)

Irrigated forages were attractive to farmers particularly in Ethiopia, followed by Tanzania and somewhat less so in Ghana, though fodder did not display high returns when irrigated using intense labor methods. The attractiveness of irrigated forages tends to be inversely related to farm size and more directly related to access to alternative feed resources. In Ethiopia, ILSSI began with 14 farmers in 2014/2015 and increased to 399 towards 2018, which is largely a result of farmer to farmer information flow. Anecdotal evidence exists that **some farmers replaced *Khat* with irrigated forages, because of benefits to income through either cash sales in emerging fodder markets or through increased livestock productivity** when improved animal breeds were fed irrigated fodder. Fodder market and feed value chain studies in Ethiopia, Tanzania and Ghana showed that **considerable demand exists for forages as a cash-crop**. Smallholder farmers can, in some cases, sell forages with even higher returns from cropping irrigated forages than commercial farmers feeding irrigated forages to their own improved livestock.

Photo: Irrigated forages in Ethiopia. *Photo Credit: ILSSI Project*

c. Inclusivity: Irrigation-Gender Linkages

ILSSI results showed **SSI diffusion is not gender-neutral and not necessarily inclusive**. Gendered-related issues affect access, use and benefit from SSI, and in turn contribute to either discontinuation of use of certain technologies or continued adoption of technologies. ILSSI developed a framework for research and practice related to key factors both external to and within the household related to SSI uptake around three phases of technology adoption: 1) becoming aware of the technology, 2) trying out the technology, and 3) continued adoption (wherein farmers use the technology and decide whether to keep using the technology, based on their direct experience) (Theis et al. 2018). In Ethiopia, Ghana, and Tanzania, ILSSI found that men and women both face constraints at each of the stages of technology adoption, though these differ in nature and severity between men and women. Research shows **high potential for benefits from SSI, but also a lack of equal opportunity** to *enter* into irrigated production and *benefit* from SSI. Adopting SSI will almost always affect gender roles and relations in some way.

Text box 2. ILSSI research and knowledge products on gender and nutrition used by development projects

The Integrating Gender and Nutrition into Agricultural Extension Services (INGENAES) is a large USAID-funded consortium focused on advancing learnings to ensure women benefit from extension services, training, and technology diffusion. INGENAES is developing a gender and nutrition technology assessment toolkit to guide practitioners to promote technologies more inclusively. INGENAES relied on ILSSI products to develop this assessment toolkit and referenced the ILSSI gender-irrigation technology framework paper (Theis et al. 2017) and reached out to the ILSSI team for feedback on the toolkit.

2. What is the adoption potential of SSI?

Key Message: If SSI reaches its potential for expansion in area and number of farmers reached, it could have a substantial impact on agricultural growth, human well-being and poverty reduction.

With the understanding that SSI can have a positive impact on livelihoods, ILSSI also examined the extent to which SSI could be adopted in each project country. Table 4 below provides a summary of the potential area, number of producer beneficiaries (direct) and the net profit to farmers specific to SSI.

Table 4. Adoption potential of SSI per country over the next ten years

Country	Area (hectare)	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[2]
Tanzania	750,000	3,000,000	US$ 781 million	Across country

3. What is feasible and sustainable for SSI given water and land available for irrigation?

Key Message: Water resources are adequate in project countries to enable scale up of SSI to reach millions of farmers with promising net profits. In most areas, water resources need to be used conjunctively (ground and surface water), and/or with good tools and practices for on-farm water management.

Land suitability analysis in the three countries showed that there is a **substantial amount of suitable land to scale up irrigation**. Most importantly, the majority of this suitable land is biophysically (e.g. in terms of water resources availability, yield production, etc) and socio-economically (e.g. market access) convenient to scale SSI.

Watershed and scaling analysis further suggests that there is a **substantial amount of water resources potential to scale up SSI**; however, the generated surface runoff and groundwater recharge at field level may not meet irrigation requirement within the field. Runoff generated and groundwater recharged in nearby non-agricultural land (e.g. bushland, forest land, etc) may be used to meet the demand at the agricultural field level. Moreover, the groundwater and surface runoff should be used in an integrated manner (i.e. conjunctive use) to reduce negative environmental impacts. Evidence-based planning is needed to ensure SSI is developed in appropriate locations with good water productivity to avoid negative externalities on the environment.

4. What are the constraints to adoption? What are the trade-offs between approaches?

Key Message: Resource availability provides opportunity for upscaling SSI, but there are constraints to adoption and productivity. Each crop-technology combination presents trade-offs relative to achieving a range of FtF goals.

ILSSI identified potential **challenges to scaling SSI with regards to water availability from farm to watershed scale**. Notably, field scale and site specific IDSS analysis found constraints to use of a single water resource (i.e. only on groundwater or surface runoff), as well as unsuitable water and fertilizer application, poor tillage practices, and inadequate pest management. For example, the common practice of over-irrigation lowers agricultural productivity and can cause adverse environmental impacts. Many farmers across countries under or over water, suggesting the need for improved on farm water

[2] The Northern Region here denotes the area through the period of the research (2013-2018) and does not refer to the new boundaries of regions established in 2019.

management. Generally, **agricultural water management (AWM) tools and techniques can be used to improve water and agricultural productivity.** For example, WFD and TDR helped farmers to increase income by up to around 35% in some cases, through improved irrigation scheduling and water productivity. The field scale analysis also showed that combined application of urea and DAP (diammonium phosphate) with appropriate rates can double (or even triple) the yield compared to the current farmers practice. Moreover, results showed that **conservation agriculture practices contribute to a range of benefits**: increased crop yield, reduced yield variability and highest profit and nutrition outcome while improving soil health and reducing negative environmental impacts. For example, onion production with conservation agriculture had a 35% higher yield compared to conventional agriculture in Dangila. The application of soil cover on onion plots reduced the soil evaporation by 26% compared to conventional tillage while adding organic matter to the soil.

Photo: Farmers learn how to use irrigation scheduling tools (wetting front detector) at a Farmer Training Center in Ethiopia. *Photo Credit: IWMI*

Text box 3. Irrigation scheduling tools expanded in projects and information services through ILSSI

The irrigation scheduling tools gained attention in Tanzania and Ethiopia and has been integrated into various projects and capacity development projects. In Tanzania, Sokoine University of Agriculture (SUA) is developing a model farm designed to showcase working agricultural production systems and suitable irrigation technologies, including best water management practices. SUA is using research results from ILSSI in their model farms, including the WFD and other related soil moisture measuring and irrigation scheduling tools. SUA will share good practices identified by ILSSI through their model farm, which is used to educate young scientists and demonstrate options to extension workers and other related stakeholders nationally.

Labor is a major factor for farmers adoption, cost and profitability of SSI. Labor available in the household is often linked to the extent to which a household engages in irrigation; this is particularly the case given the labor-intensive methods commonly used. In some countries, having more household labor increases irrigation activity, but in most cases, farmers are labor constrained. Women farmers are particularly affected by labor constraints. In addition, household gender and age structure likely influence willingness to apply for credit to invest in SSI, as well as willingness to adopt and sustain use of SSI technologies. Results suggest that labor costs are sometimes higher than the investment cost of a motorized pump.

Most farmers across the project countries did not irrigate with labor saving technologies, such as pumps, but relied on labor intensive methods, such as buckets. These **methods for irrigation limit the area that can be irrigated**, occasionally affect crop choices of farmers, and ultimately limit the extent to which SSI will be able to expand and contribute to economic growth and well-being. Access to labor saving, more advanced technologies, is limited. Research shows that even when farmers want to adopt newer technologies, the **lack of access to appropriate financing and underdeveloped technology supply chains, reduce farmers' access to SSI opportunities**, particularly for women and resource poor farmers.

In general, the results suggest **that multiple benefits and impacts need to be considered in terms of trade-offs**, moving beyond technical efficiency and cash income (Table 5). For example, the introduction of manual WLT may increase household income and enable access to water for multiple uses, but may not substantially reduce labor input. In other cases, mechanized technologies, such as petrol pumps, may save labor and increase incomes, yet not reduce overall household labor or enable improved access to water for the household for multiple uses. Therefore, **technology selection is better considered across a range of potential benefits** for households, as well as program or local and national development goals.

Table 5. Summary of the opportunities and challenges related to water lifting technologies

	Labor saving	Yield	Water productivity	Profit	Multi-purpose use
Control	0	0	0	0	0
Rope and Washer	0	0	0	-/0	+
Solar	++	+	0	++	++
Service provision & drip	+/-	++	++	+/-	-

++, + and – represent a high, medium and low effect; 0 is neutral.
Case study from Lemo, Ethiopia.

A number of tradeoffs also emerged from the studies on irrigated forages. Using the FEAST to assess feed resources in a farming systems context and to prioritize feed interventions, ILSSI explored two irrigated forage options: annual forages that allowed integration of fodder cultivation with crop cultivation within one year of cultivation and perennial forages where land was allocated exclusively to fodder production over several years. At the same time, there are **trade-offs to be considered between forage varieties, yields, and farmer preferences, alongside the type of livestock**. On-farm livestock productivity trials and forage quantity/quality-livestock productivity modeling showed that irrigated forages have higher returns when fed to improved livestock rather than to local animals. In the latter case irrigated forages could have negative cost – benefit ratios. In this regard, the research suggests income implications based on the type of livestock, which is often linked with existing farm wealth and size.

Text box 4. Improving incomes through irrigated fodder

While farmers identify lack of quality and consistent feed as a primary constraint, they had not been irrigating fodder prior to the ILSSI project. Farmers in Ethiopia found an improved income source from milk sales from feeding their cattle the irrigated fodder. Surplus milk is sold to the emerging market for dairy products and collected at 'milk sheds'. Average milk yield information suggests double production with irrigated Napier and legume forages - from 2.3 liters to 4.6 liters per day per local cow. Farmers with 3-4 local breed milking cows are collecting around Birr 4000 – 5000 (USD 140-175) per month. There are additional benefits from providing cows with high quality irrigated forages, for example, livestock fattening before holiday periods, improved calves, manure for soils, biogas production, among others.

5. What changes in policy, practice and investments would enable scaling of SSI?

Key Message: Increased investments and targeted interventions are needed to enable inclusive, broader access to SSI, in order to reach potential beneficial outcomes, including improved nutrition and increased income.

Investments in SSI can be nutrition-sensitive, contributing to food security through various pathways. However, investments should be structured specifically to target nutrition outcomes. Not only is there a need for policy level, multi-sectoral commitments to irrigation toward these goals, but interventions should include complementary activities in nutrition training and nutrition sensitive messaging.

While water and land resources are suitable with high potential for SSI expansion, **evidence-based planning is needed** to ensure SSI development is in appropriate areas. Tools such as the IDSS are helpful for assessments. Furthermore, monitoring of water resources (groundwater and surface water) are important to monitor sustainability of use, considering factors such as availability and quality. Most farmer-led irrigation that uses SSI technologies is currently excluded from planning and monitoring, despite the growth, and potential of the sector.

To further encourage sustainable intensification through SSI, water productivity needs to be improved. **Irrigation development interventions need to go beyond water lifting**, which is often the primary focus of development programs and project. Affordable scheduling tools and conservation agriculture practices can improve water productivity, and in turn reduce negative externalities, such as water scarcity or pollution, while also increasing yields, quality and income.

Photo: Development Agent in Ethiopia demonstrates the wetting front detector.
Photo Credit: Apollo Habtamu

Project activities should be planned around the trade-offs between technologies and practices based on their objectives. Not all water lifting and other technologies lead to unilateral outcomes. Much like large-scale irrigation schemes, investments in SSI at household or group level should consider priority goals when selecting technologies to introduce. In addition, activities should identify where labor is costly and scarce and therefore, where SSI technologies can reduce labor requirements in agricultural intensification.

Access to finance may increase technology adoption and, therefore, expansion of SSI toward full potential. This applies to both the technology suppliers in the private sector and the buyers in the market. In present conditions, most smallholder farmers will not be able to invest in any SSI technologies. The unequal access to SSI will likely limit the ability to meet the full potential irrigated area and fail to reach the potential millions of small scale farmers who could benefit from SSI technology adoption. Appropriate terms of repayment (interest rates, repayment schedules, methods of debt collection) are also needed to create incentives both for farmers to borrow for irrigation investments and to ensure profitability from SSI investment. While public and private sector financial service providers face constraints on their reach into rural and remote areas, innovative financing options can be refined and piloted based on lessons and case studies from ILSSI and others (Merrey and Lefore 2018; Otoo et al 2018). At the same time, technology supply chains need to be strengthened to extend the market availability. Policy and regulatory incentives may stimulate private sector expansion of SSI technology markets, but care must be taken to ensure that the benefits from tax and tariff reductions reach smallholders through lower technology prices and better service packages.[3]

[3] The Government of Ethiopia approved a tariff removal on irrigation equipment in May 2019, following earlier recommendations, including from the Ag Water Solutions project in 2014.

Text box 5. Challenges and opportunities to accessing credit for SSI investments

ILSSI's approach in field tests was to work with local financial service providers or with groups of farmers to ensure full cost recovery of technology investments, i.e. ILSSI did not give pumps away free to farmers. Through this experience, as well as quantitative and qualitative studies, ILSSI identified challenges and opportunities related to finance access for small farmers:

- Access to credit increases likelihood that farmers will adopt technologies in some contexts
- Access to credit is very low in rural area; most microfinance providers do not reach farmers
- Microfinance providers, including village savings and loans organizations, often limit the amount of loans well below the cost of pumps
- Farmers prefer informal or semi-formal where cost of credit is high
- Pump sharing groups have high conflict, so smaller groups are more promising
- Repayment rate on the pumps was low
- Rural microfinance
- Supply: Finance providers see irrigated production as lower risk than rainfed

ILSSI research suggests that innovative finance opportunities are emerging and may be adapted from other sectors, such as "uber for irrigation", which provides optimism for future entry points on credit.

Solar pump water lifting could be a promising option for smallholder farmers. Solar pumps may reduce labor costs and decrease reliance on expensive inputs, particularly fuel; however, the initial investment is higher than other technologies. A business model analysis suggests both private and private-public interventions could support smallholder access to small scale irrigation (Otoo et al 2018; Gebregziabher et al n.d.). Moreover, ILSSI also identified suitable areas for solar irrigation development in Ghana and Ethiopia (Worqlul et al. 2018; Schmitter et al 2018a; Owusu et al. n.d.).

Photo: Installing a solar-based pump in southern Ethiopia. *Photo Credit: IWMI*

Policy and regulation currently lag behind the expansion of SSI; farmers are already identifying their own opportunities and expanding irrigation. While care must be taken not to discourage farmers from their own initiatives in irrigation, more guidance and planning is needed to achieve positive outcomes and to avoid negative externalities. For example, existing institutions need to be strengthened in planning and monitoring water quality, which research suggests is being affected through agro-chemicals associated with irrigation. In some cases, no guidance exists on allowable levels of chemicals in water bodies. In addition, more emphasis is needed on community and watershed level governance of conjunctive water use. ILSSI research points to the geographical areas where groundwater needs to be managed to avoid water scarcity.

Text box 6. ILSSI informs policy on irrigated fodder in Ethiopia

Over the course of the ILSSI project, irrigated fodder gained momentum in Ethiopia. The rapid uptake driven largely by farmers themselves, resulted in the recommendation of the Government of Ethiopia's Agricultural Transformation Agency (ATA) to consider irrigated forage production as a potential transformative intervention for Ethiopian smallholders in order to increase income and food security. ILSSI, together with Africa RISING, developed the "Irrigated fodder opportunities for small scale irrigators" brief on irrigated fodder opportunities to share results with policy makers.

Overall, one of the key recommendations of ILLSI is to target more inclusive development of SSI**.** Expansion to the potential area and numbers of farmers indicated in the upscaling studies assumes more farmers at different levels of socio-economic status can get access to SSI. Notably, public and donor activities in SSI **should apply lessons on how to integrate women into SSI production,** including: increasing access to information, securing rights to assets, supporting access to credit and markets, strengthening decision-making on income, and focusing on irrigated crops of interest to women (Theis et al. 2018). Ultimately, some **support to smallholders at lower levels of economic status is needed to ensure inclusive access, adoption and benefit.**

C. Country level results

1. Ethiopia

Results at a glance: Ethiopia

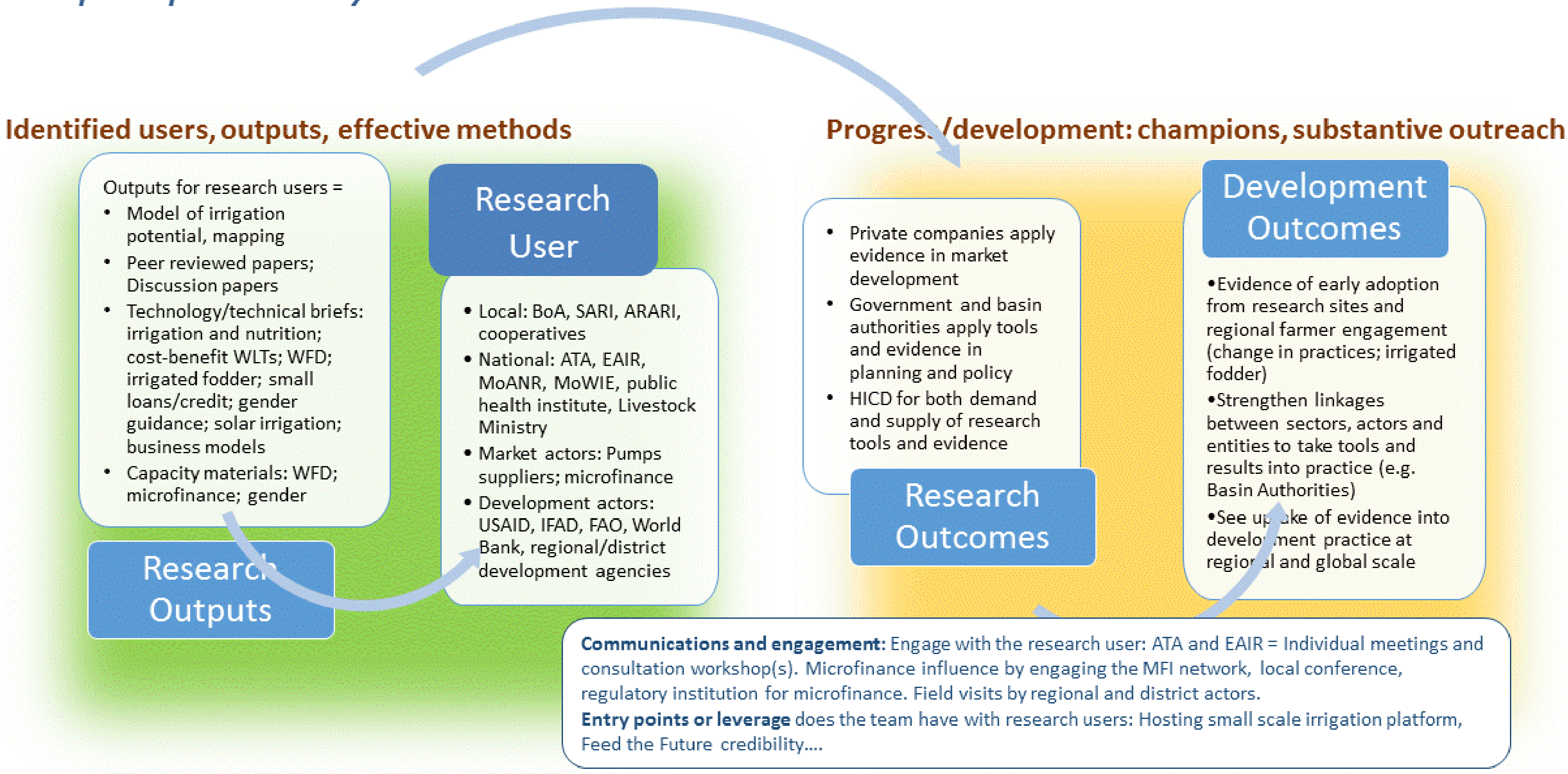
Key findings

- Potential for substantial land and water resources exist for scale SSI in Ethiopia. ~1 million ha of land is economically and biophysically suitable for SSI development
- High potential for net income of ~2.6 billion USD/year from SSI adoption
- Irrigation can be promoted as a nutrition-sensitive agricultural intervention
- Irrigation has a strong positive effect on the household's economic access to food and on nutritional outcomes of women and children
- Irrigated fodder can contribute to animal and human nutrition
- Groundwater is inadequate in some areas requiring conjunctive surface water use and improved field level water management and tillage practices
- Irrigation scheduling improves yields, produce quality, and reduces costs
- CA increases crop yield, reduces yield variability, and improves soil
- SSI technologies are profitable with high value vegetables
- Labor is a key factor in profitability and technology adoption
- Access to appropriate financing is low; access to credit may increase adoption
- SSI technology supply chain is underdeveloped
- Movement towards more women's involvement in decision-making
- Women tend to have significantly less access to information and training on irrigation
- FEAST is useful as a rapid tool to assess feed resources and prioritize interventions
- Promising forages include oats-vetch mixes and Napier and Desho grasses**;** multi-purpose forages offer multiple benefits
- Forages as cash crops have potential (fodder markets exist already); the sale of irrigated forages is more profitable for small holders with low producing animals

Recommendations

- Nutritional benefits of irrigation may increase with complementary activities
- Irrigation interventions should be considered as a package: water lifting, application, scheduling tools, fertilizer guidance, CA practices
- Groundwater recharge should be enhanced
- Appropriate institutions at multiple levels should be strengthened to prevent negative externalities of SSI
- Interventions should target women farmers specifically
- Programs/projects should consider trade-offs between technologies
- Policy makers and researchers need to give more attention to substituting high value crops to replace Khat

Ethiopia Impact Pathway



a. Contribution of SSI to agricultural growth and human livelihoods, particularly nutrition and income

Ethiopia irrigation profile

Irrigated production in Ethiopia is dominated by Khat[4], coffee, and vegetables. Agricultural income per hectare is two times more for irrigators compared to non-irrigators during the dry season. Producers use mostly groundwater and river water, but still rely on traditional methods[5] for extracting water. Only 14 percent of irrigating households own a pump, whereas 25 percent of households report using a pump for irrigation (owned jointly or rented). Water application is also largely traditional, being buckets or watering cans and flooding. Two-thirds of surveyed households that were irrigating, did so in the dry season.

Livestock is an integral part of the agricultural production system. Up to 30% of the direct income is derived from the sale of livestock and livestock products. Shortage of feed quantity and quality was ranked by farmers as the main constraint for livestock production. Most farmers depend on purchased concentrate feeds to supplement lactating cows and draft oxen. Supplementary forage production was generally not practiced by farmers prior to the ILSSI interventions.

Linkages between SSI, nutrition and income

Irrigation appears to have nutrition and food security benefits. While irrigation is not associated with a higher Household Dietary Diversity Score (HDDS)[6], Women's Dietary Diversity Score (WDDS) appears to be higher for irrigators than non-irrigators. Individuals who irrigate consume more vegetables, eggs, and sweets, thus providing key nutrients for child growth and overall health. Consequently, however, higher income from irrigation may lead to increased consumption of processed, high sugar, high fat foods. There is also a positive association between irrigation and consuming Vitamin A-rich plant sources. For child level nutrition outcomes, children under five in irrigating households have a higher weight for height score (wasting)[7]; irrigation is associated with reduced child wasting, but not stunting. This indicates irrigation may be improving households' food security.[8]

The farm simulation results also highlight the importance of the purchase of supplemental foods with the profit from sales of irrigated crops. The IDSS analysis indicates that available nutrient intake of calories, proteins, fat, calcium, iron and vitamin A per day and adult equivalent (AE) increased under alternative SSI scenarios. Additionally, IDSS analysis suggested an increase in milk and eggs consumption from

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[4] Khat accounts for 40% and 34% of irrigated plots during the wet and dry seasons, respectively.

[5] This report uses the term 'traditional' to represent labor intensive methods such as buckets, watering cans, or similar vessels such as calabash. This is not intended to indicate that the methods are customary or cultural.

[6] The Household Dietary Diversity Score (HDDS) indicator is used as a proxy measure of a household's food access. The score is comprised of 12 food groups. The Women's Dietary Diversity Score (WDDS) has 9 food groups and was found to be strongly associated with micronutrient adequacy for 11 micronutrients. The indicator was to be used as a continuous variable (ranging from 0-9 food groups consumed) and averaged to generate a mean value for populations. It however does not allow the assessment of the percentage of the population with low or adequate dietary diversity.

[7] Stunting, or low height for age, is caused by long-term insufficient nutrient intake and frequent infections. Wasting, or low weight for height, is a strong predictor of mortality among children under five. It is usually the result of acute significant food shortage and/or disease.

[8] The ILSSI intervention was not designed to address the multi-determinants of malnutrition. Recent studies that include nutrition-sensitive and nutrition-specific components still do not see a large improvement in child nutrition indicators. This is because, at least for stunting, the intergenerational effect of malnutrition is difficult to overcome. Improvements in child nutrition requires multi-sectoral improvements. Irrigation is one component, but results show it is not sufficient to move the needle on stunting. We did not explore the associations between irrigation and hygiene and sanitation practices within the household (this will be done in ILSSI Phase 2), poor access to healthcare, etc. These factors may also be at play. Parents' knowledge is also crucial for improved infant and young child feeding, and ILSSI did not have include this component in the design.

purchase had more impact on nutrition improvement at the household level than the consumption of additional animal source food items from improved animal production on farm. However, there is consistent deficiency in fat and calcium even for irrigators. Moreover, irrigated fodder and conservation agriculture had a positive impact on income and nutrition, mainly through the income pathway.

Linkages between SSI and Income and other livelihood benefits

As indicated above, the primary pathway to nutrition improvement for irrigators appears to be income, which makes it particularly important to assess profitability of irrigation. IDSS results showed higher annual net profit for scenarios associated with irrigation of vegetable and fodder. In general, low-investment cost water lifting technologies, such as pulley, had a higher benefit cost ratio but a lower profit amount in comparison to the rope and washer pump and motorized and solar pumps. Cost-benefit analysis suggests that across sites and regardless of crop type, investment in diesel/petrol pumps is profitable and could be scaled up without subsidy. The economic returns from solar pump irrigation is highest with drip irrigation and high value vegetables. The feasibility of irrigation using manual pumps, is highly dependent on labor and the crop type.

Analysis from the irrigation scheduling interventions also show a positive effect on income through reduced labor input and increased yield (Schmitter et al., 2018b). Use of the WFD improved farmer income from yield gains combined with reduced input costs for labor, fuel and fertilizer.

Irrigated fodder holds potential to reduce animal feed constraints, improve animal productivity and improve household income. ILSSI identified farmer preferences for fodder, as well as benefits of irrigated fodder for livestock productivity. ILSSI found a 4-fold increase in demand by farmers for oats-vetch, in addition to substantial farmer-to-farmer seed exchange.

A key conclusion is that investment in labor-saving technologies for lifting, application and management can improve profitability, as well as the likelihood to adopt and sustain use of the technologies. Different technologies, however, have trade-offs between income and consumption, in addition to labor demands.

Linkages between SSI and gender

Men's and women's shares of labor input varies dramatically with the type of technology utilized. Motor pumps reduce the amount of time men and women spend irrigating compared to traditional methods. While roughly equal numbers of men and women provide labor for irrigation using traditional methods, men are much more likely to provide labor when pumps are used.

In terms of decision-making, data suggests a movement towards more women's involvement in decision-making, especially on irrigated production. Many men and women involved in the 1-5 Gender Training Program reported more joint decision-making and men supporting women in their roles. However, women perceive that men may consult with their spouses but often have final decision-making authority. Notably, women have lower input into decisions on income, which has implications for distribution of benefits from SSI within the household. Women tend to have more control over income from the sale of vegetables produced on plots near the home and for daily expenses such as food; men control decisions regarding larger expenditures.

Still, a large gap in access to information between men and women exists. Data indicates that women have much less access to information and training programs on irrigation (58% female vs. 80% male) than men; invitations to meetings and trainings are typically sent only to the head of the household.

b. Adoption potential of SSI

Given the benefits of adopting SSI to livelihoods and well-being, the upscaling analysis results are promising. Upscaling results [9] found about 1 million ha of land is economically and biophysically suitable for nutritious dry-season, small-scale irrigation development over the next 10 years. Net benefits from adoption are estimated at around US$ 2.6 billion per year. A high probability of adoption for SSI is at Lake Tana and Ethiopian Great Rift Valley areas, while Amhara, Oromia and SNNPR have the highest potential (Figure 4a). However, analysis on the probability of water scarcity due to adoption of SSI suggests that this could become an issue; the Rift Valley area has the highest risk (Figure 4b).

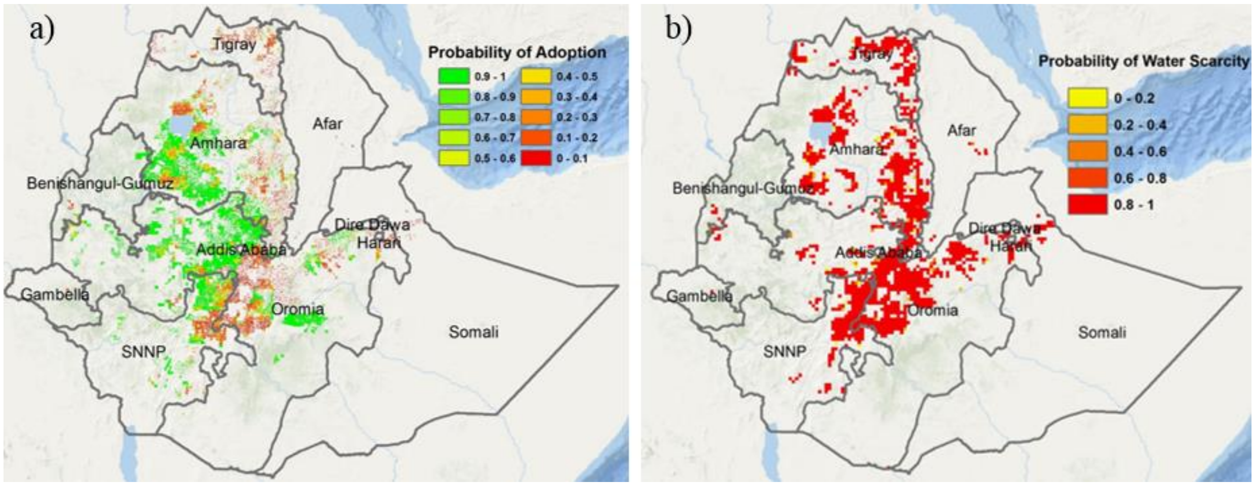


Figure 4. Probability of a) adoption and b) available water scarcity due to adoption of small scale irrigation

Note: (a) green areas show high adoption probability of SSI, yellowish areas indicate moderate level of adoption and red shows low level of adoption probability; (b) red areas shows high probability to have water scarcity due to adoption of SSI with increased water usage, and yellowish areas showed minimal probability of water scarcity due to adoption. The SSI adoption was studied only in agricultural areas, therefore, forest land, grassland, etc were not considered in the analysis.

c. Environmental feasibility, sustainability and trade-offs

Potential land suitable for irrigation

IDSS analysis also showed strong potential for SSI in Ethiopia. In Figure 4, the preliminary suitability map (85% as the threshold for suitable) shows 60,025 km^2 (~5.3% of landmass) suitable for surface irrigation (excluding groundwater resources). Abbay basin (Blue Nile basin) has the largest area of suitable land (21,186 km^2), and the Rift Valley basin has the highest percentage (20%) of suitable land for irrigation.

[9] The upscaling analysis focused on dry season irrigated crops determined based on household survey information and literature for each context: onion, cabbage, pepper, lentils and vetch fodder. These crops were studied only in agricultural lands and in rotation with existing rainfed crops.

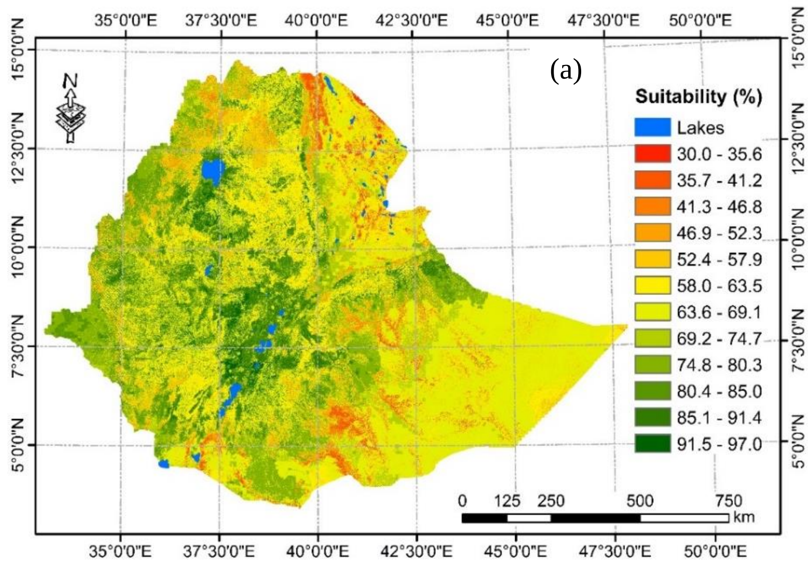


Figure 5. Preliminary suitable land for surface irrigation

Biophysical potential for and constraints to scaling

Studies indicate that rainfall is larger than potential evaporation during the rainy season. A substantial amount of water resources is available for SSI to produce vegetables and fodder (water yield is far more than the irrigation water requirement in more than 83% of agricultural land). Analysis in four sites at the field and watershed scales shows generally that there is abundant water and land resources to scale up SSI, especially in the Lake Tana area.

However, there are extended dry spells and droughts, and high variablity of rainfall; rainfall is inadequate during the cultivation period of the dry season. Robit and Dangishta watershed analysis suggested that there is ample water resource potential to support irrigation, but groundwater recharge may *not* meet the irrigation water requirement for dry season cultivation. Irrigation on the sloping lands from shallow groundwater could aid only partially in dry season production; deep groundwater reserves or surface water would also be needed. Based on limited data available, the shallow groundwater accessible under 25 m from the surface can only irrigate 8% of the suitable potential land using simple water lifting technologies powered by human, animal, diesel and solar. [10] Where groundwater recharge is often not sufficient to support the irrigation water requirement (e.g. Adami), conjunctive use with surface runoff may help to reduce adverse impacts on the aquifer. Otherwise, continuous use of groundwater for SSI may deplete the aquifer in some watersheds. Indeed, expansion of smallholder irrigated land in the Ethiopian highlands is likely to be constrained by groundwater availability.

Limited availability of groundwater suggests another reason for enhanced on farm water management. Recharge in the upper Blue Nile could improve with practices such as deep tillage or *Berken* plow that increase permeability and, therefore, root penetration and agricultural productivity, in addition to decreasing erosion and runoff (Muche et al., n.d.; Abdela et al. n.d.). The adoption of these technologies in the Ethiopian highlands could enable more groundwater availability for irrigation and reduce some negative impacts of intensification.

[10] Note: This is without accounting for lateral flow between grids of 5 km. Groundwater irrigation potential may increase if lateral flow is accounted.

Also, smallholder farmers often under- or over-irrigate which results in low water productivity. Irrigation management tools, in conjunction with the use of manual water lifting technologies, hold potential to improve productivity for high value crops (Schmitter et al. 2018a). IDSS analysis showed that over-irrigation[11], besides lowering agricultural productivity, can cause increased surface runoff, leaching and soil nutrient losses. Suitable fertilizer guidance to farmers alongside irrigation and scheduling tools may help optimize effects between water and nutrient management, including avoiding soil degradation (Gedfew et al., 2016 and 2017).

Multiple benefits were observed from producing vegetables under CA and drip irrigation, including: increased yield, increased water productivity, improved soil quality, and reduced labor when compared to conventional farmer's practice. A substantial amount of water saving was observed, which helped the farmers in the field sites to produce twice in the dry season alone. Furthermore, CA with drip irrigation also helped to minimize soil erosion, weeds, and labor hours. The combined on-farm water management tools and practices can help ensure sustainability in the long term.

Text box 7. Youth expand into irrigated vegetable production after observing ILSSI success

A number of Ethiopian youth used the demonstrated success of ILSSI research farmers to obtain land from their families to start dry season irrigated farms in Robit. All the youth involved observed practices from the ILSSI project farmers on water lifting, on-farm water management and agronomic practices. All the youth involved made profits the first season, which encouraged other family members to begin dry season irrigated production.

Photo: Gared Tibeb attending to tomato plants on his 62m² plot loaned by his father, Robit
Photo Credit: ILSSI Project

Potential for irrigated fodder

In addition to IDSS and field studies on water, an additional analysis using FEAST showed high probability of success for feed technologies under SSI. This included fast growing, short-lived annual forages such as oat-vetch fodder that do not occupy cropping land for the entire cropping period, and perennial grasses on soil bunds, backyards and farm boundaries. Forage technology options vary by

[11] irrigation exceeding the optimal crop water requirement

location; Amhara sites had high yielding perennial grasses while oats-vetches mixes and intercropped options did well in SNNPR.

Text box 8. Spontaneous scaling of irrigated fodder

The number of farmers growing forages in the Robit-Bata kebele grew from only 17 farmers in 2015 to 183 in 2017. The number of irrigated forage producers is well over 400 when other areas are included. More farmers have been reached on irrigated fodder opportunities and practices through field days and experience sharing events. Farmer-to-farmer technology sharing is spreading the information; interviews with three trained farmers showed that the interviewed farmers in turn shared the technology to seven additional farmers. As evidence of the high interest from farmers, the plot area assigned to irrigated forages by individual farmers grew from $100m^2$ to $1000m^2$ on average over the life of the project. Farmers and government agencies in the Amhara region are beginning to scale irrigated fodder production to more communities in the region.

Some farmers are removing khat and planting forages. For example, seven farmers in one sub-kebele removed khat and planted Napier grass. Farmers state that they do not need to apply the pesticides to irrigated fodder as they do to khat. They also claim that forage production requires less irrigation water compared to khat.

d. Constraints to adoption of SSI

Credit poses constraints to adopt manual and motorized technologies; access to credit is a positive factor in technology adoption (Hagos et al., 2017). In addition, households who had access to credit invested in higher cost technologies than those who had no access to credit. It shall be noted that many maximum loan amounts are still below the costs of water lifting technologies.

Currently, Ethiopia has an underdeveloped SSI technology market (Hagos et al. 2018). A select number of technologies are available in the main cities for water lifting, but there is no observable supply of supporting tools and equipment, such as for irrigation scheduling. The current market structure displays oligopolistic market characteristics with significant implications for access to technologies. At the same time, there are also demand constraints; willingness to pay studies suggested many households were unwilling to pay the actual market prices (Gebregziabher et al. 2018). Carefully structured business models could be used to scale SSI, notably with solar pumps (Otoo et al 2018).

While irrigated fodder showed high potential in Ethiopia, some trade-offs should also be noted. On-farm livestock productivity trials showed (supported by the modelling of livestock performance conceptual framework), that irrigated forages benefit farmers with improved livestock breeds more than farmers with local livestock, i.e. conversion of oat-vetch biomass into milk depends on the genetic potential of the dairy animal. However, farmers with low producing livestock could still benefit from irrigated forages. A rapid assessment of fodder markets found significant market demand for forages**.** Notably, women have been the major players in the green forage market. Samples were collected from all fodder markets and analysed for feed price quality relationships.

2. Ghana

Results at a glance: Ghana

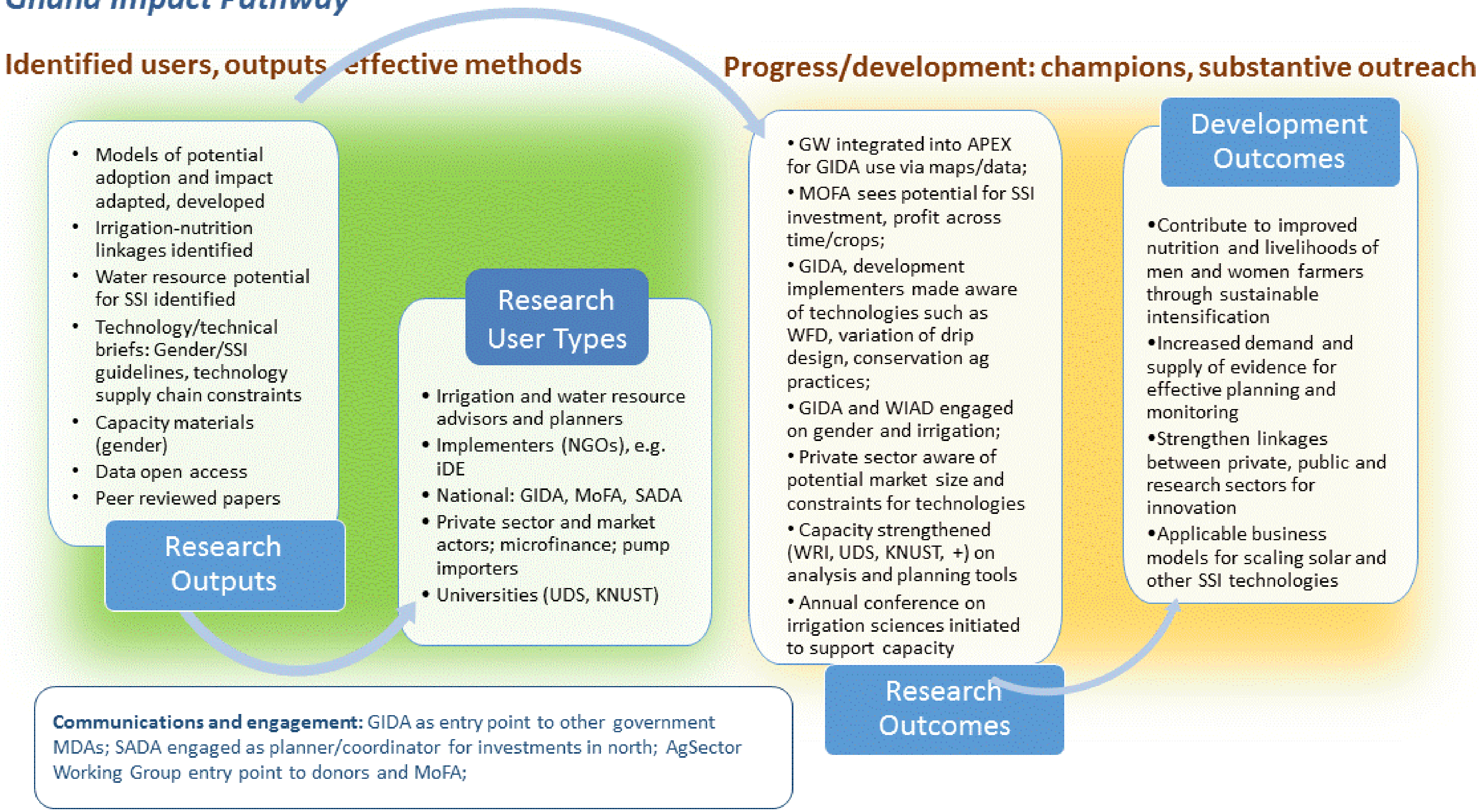
Key findings

- Around ~211,000 ha of land is economically and biophysically suitable for SSI development
- SSI adoption could generate net income of ~$285 million USD/year benefiting 690,000 smallholder farmers
- Irrigation in its current form, is important but not sufficient to dramatically improve nutrition; expansion is severely restricted by labor intensive, traditional methods
- Irrigation is positively associated with household dietary diversity (economic access to foods) driven by income increases and production changes; increased consumption of meat and vegetables comes largely from producers' own farms
- Available water resources can meet irrigation water requirement in most (~68%) of the suitable land for SSI
- Climate change may significantly affect the land suitability for irrigation
- Irrigation scheduling can improve water productivity, yields with consistent use
- Motorized pumps are profitable with high value vegetables
- High production costs (including labor, fuel) increase risk, decrease profit
- Climate variability, low soil fertility, and poor land and crop management practices are constraints
- Improved fertilizer rates can substantially increase crop yield
- Cropping of fodder improved soil residual nutrient and increased rainfed season crop
- Feed and Fodder value chain is emerging

Recommendations

- SSI needs to be carefully sited and managed to reduce negative environmental externalities
- Labor-saving irrigation technologies likely lead to improvements in productivity, income and nutrition outcomes
- Improvements in dietary diversity require complementary nutrition-sensitive and specific interventions
- Water management and productivity need to be improved in order to increase incomes
- Appropriate credit for agriculture and irrigation may incentivize investment in the SSI technology market
- Interventions that aim to increase inclusivity of economic development should increase women's access to information, technologies and tools, while also addressing household level decision-making
- Demand for off-farm produced feed exists in an emerging feed and fodder value chains, but farmer/markets awareness is needed on benefits and production

Ghana Impact Pathway



a. Contribution of SSI to agricultural growth and human livelihoods, particularly nutrition and income

Ghana irrigation profile

Irrigation in northern Ghana is dominated by onion production. Groundwater is the largest source of irrigation, followed by water from dams, rivers and ponds. Traditional methods of obtaining water and applying it to farmers' fields are common; buckets are the main method of obtaining, lifting and applying water, reported by 86% of irrigators. Only 10% of households in the surveyed area use a pump for irrigation; of those who use a pump, only 25% own the pump. The prevalence of manual equipment influences outcomes for nutrition and income. Irrigators that use any type of pump or gravity irrigate more land with higher potential for increased income and productivity gains. Bucket irrigators can only irrigate small plots of land and grow crops that consume less water. Given the high labor intensity of irrigation in Ghana, it is not surprising that households with more productive members (between 15 and 60) are more likely to irrigate.

Linkages between SSI, nutrition and income

Irrigators had a higher HDDS compared to non-irrigators, largely from differences in consumption of vegetables, fish, milk products, and honey and sugar (sweets). Irrigators are more likely to consume certain vegetables, meat and poultry, sugar and honey (sweets), milk and milk products and fruits, compared to non-irrigators. In the case of vegetables, meat, and poultry, irrigators are more likely to consume these foods from their own production; this suggests that the production pathway is more dominant for consumption of these foods. However, no association between irrigation and nutrition dense foods was observed. Likewise, irrigation is not associated with nutrient adequacy or micronutrients for women of reproductive age. For child level nutrition outcomes, irrigation is not associated with reduced stunting or wasting.

The IDSS nutrition simulation results showed an increase in potential available quantity intake, from the baseline to the irrigation scenarios, for all nutrition variables. Particularly, the calcium intake available for the household increased from the baseline to the irrigation scenarios 5 to 7 times as calcium was available from production and consumption of amaranth.[12] There was also modest improvement in vitamin A intake through the consumption of corchorus. Moreover, revenues from irrigated crops can help purchase supplemental food items, especially animal products.

Linkages between SSI and income and other livelihood benefits

IDSS analysis showed motorized pump scenarios generated three to five times higher net profit (5,800 GH₵ on average) for high value vegetables than the baseline scenario with low SSI investment. However, the profit was found to be more variable (risky) in motorized pumps scenarios than in baseline (Balana et al. 2019). Field tests showed profitability for SSI (Katic 2017), complicated by strong seasonal price fluctuation for typically irrigated crops such as onion. Profitability and economic feasibility analysis of sets of '*crop type–SSI technology*' combinations among dry season irrigated crops (corchorus, onion, amaranths, and cowpea) grown under SSI technologies (pump-tank-hose, watering can, and rain/roof water harvesting and drip irrigation) showed river water or shallow wells with motorized pumps is profitable for high value crops. Fuel costs and upfront investment in pumps constrain profitability (Balana et al., 2017), so should be utilized to full potential. In addition to technology costs, the high credit and

[12] Amaranth was inter-cropped with onion to provide more frequent cash income to cover pump running costs; amaranth appears to be preferred particularly by women farmers.

labor costs undermine profitability. Notably, irrigation labor is a higher cost than the cost of motor pumps.

Results also show the potential income benefits of inter-cropping and moving away from mono-cropping. For example, intercropping onion with amaranth boosted annual cash flows almost by 30% over mono-cropping onion. Given the high cost of credit, farmers interplant with a continuous production crop to cover fuel and other input costs *without borrowing* (Balana et al. 2017; Kadyampakeni et. al. 2017).

Text box 9. Expanding the benefits of irrigation to seed producers in Ghana

Farmers working with ILSSI researchers in Ghana increased their areas under irrigation, in some cases 10 fold, while many other farmers in neighboring communities obtained plots to work alongside the sites. In Zanlerigu of the Upper East region, onion seed farmers began producing seed under irrigation within the common fenced area. The irrigated seed farmers are selling their seed directly to the farmers in the ILSSI field sites and to other farmers in the area, to address the shortage of quality onion seed in the market.

Linkages between SSI and gender

Photo : Female farmer harvesting lettuce.
Photo Credit: Felix Antonio, Information Services Department, Ghana

In Ghana, both men and women are responsible for irrigating using traditional methods such as buckets, but more men provide labor for irrigation when pumps are used. There are strong social norms regarding ownership of assets–including irrigation pumps; both men and women report that men own irrigation pumps. It is widely accepted that men own large assets like motor pumps (also livestock) even if women use the equipment.

There is a trend towards greater participation by women in production activities both on jointly managed plots and women-owned plots. Women provide labor on family plots while also maintaining their own, often smaller, plots. Women plant different crops on their own plots, which are not considered the main crops according to many male farmers. Other aspects of decision-making also reduce participation and benefits of SSI for women. Women often lack access to land and water, as well as labor, for irrigated production; women tend not to seek land to farm unless they are confident they have the resources to maximize production.

b. Adoption potential of SSI

Ghana has substantial potential for upscaling SSI (Table 6). The estimated national SSI development potential is 211,000 ha, more than half the total potential in the country. There is a high probability of adoption of SSI in the Northern Region of Ghana at 115,000 hectares for vegetables, pulses and irrigated fodder in the dry season over the next 10 years, a substantial increase over existing total irrigation. Net benefits from adoption are estimated at US$ 285 million per year for irrigating farmers, benefitting

690,000 people. Dry-season runoff is a binding constraint in much of the areas with SSI potential (Figure 6).

Table 6. Adoption potential of small scale irrigation in Ghana

Region	Expected adoption area (thousand hectares)	Expected profits received by irrigators (million USD/yr)	Expected beneficiary population (thousand people)
Ashanti	5	5	15
Brong Ahafo	16	14	52
Central	1	2	4
Eastern	16	24	54
Greater Accra	3	6	11
Northern	115	133	377
Upper East	20	39	65
Upper West	27	48	89
Volta	7	13	23
Western	0	0	0
Total	211	285	690

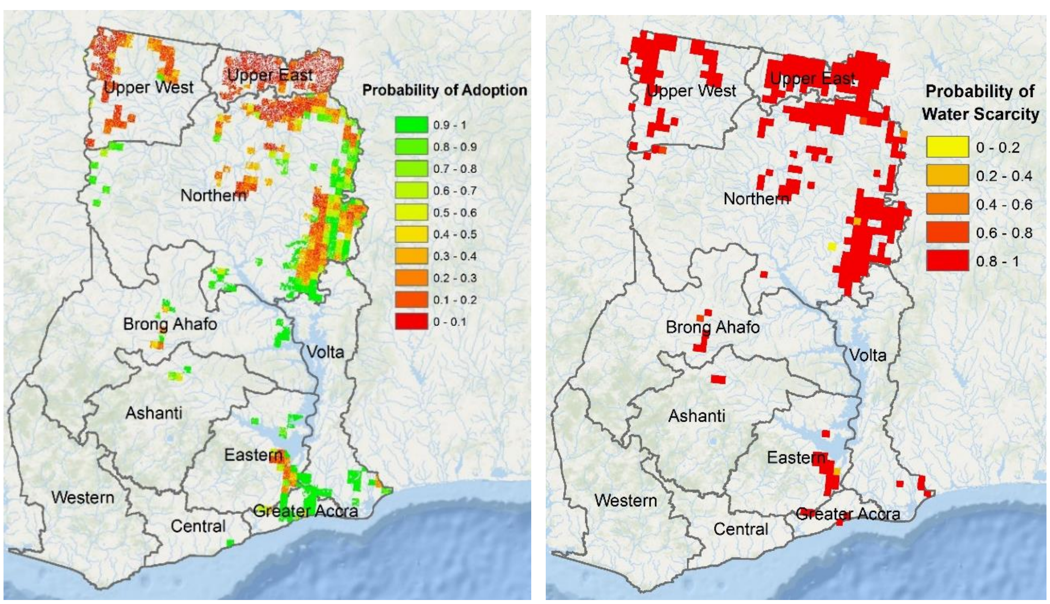


Figure 6. Adoption probability of a) small scale irrigation and b) available water scarcity due to adoption of small scale irrigation

Note: (a) green areas show high adoption probability of SSI, yellowish areas indicate moderate level of adoption and red shows low level of adoption probability; (b) red areas shows high probability to have water scarcity due to adoption of SSI with increased water usage, and yellowish areas showed minimal probability of water scarcity due to adoption. The SSI adoption was studied only in agricultural areas, therefore, forest land, grassland, etc were not considered in the analysis.

c. *Environmental feasibility, sustainability, and trade offs*

Potential land suitable for irrigation

ILSSI researchers found that approximately 2% of the land in Ghana was *highly* suitable for surface irrigation (at 85% value for land suitability) and 7% of the country is suitable for irrigation, excluding groundwater (Figure 7).

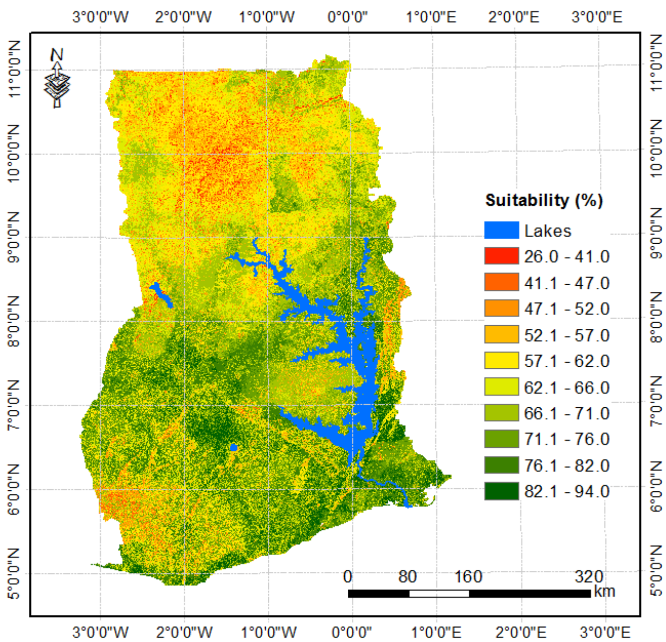


Figure 7. Preliminary suitable land for surface irrigation

Effect of climate change on irrigation area suitability

Climate change analysis on the irrigation land suitability[13] centred in the major river basin systems suggests the suitable land in the South Western River Basin System will increase by 12% and 2% for 2050s and 2070s, respectively, while a significant suitable land area *reduction* will be expected in Volta and Coastal River Systems for both future time horizons, focusing on surface water sources. This research points to a need to further explore groundwater options for irrigation.

Biophysical potential for and constraints to scaling

Although the coverage of agricultural land from the total land in Ghana is relatively small (~11.5%), the available land has very good potential for SSI. The most productive areas for SSI during the dry season are located in the north-eastern part of the country.[14] While there is high potential for vegetable and fodder production in Ghana, this may require use of both surface and groundwater resources and include areas currently under permanent tree crops (e.g. cocoa) or grassland. In addition, the available water resources meet the irrigation water requirement in most parts of the country (~68%).

Field test results, alongside an evaluation of the agro-climatic conditions in the study of watersheds in the White Volta Basin in Ghana, show opportunity for small- and medium-scale irrigation; water is the key

[13] The climate change data used was the Representative Concentration Pathway (RCP) 4.5, which considers "moderately optimistic" assumptions. The downscaled climate data includes rainfall and minimum and maximum temperature at a spatial resolution of 1 km for the period 2041 to 2060 (2050s) and 2061 to 2080 (2070s).

[14] The southern, southeastern and central part of the country is either grassland, forest land or used for cultivation of perennial crops. Therefore, the potential for small scale irrigation was studied only on agricultural land.

limiting factor to dry season production (Kadyampakeni et. al. 2017). Climate analysis shows an increasing trend for potential evaporation in some watersheds. The timing and length of dry spells indicate that water availability may be a constraint to irrigation throughout the dry season.

Productivity is constrained by poor water management practices, notably under- or over-irrigating. One year of data suggests that use of irrigation scheduling conserves irrigation water. Physical water productivity (WP_{ph}) of onion on plots with WFD had 21% higher WP_{ph} compared with farmer practice. Economic water productivity (WP_e) of onion also improved. The WFD could reduce the incidence of over-irrigating and improve WP_e (Balana et al. 2018). However, a second season of data was not consistent (Adimassu 2018), suggesting need for further studies. CA could add to improved water productivity, along with improved soil quality and field level water management. Farmers noted that they observed CA reduced erosion, weeds and labor (from tillage and weeding). In addition, CA practices enhanced crop yield.

Potential for irrigated fodder and forage value chain

Improved forage cultivation was not practiced in the ILSSI study sites in Ghana, but forage markets are emerging. Animal disease was ranked as the main constraint for livestock production, but lack of water and dry season feed shortages were also reported to be limiting factors. FEAST identified planting of irrigated cereal forage and of food-feed-crops as promising entry points for feed improvement. Following field testing of irrigated feed varieties, farmers expressed preference for selling in fodder markets rather than feeding of own livestock.

d. Constraints to adoption

Notably, land holding arrangements appears to matter in Ghana where rented as well as inherited plots, are less likely to be irrigated, compared to allocated plots. Inter-seasonal shifts and complexities of renting and using family plots was highlighted as a constraint by women.

Agricultural labor is a crucial constraint to expanding and scaling SSI in Ghana, a finding across all analytical methods. Investments should give priority to addressing labor constraints, notably through mechanization of water lifting and application.

Photo: Sweet potato yields doubled under CA practices. Farmer harvesting in Yemu Ghana. *Photo Credit: iDE*

Despite the observed benefits of CA, challenges to upscaling include a lack of farmer willingness to adopt new practices, overcoming the strong culture of mono-cropping, and inadequate mulch material. Overall, there is significant potential to expand vegetable gardens through the application of CA with drip irrigation, albeit with significant challenges to adoption.

Furthermore, despite the emergence of a fodder market, farmers are not irrigating forages for market. The largely labor-intensive methods used for irrigating also pose challenges for producing enough biomass for animal production, while preference to mono-crop onion also limits expansion of irrigation for new crops. The fodder market survey gives positive indications for supply and demand. However, trade-offs exist between irrigating forages and promoting food-feed crops.

The majority of farmers involved in irrigated production lack access to any form of credit (formal and informal). Access to credit is positively associated with factors such as extension, education, existing savings accounts and higher trust in financial institutions; access to remittances reduce the likelihood to seek credit. Older farmers were less likely to have access to credit, though increased farmer experience in production appears to be positively related to access to credit. The high cost of credit, however, limits profitability for irrigated production.

The current policy and market conditions do not support scaling SSI. Most irrigation equipment is available only in large cities. Importation of cheap and low-quality pumps appears to be increasing, though monitoring and enforcement of quality standards and import regulations remain weak. This creates unfair competition to established and licensed importers that adhere to the regulations. While imported agricultural machinery and spare parts are exempt from customs duties and value-added tax, the lengthy and inefficient official process, including poor coordination between sectors and institutions, contributes to high transaction costs for importers; thus, some importers do not pursue the exemptions. In addition, there appears to be no preferential financing options to support importation of agricultural equipment. Such costs are passed to the end-users through higher prices. Smallholder farmers generally lack ‘economic access’ to irrigation equipment; purchases are cash-based and suppliers currently offer limited financing options. The weak support through policy and regulatory institutions, as well as low access to financial mechanisms, undermine the development of a robust technology supply chain for irrigation.

3. Tanzania

Results at a Glance: Tanzania

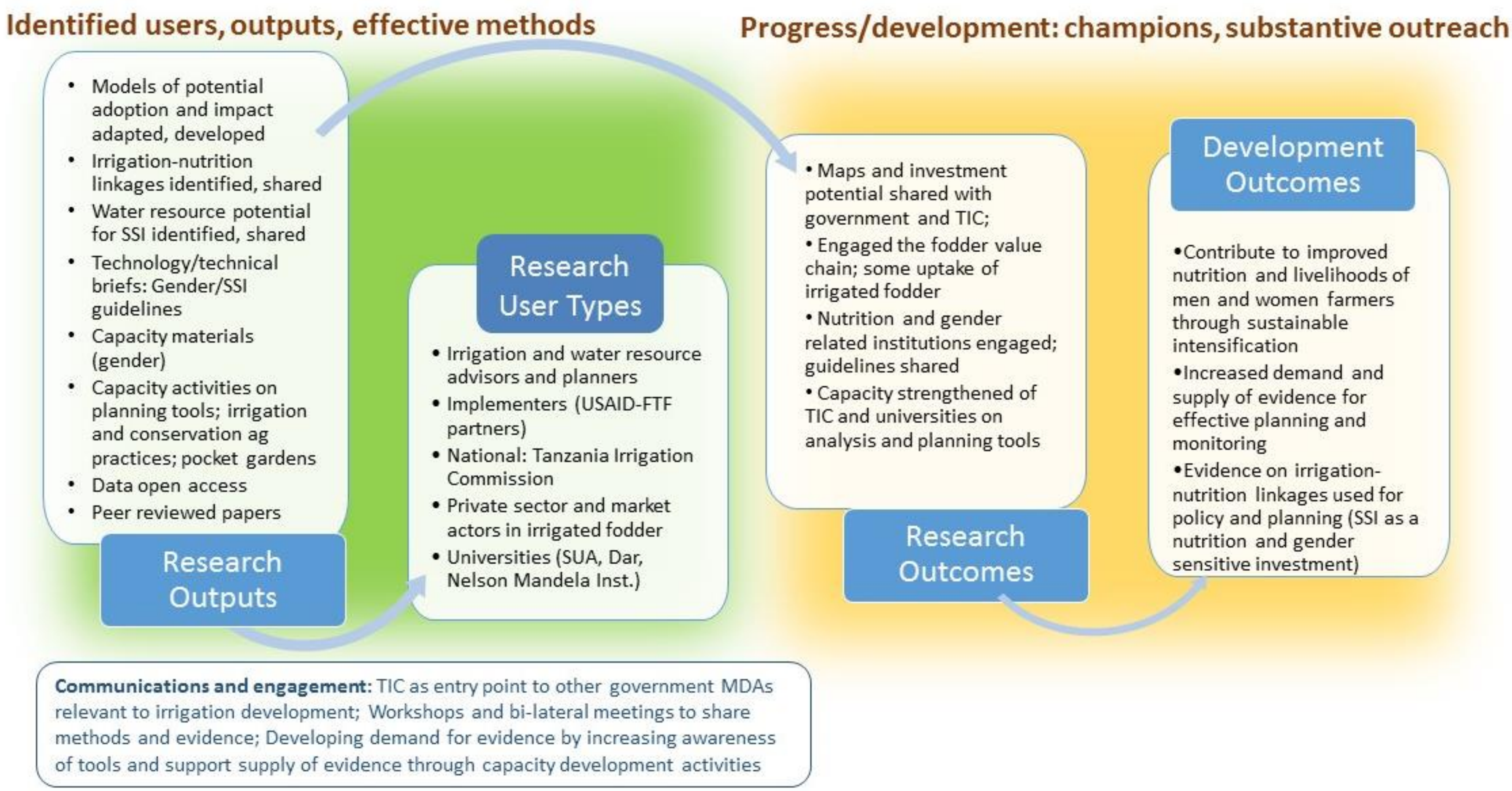
Key findings

- Approximately ~754,454 ha of land is economically and biophysically suitable for SSI development,
- A net income of ~780 million USD/year from the SSI adoption benefiting 3 million smallholder farmers Yields improved under deficit irrigation for tomato and eggplant
- Recommended crop water requirements can be reduced for certain vegetables according to location
- Motor pumps are financially feasible for high value vegetable production
- Payback period for motor pumps would be less than one year, *if* credit costs are reasonable and credit is accessible
- Pocket gardens use less water and labor than conventional gardens
- Income from pocket gardens are modest, but women can control the income and supplement household consumption
- The suitable land for SSI in the Tanzanian watersheds was generally small since the majority of the watersheds are covered by non-agricultural land
- Since the suitable land for SSI was small, the available water resources was sufficient to support the dry season cultivation, and SSI did not affect the watershed water balance dynamics,
- Multiple cropping of fodder (oats/vetch) improved soil residual nutrient and increased rainfed season crop yield
- System of Rice Intensification (SRI) production ensured higher crop water productivity compared to the traditional rainfed rice
- Motorpump-based irrigation provided profit, but with a benefit cost ratio less than one; return on investment was reduced by high investment and operating costs (pump, labor, fuel)
- Reduced profit under alternative SSI technologies (motor pump) do not allow households to purchase supplemental food for nutrition (using FARMSIM analysis)

Recommendations

- Recommended crop water requirements can be reduced for certain vegetables according to location
- Irrigation service provision, such as pump rental, could be an effective approach to reducing costs to farmers but still enable irrigated production of vegetables
- Suitable finance products are needed to improve access of farmers to purchase and/or rent pumps
- Home gardens offer a feasible entry point to increase production of vegetables with relatively lower water input, but need to be designed carefully to ensure increased benefits for women farmers
- Expansion of irrigated production will require attention to integrated pest management to maximize benefit
- Irrigated fodder production requires further research on the potential for animal and human nutrition
- Nutrition messaging needs to be integrated into irrigation investments/activities to gain more nutritional benefits

Tanzania Impact Pathway



a. Contributions of SSI to agricultural growth and human livelihoods, particularly nutrition and income.

Tanzania irrigation profile

Close to half of all plots farmed in the dry season are irrigated, especially tomato and rice. The vast majority of plots in the Tanzania sample were irrigated with surface water from rivers (80%), while groundwater was used on only 11% of plots. Water was usually obtained by gravity (72%), though 19% of plots use motor pumps. Flooding was the main method of irrigation application (59%), followed by furrows (14%) and buckets (11%). Motorized pumps were used by 23% of households surveyed; 54% of the households own the pump with the rest jointly owned or rented. About 1/3 of men and women said that men own the pump in the household.

The availability of productive household (family) labor was an enabling factor for irrigation. Households with fewer productive members were considered labor constrained. However, this does not imply that the availability of labor, in general, is not a constraint. In addition, the larger the land size, the higher the likelihood of using motorized (and more expensive) technologies in Tanzania. Input complementarity is also found, i.e. use of more chemical fertilizers increases the likelihood of irrigation.

Linkages between SSI, nutrition and income

Irrigation was positively associated with HDDS driven largely by increases in income from the sale of irrigated crops. In particular, irrigation had positive effects on the consumption of dairy products, sugar and honey and was positively associated with the consumption of vitamin-A rich and animal source foods (both at the household level and in women's diets). However, irrigation was not associated with minimum dietary diversity for women and child nutrition. Irrigation was associated with vitamin A-rich animal source foods only. Irrigation was not associated with nutrient adequacy for women of reproductive age. Finally, irrigation was not associated with improved child nutrition indicators.

The nutrition simulation results from IDSS analysis indicate that the quantities of crops and livestock products available for consumption to families in the studies met and exceeded the minimum daily requirements per AE for calories, proteins, iron and vitamin A, but were insufficient for calcium and fat.

Linkages between SSI and income and other livelihood benefits

Irrigated production with motor pump, drip and furrow irrigation showed a higher net present value and profit than non-irrigated scenarios. However, the use of a motor pump and drip irrigation, had the lowest profit value and a negative benefit cost ratio, notably due to crop disease. Producers ranked disease and pests as the primary constraint to irrigated production.

Photo: Installing drip systems in Rudewa. *Photo credit: SUA*

Different scenarios were considered based on technology and crop types (African eggplant and tomato). Results suggest motor pumps are financially feasible for growing high value vegetables when the payback period is lower than one year. However, it should be noted that this assumes access to microfinance at relatively low interest rates, whereas there are no observed microfinance institutions lending for irrigation in the project areas. Furthermore, attempts at group ownership of pumps faced challenges; groups of under five people with the pump storage point within 1-3 km appeared to have more success with cost recovery.

In addition, homestead gardening using pocket gardens showed a lower rate of water application than conventional plots, lower labor requirements (reduced by 50-75% compared to conventional plots), as well as higher yields. However, the returns were relatively low (cost-benefit ratio is positive at 1.41). Women farmers reported about $25 USD from one pocket per season. While low, women responded positively because they have full control over income generated from commercial sales from the pocket gardens. The ILSSI national partner extended training for pocket gardening to other parts of Tanzania based on demand from women farmers.

Linkages between SSI and gender

Men provided labor for irrigation using both traditional methods (mostly gravity, but also manual pumps and buckets) and motorized pumps. Women involved in irrigation using traditional methods (i.e. labor intensive watering can and buckets) tend to spend more time irrigating than men (129 hrs/yr/acre for women compared to 73 hrs/yr/acre for men). Though having access to motorized pumps reduced the time spent irrigating for women, ILSSI research showed few women provide labor for irrigation using pumps.

Slightly more women appeared to have greater decision-making related to the use of income from the sale of irrigated crops between survey rounds. Qualitative research showed acceptance for joint decision-making among men and women, although, typically, this means that women provide input and men make the final decision about cultivation and sales of farm goods and assets. Women, however, tend to control output and income from the sale of crops grown in their gardens.

b. Adoption potential of SSI

There is substantial potential for upscaling SSI areas (Figure 8). SSI potential is spread across the entire country, totalling 754,454 hectares for vegetables, pulses and irrigated fodder in the dry season over the next 10 years. The top three regions for SSI are Mbeya, Niombe and Dodoma, though many other regions are close behind these in adoption area. Net benefits from adoption are estimated at US$ 781 million per year benefitting 3 million people. Dry-season runoff is a binding constraint in much of the areas with SSI potential, as shown in the panel on the right in Figure 8,which is critical given the high reliance on surface water by irrigators. There is substantial biophysical potential to scale up SSI in Tanzania, which could help to offset the severe effects of unreliable rainfall and periodic droughts.

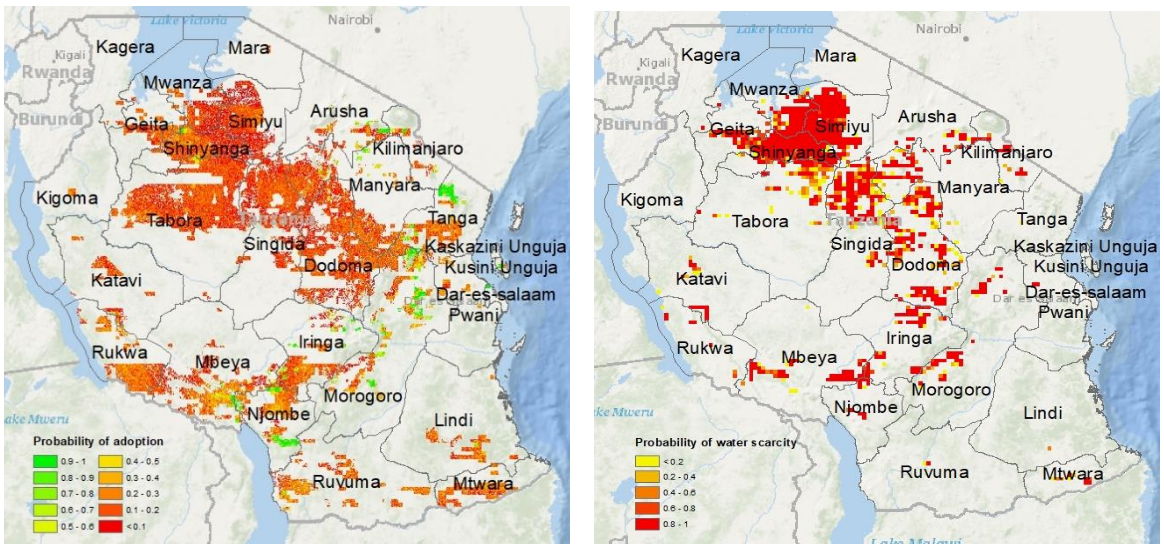


Figure 8. Probability of a) adoption of small scale irrigation and b) water scarcity associated with adoption of small scale irrigation

Note: (a) green areas show high adoption probability of SSI, yellowish areas indicate moderate level of adoption and red shows low level of adoption probability; (b) red areas shows high probability to have water scarcity due to adoption of SSI with increased water usage, and yellowish areas showed minimal probability of water scarcity due to adoption. The SSI adoption was studied only in agricultural areas, therefore, forest land, grassland, etc were not considered in the analysis.

c. Environmental feasibility, sustainability and trade-offs.

Potential land suitable for irrigation

Taking 85% as a threshold for land suitability for irrigation, ~4% of the Tanzanian land was suitable for surface irrigation (Figure 9). Analyzing the suitable land by the major river basin systems showed that the Rufiji Basin System has the largest area of suitable land (19%) followed by Lake Tanganyika Basin (18%) and Wami Ruvu Basin (17%). The Wami Ruvu Basin, which is the sixth largest basin, has the highest percentage (40%) of suitable land for irrigation in the basin. These estimates do not include groundwater potential.

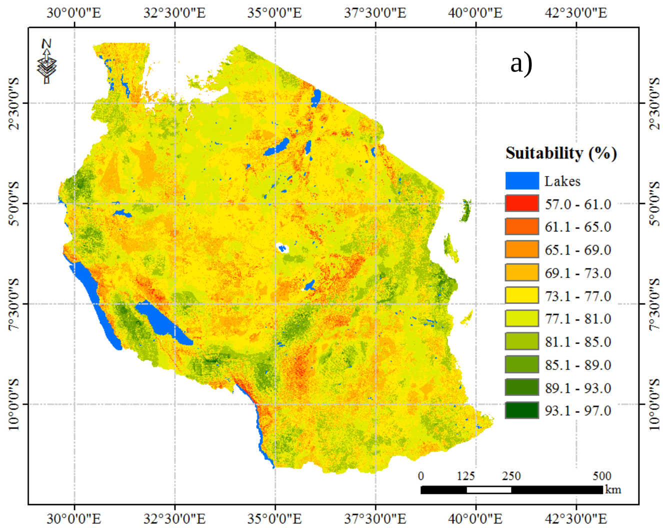


Figure 9. Preliminary suitable land for surface irrigation

Biophysical potential for and constraints to scaling

The most productive areas for SSI during the dry season are located in central and southern Tanzania. There are some pockets of land in the northern parts of Tanzania, which can produce optimal yield.[15] The soil loss in Tanzania is generally low.

Watershed level analysis was conducted in three sites in Tanzania: Mkindo, Rudewa, and Babati. The Mkindo and Rudewa watersheds are part of the Wami basin. The average annual rainfall in the Tanzanian watersheds is about 700 mm, but evaporation is high, with the average annual water resources very small. Since the irrigated area in the studied watersheds was not substantial, SSI does not affect the overall water balance dynamics.

Field data and IDSS simulations at the three sites helped to understand the opportunities, gaps and constraints of vegetable production in Tanzania. Annual crop production in the three sites was far below the global average yield, due to climate variability, low soil fertility, and poor management practices. The application of fertilizer (e.g. elemental nitrogen) and crop rotation are potential solutions. The SRI ensured higher crop water productivity compared to traditional rainfed rice. For example, SRI rice cultivated with 3-days wetting and 5-days drying produces 86% higher yield compared to the traditional rainfed rice.

Smallholders often under- or over-irrigate, but ILSSI also found that the crop water requirements (CWR) are not necessarily adapted to the specific biophysical environment. Field studies confirmed different tolerances for studied vegetables towards deficit irrigation; in some cases, such as tomato, yields improved under deficit irrigation.

CA with drip irrigation was found to improve the soil quality and structure and agricultural water management in the vegetable gardens. Soil erosion, weeds and labor were reduced in CA plots. However, yields were negatively affected by water logging and pests. The mulch material potentially minimized soil evaporation and adversely affected the crops. In addition, more pests were observed in CA plots possibly

[15] The grasslands, reserved parks and forested area as well as water bodies were not considered for upscaling of small scale irrigation; only agricultural land was studied.

associated with the banana leaf used as mulch. In general, CA reduced soil erosion, labor, and water use, but practices need to be tailored for local conditions, including testing types of mulch material.

d. Constraints to adoption of SSI

Several factors appear to constrain irrigation's full potential. If irrigation is to have a more meaningful effect on nutrition through increased income and diversified food production/availability, and if there is to be expansion of adoption of SSI, there is a need to address the challenges that irrigated agriculture is facing.

Farmers rank disease and pest damage to key irrigated crops (tomato and rice) as primary constraints. At the same time, farmers also reported insufficient water availability during the dry season. Research found that some crops perform better under deficit irrigation,[16] suggesting the need for new or adapted crop water requirement advice; for example, tomato yield improved with a 20% reduction in water applied. It is also necessary to invest in improved water management tools and techniques. SUA is integrating WFD and other irrigation scheduling tools adopted from ILSSI in future demonstration and training sites.

As noted, credit availabilty was low in the field test areas, which can constrain farmers from obtaining irrigation technologies on credit. In terms of credit modalities, the field tests also suggest problems with group sharing of pumps, an approach promoted by some interventions. Failed group sharing appears to lead to disadoption and inability to pay back loans for technologies. An emerging recommendation is to limit group size for projects that use a group ownership approach to pumps or other technologies, but more research is needed on factors that reduce collective action problems and improve cost recovery in groups, or consider rental service business models.

While labor does not appear to be the same constraint as in Ghana and Ethiopia, there are clear gendered differences in terms of labor inputs and access to labor-saving technologies for irrigated production in Tanzania. Women are currently relegated to the use of manual, labor intensive technologies. In addition, women have little say over irrigated produce income, unless it is on homestead gardens, which generate low revenue.

At present, SSI adoption is restricted to areas close to rivers where there are river diversions. This limits expansion to areas where diversions or pumps can draw from the rivers. However, to implement SSI in all the suitable areas (including those far from the river networks), water diversion structures would need to be developed. ILSSI found that less is known about groundwater irrigation opportunities in Tanzania.

VII. Progress Toward Impact

The following ILSSI activities were implemented toward achieving impact from the research process and results: 1) promote continual learning among participants and partners; 2) ensure project activities and resulting outputs and recommendations would be grounded in local demands/needs and realities; 3) support national goals and initiatives; and 4) reach end-users, including farmers, researchers, policymakers, and various types of investors. ILSSI focused on a multi-level and multi-prong approach to outreach. At local level, ILSSI engaged directly with farmers, customary authorities, local government officials and private sector actors; this helped to ensure that the project remained focused on relevant research questions and that results directly influenced practices in the field. At watershed and national level, ILSSI has relationships with basin and irrigation authorities, through capacity development and

[16] Deficit (or regulated deficit) irrigation is an approach to improving water use efficiency (WUE) by achieving higher yields per unit of irrigation water applied without compromising quality or output. The approach may involve water stress at some point during or throughout a production cycle.

consultation workshops. ILSSI aimed to ensure demand-driven research while also sharing research results for strengthened decision-making. ILSSI also supported scientific conferences at regional and national levels, simultaneously supporting capacity and influencing thinking. Finally, ILSSI engaged in strategic global conferences and held its own symposia to provide new evidence that would shape future investments in SSI.

A. Exit strategy

ILSSI recognizes the need to ensure impact beyond the close of the initial five years of research in project countries. The core activities for the exit strategy include: 1) completing country activities in a timely manner, 2) making materials available broadly even after the project, and 3) continued monitoring of country-level opportunities for influence. More specifically, in Year 5, ILSSI held national workshops with a broad group of stakeholders to share results and discuss implications. Research summary briefs for Ethiopia, Ghana and Tanzania provided the key results and messages to enhance the effectiveness of SSI interventions. Materials continue to be added to the ILSSI website, while social media tools and platforms used to extend the reach of those knowledge products. ILSSI has continued dialogue with key partners, to share lessons and guidance documents that are informing programs and projects. ILSSI also continues to share results at global conferences that can encourage the mainstreaming of and investment in SSI by governments, donors and financial institutions. The range of HICD and outreach activities (including communications) are described in the following section.

B. HICD

Capacity for research, as well SSI practices, was generally low in all project countries. While interest is increasing in SSI and farmer-led irrigation, most countries have not invested in ensuring capacity to expand SSI investments sustainably and inclusively. ILSSI therefore developed capacities across the spectrum of key actors, including: scientists who would generate evidence; decision makers that would use scientific evidence for monitoring, planning, and investing; practitioners and advisory service providers; and producers that would apply practices and methods. Total numbers for each category of trainee are provided in Table 7.

Table 7. HICD summary of trainees

Length	Type of Trainee	Numbers of Trainees
Long-term	Total number of Students	109 (M=79,F=30)
Short-term	Total number of short terms trainees	2247
	Producers/farmers	1198
	Private Sector	55
	Civil society	691
	Government	303

Given the importance to decision-makers of national and regional planning, capacity should be increased for national and regional systems level analysis; therefore, ILSSI provided trainings on the IDSS. IDSS trainings were offered for different levels of skill and enabled trainees to work cumulatively through skills levels. Local institutions hosted trainings and trainees were self-funded to ensure commitment to learning.

Trainees used local and national data in trainings to ensure local relevance. ILSSI also invited public and private sector actors working directly with decision-making institutions, such as the ATA and the Abbay Basin Authority in Ethiopia, to create awareness of the need for data, analytical tools and systems level analysis; specific requests came to ILSSI for tailored trainings, particularly on the IDSS tools and analysis. Over the course of the project, ILSSI provided short term training on IDSS to more than 730 professionals, being 600 men and 130 women (Annex 6). The IDSS team also invited 11 scientists from project countries to Texas A&M University to receive a practical training for 60-90 days and provided technical backstopping on IDSS projects.

Text box 10. ILSSI analytical methods in IDSS adopted at institutional level in Ethiopia

One of ILSSI's aims was to strengthen the capacity of the next generation of scientists and professionals who can apply research and analysis methods, including the IDSS, to contribute to the sustainability of SSI in Ethiopia. ILSSI national partner Bahir Dar University (BDU) is institutionalizing the IDSS in its curriculum and research methods. The BDU president, in consultation with the Blue Nile Water Institute, Department of School of Civil and Water Resource and GeoSpatial Center is institutionalizing the IDSS analytical methods in a summer course. Their plan is to make BDU as a center of excellence providing IDSS capacity building to the East African region, and applying the IDSS in their research activities at the university. The BDU president is requesting ILSSI's support until the program is sustainable at Blue Nile Water Institute. In the meantime, BDU has adopted the IDSS as an elective course in the Irrigation Engineering and Management MSc program. BDU also aims to set up semi-annual courses for trainers and educators on the IDSS. Initial results were seen at the 2nd Amhara Region Agricultural Forum where several BDU graduate students were chosen to present work applying the IDSS.

Photo: Group work in Adama during the integration session of SWAT, APEX and FARMSIM model.
Photo Credit: ILSSI Project

In addition, ILSSI recognized that field level capacity needed to be strengthened to implement field pilots, including farmers, extension agents, and subject matter specialists. Subjects included irrigated agronomy, irrigated produce marketing, irrigated fodder practices, and conservation agriculture. At the same time, ILSSI provided training for both farmers and agriculture credit cooperatives in Ethiopia, recognizing the importance of appropriate finance products and terms and conditions for irrigated smallholder production.

It is important to note that ILSSI prioritized gender in research activities and also in capacity development activities through the following ways: 1) workshops on gender and irrigation (Annex 6) and 2) prioritizing women producers and women scientists in trainings.

Finally, ILSSI engaged both current and future scientists, particularly at universities and national research institutions, on research design and methods, data collection, analytical methods and analysis, as well as writing, presentation and publication preparation. In addition, ILSSI mentored promising young scientists in grant proposal writing, which will aid students and post-doctoral scholars secure their own funds for continued research. ILSSI supported 109 students at all levels during the first 5 years of the project (Annex 7).

Text Box 11: Young scientist obtains research funds through grant proposal mentoring

ILSSI scientists supported and mentored graduate student across the full range of research skills, from research design and data collection to publication and grant proposal writing. In Ethiopia, an ILSSI scientist mentored a Ph.D. student at Addis Ababa University to write a research proposal to the International Fund for Science (IFS). The student was able to secure $10,000 USD to undertake his Ph.D. research. While ILSSI scientists published numerous peer-reviewed publications with students, support from funded grant proposals provides students with complementary skills to continue their research after ILSSI's support.

In sum, ILSSI developed capacities across the spectrum of scientists who would generate evidence and of decision makers that would use scientific evidence for monitoring and planning.

ILSSI's capacity development approach evolved to become equally focused on creating awareness and skills at multiple levels and across institutions, toward ensuring sustained investment in capacity.

C. Outreach and influence

1. Utilization of research outputs

ILSSI's research methods and results have been adopted and applied in different ways at multiple levels. At the global level, ILSSI sought to influence investing and regional policy, as well as future research, through sharing research results. At the national level, ILSSI engaged with policy and program decision-makers and planners, toward shaping future policy and programs that would enhance opportunities for SSI access and help countries reach the potential benefits. Finally, at the sub-national level, ILSSI worked with local government agencies and departments, including extension, to strengthen capacity, while also raising awareness of farmers on new and suitable approaches and practices related to SSI and irrigated fodder. In addition, ILSSI actively engaged various audiences through social media, including webinars, blogs and social media platforms; ILSSI leveraged all partner social media to amplify messages (Annex 8).

a. Global-level

Donor and public agriculture institutions are increasingly recognizing the potential and benefits from SSI and farmer-led irrigation, but little knowledge exists that can inform investments and programming. Therefore, ILSSI shared research results and sought to influence debates at global level on SSI; select events are noted in Annex 9. ILSSI contributed to the growing interest in farmer-led irrigation through SSI technologies, including the range of benefits and limitations on expansion. In this regard, ILSSI was uniquely placed to provide evidence for on-going discussions.

Text box 12. Water-Nutrition linkage evidence as an input to the Expert Group Meeting of the UN Standing Committee on Nutrition

In early 2018, the UN Standing Committee on Nutrition contacted the CGIAR Research Program on Water, Land and Ecosystem to develop a paper on water-nutrition linkages for the Expert Group Meeting on Nutrition and Sustainable Development Goals, which took place on June 19-20, 2018, at the United Nations Headquarters in New York, USA. This paper was prepared specifically for the High-Level Political Forum, the United Nations' central platform for follow-up and review of the 2030 Agenda for Sustainable Development and the Sustainable Development Goals that took place in July 2018. The paper reflects much of the work completed under ILSSI on water-nutrition linkages but also identifies a series of additional insights and research gaps that will be explored in the future, many of which will be components of the ILSSI project in the future.

Reference: Ringler, C.; Choufani, J.; Chase, C.; McCartney, M.; Mateo-Sagasta, J.; Mekonnen, D.; Dickens, C. 2018. Meeting the nutrition and water targets of the Sustainable Development Goals: achieving progress through linked interventions. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE); Washington, DC, USA: The World Bank. 24p. (WLE Research for Development (R4D) Learning Series 7). doi: 10.5337/2018.221

b. National level

ILSSI sought to inform national decision-making and programming on investments on SSI, particularly as African countries have tended to neglect the potential of SSI in agricultural development. ILSSI approached this using the continuous engagement approach at sub-national and national level, i.e. ensuring consultation and input on research questions and design, as well as frequent engagement around emerging research results and evidence. ILSSI also identified opportunities at the national level to support and convene conferences and workshops on SSI (Annex 10).

Text box 13. ILSSI's unique analytical approach adopted by a number of institutions in Ethiopia

The IDSS combines a set of models for integrated planning and monitoring, which offers a helpful approach to governments and other organizations as they prioritize irrigation. ILSS established a Memorandum of Understanding with the ATA and the Ministry of Agriculture and Natural Resources (MoANR) in Ethiopia to facilitate the use and adoption of the IDSS to inform decisions on the impacts of agricultural transformation agendas on biophysical and socio-economic factors. ATA and MoANR were trained in the application of the IDSS suite of models in order to better inform decision-making. The Abbay Basin Authority under the Ethiopian Ministry of Water, Irrigation and Energy also participated in extended capacity development on IDSS tools to assess the available water and land resources in the basin to implement different water resource development projects as well as to identify strategies that reduce soil erosion and ecosystem degradation. The Development Bank of Ethiopia (DBE) also sought to generate capacity for their engineers to use the IDSS to improve decision-making. The Ethiopian Construction Works Design and Supervision Enterprise (ECWDSE) also requested a special IDSS course to improve the efficiency and quality of their project activities.

Given the critical role that women farmers play in food production in Africa, ILSSI invested in raising the prominence of gender in irrigation planning and investment. In March and April 2016, ILSSI convened workshops on gender and irrigation in project countries in collaboration with national partners, bringing together 150 experts from government, non-governmental organizations, and research institutes. The workshops focused on identifying constraints to women's equal access to irrigation. Participants expressed strong interest in promoting gender equality in irrigation to improve agricultural growth, household nutrition, and women's empowerment, and recognized the need to overcome constraints to women's access to water for agricultural and domestic uses. Based on both quantitative and qualitative research, as well as feedback from the workshops, ILSSI developed a guidance tool on Making SSI Work for Women. The tool has been supported and adopted by key decision makers and also included in multiple trainings in Africa by other projects and organizations.

Text box 14. ILSSI gender research and knowledge products used by WARIDI and SAFI

Water Resources Integration Development Initiative (WARIDI) is the follow-up to iWASH and the main water-related USAID-funded project in Tanzania. Tetra Tech is the prime project contractor and Winrock is the primary sub-contractor of the project. Another sub-contractor of WARIDI, IRIS, is responsible for designing the gender strategy for WARIDI. IRIS staff contracted IFPRI after their staff found ILSSI blogs and gender-irrigation workshop materials that were available online. IRIS expressed interest in using the ILSSI gender and irrigation tools developed to collect data and in trainings/capacity strengthening for project managers in their program. In addition, the Studying African Farmer-led Irrigation (SAFI) project is integrating the ILSSI gender knowledge products into their upcoming workshop on irrigation planning in Sub-Saharan Africa.

Other organizations have also contacted ILSSI to indicate their intention to include ILSSI's gender results into their project management briefs.

c. Sub-national and local level

While ILSSI was well-placed as an influencer at national and global levels, the project also invested in outreach at local levels. In addition to HICD activities, ILSSI held field days to share research activities and results at the sub-national level, particularly at the village and district levels. For example, through national partners, ILSSI held various field-days on SSI technologies (e.g. solar pumps and WFDs), irrigated production generally and CA specifically (e.g. vegetable production, irrigated farming as a business, and marketing). Demonstrations and knowledge exchanges on irrigated fodder proved to be particularly effective in Tanzania and Ethiopia. ILSSI also supported farmer exchanges and irrigated farm tours for producers engaged in ILSSI study sites.

Photo : Farmers and service providers in northern Ghana learning about the use and maintenance of motor pumps for irrigation. Photo Credit: Dr. Sylvester Ayambila, UDS

2. Technologies utilized by ILSSI

a. Technologies ready to scale

1. ILSSI's suitability assessments, cost-benefit analysis, and business cases analysis suggest high potential for solar irrigation pumps in Ethiopia. ILSSI developed business models for Ethiopia that suggest potential approaches to profitable investment given the contextual constraints.
2. WFD was assessed with USAID support and considered positive for potential scaling, though numerous constraints are identified for commercial scaling. WFD garnered the highest interest in Ethiopia, where it is now integrated into other funded projects, including one project led by FAO. In addition, the Ghana Irrigation Development Authority expressed interest in the WFD for use outside FtF ZOI; at the local level, the District Department of Agriculture expressed interest in larger scale use given the potential for improving water productivity, particularly in water scarce areas. In Tanzania, SUA intends to include the WFD in its demonstration sites being developed for promoting irrigation. In sum, WFD holds promise for scaling but with constraints to large commercialization. Steps have been made toward public sector acceptance and demand.
3. ILSSI provided scientific evidence on the effect of the Berken plow to improve groundwater recharge, which is important to ensuring sustainable irrigation. The Berken plow makes more water available for supplementary and dry season irrigation, while also strengthening water productivity at multiple scales. Separate studies and support have been provided to the private sector designer and local manufacturers for commercialization. Relevant public sector institutions have been invited to see demonstrations and have received evidence generated through ILSSI.

b. Uptake of technologies

The WFD received serious attention by public institutions in all three project countries. In Ethiopia, other projects are now applying WFD in the farmer fields, including on communal irrigation schemes. ILSSI provided technical training and backstopping to the Ethiopian Institute for Agricultural Research, as well as presentations to the national program for Small Scale and Micro Irrigation for Ethiopian Smallholders (SMIS) that seeks to improve capacity in smallholder irrigation nationally. In Tanzania, SUA is installing and applying the WFD and other irrigation scheduling tools on their new model farms for irrigation technology, which were introduced by ILSSI. In Ghana, requests have been made by the Ghana Irrigation Development Authority for training at an institutional level on the WFD and related irrigation scheduling tools toward introduction in public irrigation schemes outside of the FtF ZOI.

VIII. Lessons, Challenges, and Opportunities

Lessons:

Between 2013 and 2018, ILSSI built strong partnerships between cooperative partners and national research partners. One of the key lessons learned was the importance to engage research partners early to integrate questions and activities, identify capacity gaps and strengthen a wide range of skills as the research continues, and build upon existing policy, scientific and outreach networks of all project partners. A significant challenge encountered by ILSSI was to identify research and implementation partners with an existing skill and resource base sufficient to ensure high quality data collection, management and analysis. Often, the universities in the FtF ZOI have lower capacity in these areas, posing challenges (and potential opportunities for capacity development). Partnerships may need to target either capacity development or research activities, but it may not be both in all cases. ILSSI recognized that capacity strengthening should include a range of skills that ensure research projects operate efficiently and effectively, such as project accounting and grant proposal writing for faculty, staff, and students.

Another key lesson for ILSSI related to HICD. ILSSI gave attention to both generating demand for evidence by decision-makers, including building skills and trust in analytical methods, and supporting a pipeline for supplying evidence in future. ILSSI invested in strengthening the skills of national institutions and scientists to supply science-based information. This approach helped ILSSI to institutionalize analytical methods at multiple levels.

Challenges:

Unfortunately, ILSSI’s resources were not adequate to address capacity in supporting services for SSI, notably the weaknesses of extension services in irrigated production, the capacity gaps and poorly resourced rural banks and microfinance organizations, and the high risks of expanding technology supply markets in African countries. Such constraints are in addition to the widely known deficiencies with input and output markets. These challenges hindered ILSSI’s ability to have a bigger impact on the numbers of men and women farmers sustainably adopting SSI technologies. While ILSSI adjusted research to identify business models in response to these barriers, the business models will need to be tested with and by the private sector to assess wider applicability.

Opportunities:

At a broader level, ILSSI’s work coincided with a gradual shift in recognition of the importance of SSI to the transition to irrigated, intensified agriculture in Africa. Organizations and investment institutions such as the African Union, the African Development Bank, and the World Bank have become more receptive to the large potential of farmer-led SSI, which ILSSI has helped to demonstrate. In this regard, ILSSI’s advocacy at numerous international and bi-lateral forums was important to the global dialogue. The potential is indeed substantial, and ILSSI has shown that SSI can contribute to improvements in agriculture-based economic growth, as well as human and animal nutrition.

Text box 15. Use of the IDSS to forecast impact on research products

With developments of the IDSS in the first phase of the project, ILSSI will use the IDSS system in the renewal of the project to forecast the impact of its products at the time of completion of studies rather than waiting for years to determine the uptake and use of these products. The IDSS will be used to **forecast a range of possible impacts** based on assumed adoption rates. This will provide a **highly useful metric**, available **at the end of the project.** The IDSS can be used to compute or estimate all the variables related to estimated impact except for adoption rate. This is strengthened by the suitability mapping methods that estimate the land area, and natural resources available for candidate interventions related to farming systems. For example, if a range of adoption rates of 20% and 40% is assumed, a bracket or a range of potential impacts on production, socio-economic and the environment can be estimated. The stochastic output of the IDSS provides a further estimate of the variance in estimates, which may arise due to changes in prices of commodities and technologies. Such analysis will provide investors the ability to make **comparisons of the impact of various options** and to make sound decisions at the time the research is finished. The estimated impacts can include the major components of the IDSS product such as **production, environmental, economic and nutritional consequences.**

A number of gaps remain, however. The modalities by which countries can achieve the vast potential are not apparent, and differ significantly from large, public or private communal irrigation schemes. SSI development is less centralized, planned and governed; yet, support is still needed. Private sector partnerships that can reduce risks for those leading the way into emerging markets will be important. New partnerships that integrate the private sector will enable researchers and partners to test scaling opportunities, whether related to development of technology supply or to financial services. Moreover, a need exists to identify how entry points for programs and projects to make access to and benefits from SSI more inclusive. Resource poor farmers, such as women and youth, will need access to technologies and services that enable entry into irrigated value chains; this will be required to reach the numbers of farmers, and expand to the large potential areas suggested by the research. As SSI expands, the development of structures and procedures to anticipate and monitor the impact on the environment and economy, particularly given climate variability, will need to be supported. ILSSI's research results will have continued value in the future toward identifying the entry points through which SSI can be scaled, as well as strengthening institutional capacity so that external support is no longer needed.

IX. Conclusions

Research results showed that SSI can have a positive impact on nutrition and income, and therefore, support achievement of goals related to agricultural growth and improved human nutrition and livelihoods. SSI enables the transformation of agricultural livelihoods through pathways of food production, agricultural income, water supply, and women's empowerment, which can ultimately lead to changes in child and maternal nutritional outcomes. However, SSI diffusion is not gender-neutral and not necessarily inclusive; there is a lack of equal opportunity to enter into irrigated production and benefit from SSI.

SSI is profitable for farmers in most scenarios, particularly assuming high value crops. Some crop-technology combinations show higher potential for strong profit and household income, and other for household consumption increases. In Ethiopia specifically, irrigated forages show considerable demand as a cash-crop. Given the opportunities for increased income, ILSSI also assessed potential for adoption. If

SSI reaches its potential for expansion in area and number of farmers reached, it could have a substantial impact on agricultural growth, human well-being and poverty reduction. The potential for adoption has been identified for Ethiopia as 5,874,000 smallholder farmers on 1 million hectares realizing US$ 2.6 billion net income annual over ten years. In Ghana, SSI adoption potential is 690,000 smallholder farmers on 115,000 hectares realizing US$ 285 million per year over the next ten years. Finally, in Tanzania, a potential 3 million smallholders could adopt SSI on 750,000 hectares for a net profit of US$ 781 million over ten years.

In terms of sustainability, water resources are adequate in the studied countries to enable scale up of SSI to reach millions of farmers with promising net profits. However, in most areas, water resources need to be used conjunctively (ground and surface water), and/or with good tools and practices for on-farm water management. Conservation agriculture practices can also contribute to a range of benefits, though potential negative affects must also be considered. In general, the results suggest that multiple benefits and impacts need to be considered in terms of trade-offs, moving beyond technical efficiency and cash income. Therefore, technology selection is better considered across a range of potential benefits for households, as well as program or local and national development goals.

While resource availability provides opportunity for upscaling SSI, there are constraints to adoption and productivity. Each crop-technology combination presents trade-offs relative to achieving a range of FtF goals. In addition to constraints to use of a single water resource, labor is a major factor for farmers adoption, cost and profitability of SSI. Most farmers across the project countries do not currently irrigate with labor saving technologies, such as pumps, but rely on labor intensive methods, such as buckets. These methods for irrigation limit the area that can be irrigated, occasionally affect crop choices of farmers, and ultimately limit the extent to which SSI will be able to expand and contribute to economic growth and well-being. Access to labor saving, more advanced technologies, is limited. Even when farmers want to adopt newer technologies, the lack of access to appropriate financing and underdeveloped technology supply chains, reduce farmers' access to SSI opportunities, particularly for women and resource poor farmers. Increased investments and targeted interventions are needed to enable inclusive, broader access to SSI, in order to reach potential beneficial outcomes, including improved nutrition and increased income.

The initial phase of the ILSSI project built upon the considerable previous experience of programs such as Agwater Solutions and was enriched by the full engagement of national and international advisors and partners at all stages. Cooperative and national partners brought their related previous experiences to bear on the design and execution of the field, survey and analytic components of the ILSSI project. The extensive training completed at farm, regional, and national levels, including national universities and graduate students, provided a solid base of knowledge and know-how that will be important to the sustained use of ILSSI products and knowledge over time. The External Review of ILSSI provided very useful insights and advice for planning the continuation of the cooperative agreement in the renewal phase of the project. Moreover, the initial phase of ILSSI produced a number of SSI-related results that can be regarded as regional and international public goods, which contributed to the design and implementation of development programs, as well as established the basis for continuing to develop these results in the extension phase.

X. Annexes

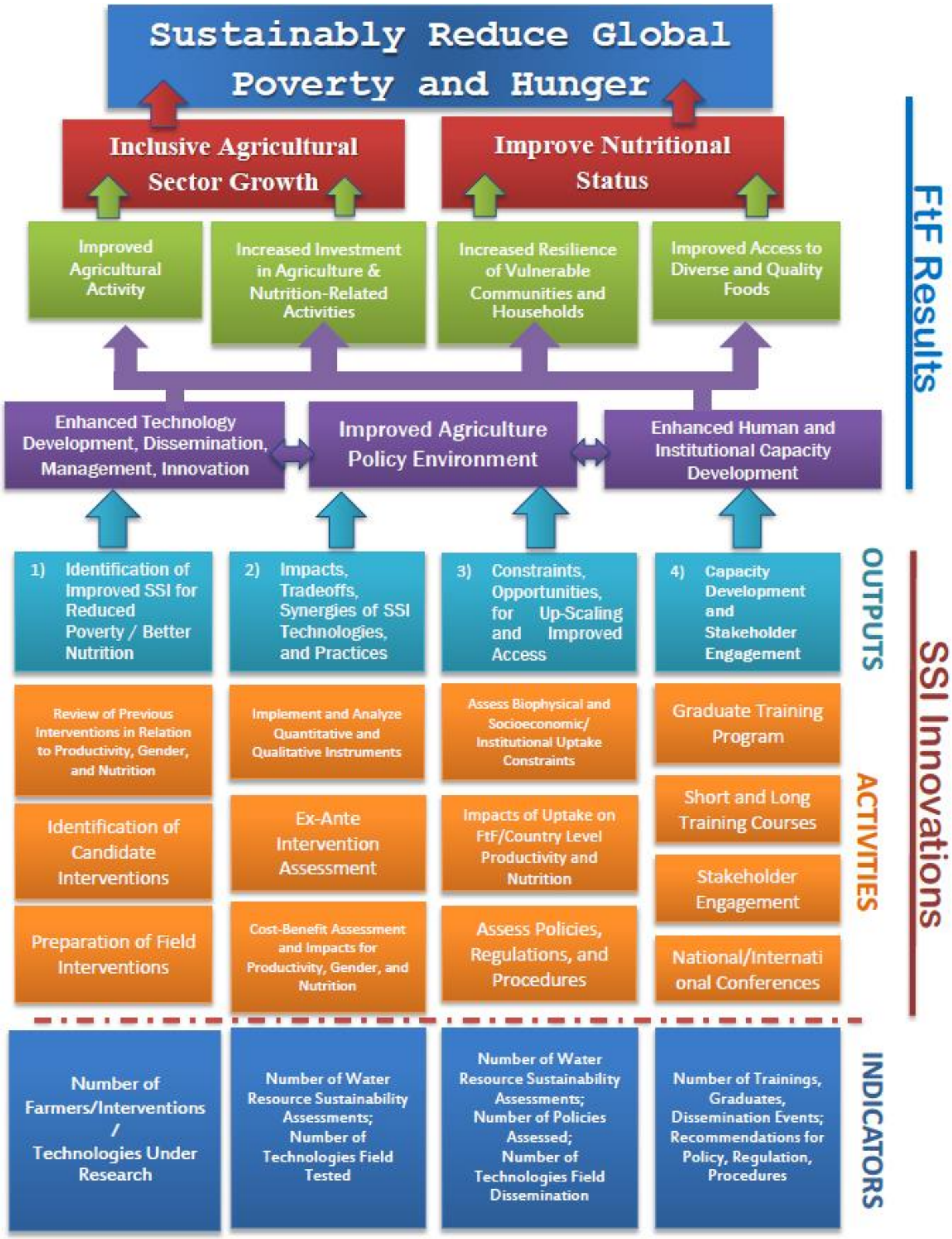
Annex 1. Partners and stakeholders engaged by ILSSI (2013-2018)

Country	Partners
Ethiopia	• Bahir Dar University (BDU) • Arba Minch University • Mekelle University • Addis Ababa University • Adama Science and Technology University (ASTU) • FtF Nutrition Innovation Laboratory • FtF Sustainable Intensification Innovation Laboratory (SIIL) • SIPSIN • Appropriate Scale Mechanization Consortium (ASMC) • Ethiopia Institute of Agriculture Research (EIAR) • Ethiopian Agricultural Transformation Agency (ATA) • Development Bank of Ethiopia (DBE) • Ministry of Agriculture and Natural Resources (MoANR) (Small Scale Irrigation Directorate) • Blue Nile Water Institute • Abbay Basin Authority • Ministry of Water, Irrigation and Electricity • Africa RISING • Productive Safety Net Program (PSNP) • Private sector (e.g. FuturePump) • Additional national, regional, and local government agencies
Ghana	• University for Development Studies • Kwame Nkrumah University of Science and Technology • University of Ghana • International Development Enterprises (iDE) • Savannah Accelerated Development Authority (Northern Development Authority) • Ministry of Food and Agriculture • Ghana Irrigation Development Authority (GIDA) • Water Resources Institute (WRI) • Africa RISING • IFDC: Feed the Future Ghana Agriculture Technology Transfer project • FINGAP (Palladium) • ACDI-VOCA
Tanzania	• Sokoine University of Agriculture (SUA) • University of Dar es Salaam (UDSM) • Nelson Mandela African Institute of Science and Technology • Africa RISING • Tanzania Irrigation Commission • Additional national, regional, and local government agencies

Annex 2. ILSSI national sub-contracted partners

Country	Institution/Organization	Type of partner
Ethiopia	Bahir Dar University (BDU)	Site selection, facilitate farmer engagement and data collection; Field experiments; Capacity development
Ethiopia	Arba Minch University (AMU)	Student-led data collection in field experiments; Capacity development
Ethiopia	Association of Ethiopian Micro-Finance Institutes (AEMFI)	Survey data collection; Collaboration on qualitative microfinance research
Ethiopia	Amhara Regional Agriculture Research Institute (ARARI)	Supported outreach to farmers for irrigation and for irrigated fodder
Ethiopia	Southern Agricultural Research Institute (SARI)	Supported outreach to farmers for irrigation and for irrigated fodder
Ethiopia	Send a Cow-Ethiopia	Field level monitoring; data collection
Ghana	University for Development Studies	Site selection, facilitate farmer engagement and data collection; Survey data collection
Ghana	Animal Research Institute (ARI) of the CSIR	Implement fodder field trials and collect data
Ghana	International Development Enterprises (iDE)	Site selection, recruit and facilitate farmer engagement and data collection for conservation agriculture
Tanzania	Sokoine University of Agriculture (SUA)	Sub-contracted for site selection, facilitate farmer engagement and data collection; Survey data collection; Support fodder field testing and market studies

Annex 3. ILSSI Theory of Change to contribute to Feed the Future Goals (2013-2018)



Annex 4. Research activities (2013-2018)

Research activity	Date	Location	Lead partner	National/Local partner	Notes
Systems level analysis	2013-2018	Ethiopia, Ghana, Tanzania	TAMU	BDU, UDS, SUA	
Baseline survey	Nov-Dec 2014	Ethiopia (15 villages, 4 districts: Bahir Dar Zuria, Dangla, Adami Tulu and Lemu)	IFPRI	AEMFI	439 households
Endline survey	Feb-Apr 2017	Ethiopia	IFPRI	AEMFI	539 households; Quantitative nutrition module for 368 households in Bahir Dar Zuria
Baseline survey	June – July 2015	Tanzania (14 villages: Kilosa and Mvomero districts)	IFPRI	SUA	451 households
Endline survey	June - July 2017	Tanzania (17 villages: Kilosa, Mvomero, and Babati districts)	IFPRI	SUA	568 households
Baseline household and intra-household survey	Nov 2015 – Feb 2016	Ghana	IFPRI	UDS	12 communities, 902 households
Endline survey	December 2017 and February 2018	Ghana	IFPRI	UDS	12 communities, 902 households
Focus Group Discussions	2016	Ethiopia, Ghana, and Tanzania	IFPRI and IWMI	Ghana: UDS Ethiopia: BDU	19 communities, 38 gender-separated FGDs with 375 men and women; Qualitative data collected by skilled local facilitators trained by ILSSI researchers on gender. In Tanzania, included sites from a Helen Keller

					International (HKI) project on home gardens.
SSI field tests	2014-2018	Ethiopia	IWMI	BDU	~60 farmers, 3 sites
SSI field tests	2015-2018	Ghana	IWMI	UDS	~60 farmers, 3 sites
SSI field tests	2015-2018	Tanzania	IWMI	SUA	~60 farmers, 3 sites
Qualitative study on microfinance	2017-2018	Ethiopia and Ghana	IWMI	Ethiopia: BDU Ghana: UDS, Water Resources Institute (WRI)	
Qualitative study on SSI markets	2017-2018	Ethiopia and Ghana	IWMI		
CA field pilots	2014-2018	Ethiopia			13 farmer fields (Robit and Dangishita); Data for 4 seasons
CA field pilots	2016-2018	Ghana			15 farmer fields (Yemu); Data for 3 seasons
CA field pilots	2016-2018	Tanzania			15 farmer fields (Mkindo); Data for 3 seasons
Irrigated fodder field tests	2015-2018	Ethiopia			FEAST applied in 2015 in representative villages (Kerekicho, Jawe, Upper Gana in SNNPR; Bahir Dar Zuria district in Amhara).
Fodder market study	2015	Ethiopia	ILRI		Near all project sites
Irrigated fodder field tests	2016-2017	Ghana	ILRI	ARI	FEAST applied; field tested: Brachiaria ruziziensis; Sorghum almum; Cajanus cajans; Lablab
Fodder market study	2017 - 2018	Ghana	ILRI	ARI	Surveys on potential for irrigated fodder for producers, sellers and buyers: 2 districts for 3 seasons. Seed samples of fodder in markets collected and analyzed by ILRI laboratory.
Fodder market study		Tanzania		SUA	

Annex 5. Publications and knowledge products (2013-2018)

<u>Peer reviewed</u>

Assefa, T.; Jha, M.; Reyes, M.R.; Srinivasan, R.; Worqlul, A.W. 2018. Assessment of Suitable Areas for Home Gardens for Irrigation Potential, Water Availability, and Water-Lifting Technologies. *Water* 10(4) (04/2018); DOI:10.3390/w10040495

Assefa T.T.; Jha, M.K.; Reyes, M.R.; Worqlul, A.W. 2018. Modeling the impacts of conservation agriculture with drip irrigation system on hydrology and water management in sub-Sahara Africa. *Sustainability* 10(12), 4763 (12/2018); DOI:10.3390/su10124763

Assefa T.T.; Jha, M.K.; Reyes, M.R.; Srinivasan, R.; Worqlul, A.A. 2018. Assessments of suitable areas for home gardens for irrigation potential, water availability and water-lifting technologies. *Water* 10(4). DOI: 10.3390/w10040495

Clarke, N.; Bizimana, J.C.; Dile, Y.; Worqlul, A.A.; Osorio, J.; Herbst, B.; Richardson, J. W.; Srinivasan, R.; Gerik, T.; Williams, J.; Jones, C.A.; Jeong, J. 2016. Evaluation of new farming technologies in Ethiopia using the Integrated Decision Support System (IDSS). *Agricultural Water Management* 180(Pt B) (08/2016); DOI:10.1016/j.agwat.2016.07.023

Dile, Y.T.; Daggupati, P.; George, C.; Srinivasan, R.; Arnold, J. 2016. QSWAT: Introducing a New Open Source GIS User Interface for the SWAT Model. *Environmental Modeling and Software* 85:129-138. DOI:10.1016/j.envsoft.2016.08.004

Dile, Y.T.; Tekleab, S.; Kaba, E.A.; Gebrehiwot, S.G.; Worqlul, A.W.; Bayabil, H.K.; Yimam, Y.T.; Tilahun, S.A.; Daggupati, P.; Karlberg, L.; Srinivasan, R. 2018. Advances in water resources research in the Upper Blue Nile basin and the way forward: A review. *Journal of Hydrology* 560 (03/2018); DOI:10.1016/j.jhydrol.2018.03.042

Domènech, L. 2015. Improving irrigation access to combat food insecurity and undernutrition: A review. *Global Food Security* 6: 24-33 (October 2015).

Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W. 2017. Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Environmental Systems Research* 6(1) (12/2017); DOI:10.1186/s40068-017-0094-5

Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.A. 2017. Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Environmental Systems Research* 6 (1). DOI:10.1186/s40068-017-0094-5

Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W. 2017. Modeling the hydrological impacts of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Science of The Total Environment* 619 (11/2017); DOI:10.1016/j.scitotenv.2017.11.191

Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W. 2018. Land capability classification for planning land uses in the Geleda watershed, Blue Nile Basin, Ethiopia. *Modeling Earth Systems and Environment* 4(2). (04/2018); DOI: 10.1007/s40808-018-0448-7

Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W.; Tolessa, T.; Kindu, M. 2018. Estimating the impacts of land use/land cover changes on Ecosystem Service Values: The case of the Andassa watershed in the Upper Blue Nile basin of Ethiopia. *Ecosystem Services* 31 (06/2018); DOI:10.1016/j.ecoser.2018.05.001

Hyandye, C.B.; Worqlul, A.W.; Martz, L.W.; Muzuka, A.N.N. 2018. The impact of future climate and land use/cover change on water resources in the Ndembera watershed and their mitigation and adaptation strategies. *Environmental Systems Research* 7(7) (12/2018); DOI:10.1186/s40068-018-0110-4

Kadyampakeni, D.; Appoh, R.; Barron, J.; Boakye-Acheampong, E. 2018. Analysis of water quality of selected irrigation water sources in northern Ghana. *Water Science and Technology: Water Supply* 18(4):1308-1317. DOI :10.2166/ws.2017.195

Moges M.A.; Schmitter P.; Tilahun S.; Dagnaw D.C.; Akale A.T.; Langan S.; Steenhuisen T. 2017. Suitability of Watershed Models to Predict Distributed Hydrologic Responses in the Awramba Watershed, Upper Blue Nile Basin. *Land Degradation & Development* 28(4): 1386–1397. DOI: 10.1002/ldr.2608

Moges, M.A.; Schmitter, P.; Tilahun, S.A. 2018. Watershed modeling for reducing future non-point source sediment and phosphorus load in the Lake Tana Basin, Ethiopia. *J Soils Sediments* 18: 309. DOI:10.1007/s11368-017-1824-z

Nakawuka P.; Langan S.; Schmitter P.; Barron, J. 2017. A review of trends, constraints and opportunities of smallholder irrigation in East Africa. *Global Food Security*: 1-17. DOI:10.1016/j.gfs.2017.10.003.

Otoo, M.; Lefore, N.; Schmitter, P.; Barron, J.; Gebregziabher, G. 2018. Business model scenarios and suitability: smallholder solar pump-based irrigation in Ethiopia. Agricultural Water Management – Making a Business Case for Smallholders. IWMI Research Report 172. Colombo, Sri Lanka: International Water Management Institute (IWMI). http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub172/rr172.pdf

Passarelli, S.; Mekonnen, D.; Bryan, E.; Ringler, C. 2018. Evaluating the pathways from small-scale irrigation to dietary diversity: Evidence from Ethiopia and Tanzania. *Food Security* 10(4): 981–997.

Schmitter, P.; Kibret, K.S.; Lefore, N.; Barron, J. 2018a. Suitability mapping framework for solar photovoltaic pumps for smallholder farmers in sub-Saharan Africa. *Applied Geography*, Volume 94: 41-57. https://www.sciencedirect.com/science/article/pii/S0143622817310457

Teklay, A.; Dile, Y.T.; Setegn, S.G.; Demissie, S.S.; Asfaw, D.H., 2019. Evaluation of static and dynamic land use data for watershed hydrologic process simulation: A case study in Gummara watershed, Ethiopia. Catena 172: 65–75. DOI:10.1016/j.catena.2018.08.013

Theis, S.; Lefore, N.; Meinzen-Dick, R.; Bryan, E. 2018. What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania. *Agriculture and Human Values* 35 (3): 671–684.

Walker, D.; Parkin, G.; Schmitter, P.; Gowing, J.; Tilahun, S.A.; Haile, A.T.; Yimam, A.Y., 2018. Insights from a multi-method recharge estimation comparison study. *Groundwater*. DOI: 10.1111/gwat.12801

Worku, G.; Teferi, E.; Bantider, A.; Dile, Y.T.; Taye, M.T. 2018. Evaluation of regional climate models performance in simulating rainfall climatology of Jemma sub-basin , Upper Blue Nile Basin, Ethiopia. *Dyn. Atmos. Ocean* 83: 53–63. DOI:10.1016/j.dynatmoce.2018.06.002

Worku, G.; Teferi, E.; Bantider, A.; Dile, Y.T. 2018. Observed changes in extremes of daily rainfall and temperature in Jemma Sub-Basin, Upper Blue Nile Basin, Ethiopia. *Theoretical and Applied Climatology* DOI:10.1007/s00704-018-2412-x

Worqlul, A.W.; Ayana, E.K.; Maathuis, B.H.P.; MacAlister, C.; Philpot, W.D.; Osorio Leyton, J.M.; Steenhuis, T.S. 2017. Performance of bias-corrected MPEG rainfall estimate for rainfall-runoff simulation in the Upper Blue Nile Basin, Ethiopia. *Journal of Hydrology* 556: 1182-1191 (01/2017); DOI:10.1016/j.jhydrol.2017.01.058

Worqlul, A.W.; Ayana, E.K.; Yen, H.; Jeong, J.; MacAlister, C.; Taylor, R.; Gerik, T.J.; Steenhuis, T.S. 2018. Evaluating hydrologic responses to soil characteristics using SWAT model in a paired-watersheds in the Upper Blue Nile Basin. *Catena* 163:332-341 (01/2018); DOI:10.1016/j.catena.2017.12.040

Worqlul, A.W.; Yen, H.; Collick, A.S.; Tilahun, S.A.; Langan, S.; Steenhuis, T.S. 2017. Evaluation of CFSR, TMPA 3B42 and Ground-based Rainfall Data as Input for Hydrological Models, in Data-Scarce Regions: The Upper Blue Nile Basin, Ethiopia. *Catena* 152: 242-251(05/2017); DOI:10.1016/j.catena.2017.01.019

Worqlul, A.W.; Jeong, J.; Dile, Y.T.; Osorio Leyton, J.M.; Schmitter, P.; Gerik, T.; Srinivasan, R.; Clarke, N. 2017. Assessing potential land suitable for surface irrigation using groundwater in Ethiopia. *Applied Geography* 85:1-13 (08/2017); DOI:10.1016/j.apgeog.2017.05.010

Worqlul, A. W.; Dile, Y.T.; Bizimana, J. C.; Jeong, J.; Gerik, T.; Srinivasan, R.; Richardson, J.; Clarke, N. 2018. Multi-Dimensional Evaluation of Simulated Small-Scale Irrigation Intervention: A Case Study in Dimbasinia Watershed, Ghana. *Sustainability* 10(5):1531 05/2018; DOI:10.3390/su10051531

Worqlul, A. W.; Dile, Y.T.; Ayana, E.K.; Jeong, J.; Adem, A.A.; Gerik, T. 2018. Impact of Climate Change on Streamflow Hydrology in Headwater Catchments of the Upper Blue Nile Basin, Ethiopia. *Water* 10(2):120 (01/2018); DOI:10.3390/w10020120

Xie, H.; You, L.; Takeshima, H. 2017. Invest in small-scale irrigated agriculture: A national assessment on potential to expand small-scale irrigation in Nigeria. *Agricultural Water Management* 193: 251-264.

Yaduvanshi, A.; Srivastava, P.; Worqlul, A. W.; Sinha, A.K. 2018. Uncertainty in a Lumped and a Semi-Distributed Model for Discharge Prediction in Ghatshila Catchment. *Water* 10(4): 381 (03/2018) DOI:10.3390/w10040381

Peer reviewed chapters

Ringler, C.; Passarelli, S. 2016. Water, nutrition, and health: Finding win-win strategies for water management. Chapter in IFPRI: *2016 Global Food Policy Report*. Washington, D.C.: IFPRI.

Schmitter, P., Lefore, N.; Barron, J.; Giordano, M. 2018b. Improving on-farm water management through irrigation information for climate-smart agriculture in sub-Saharan Africa, In Ed. C. Batchelor and J. Schnetzer, *Compendium on Climate-Smart Irrigation Concepts, evidence and options for a climatesmart approach to improving the performance of irrigated cropping systems*. Rome: Global Alliance for Climate-Smart Agriculture. Pp. 121-124. http://www.fao.org/gacsa/resources/gacsa-csa-documents/en/.

Working/discussion papers

Domènech, L. 2015. Is reliable water access the solution to undernutrition? A review of the potential of irrigation to solve nutrition and gender gaps in Africa South of the Sahara. IFPRI Discussion Paper 1428. Washington DC: IFPRI.

Kadyampakeni, D.; Obuobie, E.; Mul, M.; Appoh, R.; Owusu, A.; Ghansah, B.; Boakye-Acheampong, E.; Barron, J. 2017. Agro-Climatic and hydrological characterization of selected watersheds of northern Ghana. IWMI Working Paper 173. Colombo, Sri Lanka: IWMI.

Theis, S.; Lefore, N.; Meinzen-Dick, R.; Bryan, E. 2017. What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania. IFPRI Discussion Paper 1672. Washington DC: IFPRI.

Merrey, D. J.; Langan, Simon. 2014. Review paper on 'Garden Kits' in Africa: Lessons learned and the potential of improved water management. IWMI Working Paper 162. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Merrey, D.; N. Lefore. 2018. Improving the Availability and Effectiveness of Rural and "Micro" Finance for Small Scale Irrigation in sub-Saharan Africa: A Review of Lessons Learned. IWMI Working Paper 185. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Policy notes

Theis, S., N. Lefore, E. Bryan, C. Ringler and R.S. Meinzen-Dick. 2017. Integrating gender into small-scale irrigation. FTF-ILSSI Project Note 2. Washington, D.C.: IFPRI and IWMI.

Theis, S., S. Passarelli, E. Bryan, N. Lefore, S. Deneke, B. Nyamadi and S. Mlote. 2016. Promoting gender equality in irrigation. Feed the Future Innovation Lab for Small Scale Irrigation (FTF-ILSSI) Project Notes 1. Washington, D.C.: IFPRI and IWMI.

Other papers

Mekonnen, D.K. 2017.Beyond the drinking glass: Expanding our understanding of water-nutrition linkages. Field Exchange 54(February 2017).

Joint attribution with Africa RISING

Schmitter, P.; Tegegne, D.; Abera, A.; Baudron, F.; Blummel, M.; Lefore, N.; Barron, J. 2016. Evaluation of suitable water lifting and on-farm water management technologies for the irrigation of vegetables and fodder in Lemo district, Ethiopia. Nairobi, Kenya: ILRI. https://cgspace.cgiar.org/handle/10568/82714

Schmitter, P. 2016. Irrigated fodder opportunities for small scale irrigators. Feed the Future Innovation Lab for Small Scale Irrigation/Africa RISING Fact Sheet. Colombo, Sri Lanka: IWMI

Conference papers and posters

Adimassu, Z.; Balana, B.; Gebrezgabher, S.; Appoh, R.; Cofie, O.O.; Mul, M.; Abdulai, A.; Barron, J.; Kadyampakeni, D.; Ayambila, S.; Gandaa, B. Z.; Boakye-Acheampong, E.; Lefore, N. 2017. Small scale irrigation: Improving livelihoods through enhanced land and water productivity in Northern Ghana**.** International Conference on Irrigation and Agricultural Development (IRAD) at the University for Development Studies (UDS). Tamale, Ghana, 30-31 October 2017.

Adimassu, Z.; Appoh, R.; Balana, B.; Lefore, N.; Ayambila, S.; Cofie, O. O. 2017. Land and Water Productivity of Small-Scale Irrigation System in the Northern and Upper East Regions of Ghana. International Conference on Irrigation and Agricultural Development (IRAD) at the University for Development Studies (UDS). Tamale, Ghana, 30-31 October 2017.

Adimassu, Z.; Appoh, R.; Cofie, O.O.; Gandaa, B. Z.; Lefore, N. 2017. Improving on-farm water management with wetting front detectors in Northern Ghana. International Conference on Irrigation and Agricultural Development (IRAD) at the University for Development Studies (UDS). Tamale, Ghana, 30-31 October 2017.

Adie, A.; Yitayew, B.; Demeke, Y.; Ferede, L.; Yeheyis, M.; Bezabih, M.; Schmitter, P.; Blummel; Yimam, A. Y. 2018. Lessons from pilot trials with small-scale irrigated forage production in the Amhara Region: potential of integrating the perennial forage Napier grass with Desmodium and Pigeon Pea in cropping systems. 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Assefa, T, MK Jha, MR Reyes, K Schilling. 2017. Commercial Home Gardens under Conservation Agriculture and Drip Irrigation for Small Holder Farming in sub-Saharan Africa. *Annual International Conference of the American Society of Agricultural and Biological Engineers (ASABE)*. July 16-19, 2017, Spokane, Washington.

Balana, B.; Appoh, R.; Adimassu, Z.; Lefore, N. 2017. Economic Analysis of Small Scale Irrigation Technologies in northern Ghana. International Conference on Irrigation and Agricultural Development (IRAD) at the University for Development Studies (UDS). Tamale, Ghana, 30-31 October 2017.

Balana, B.; Abdulai, A.; Lefore, N. 2017. Micro and Rural Finance for Small Scale Irrigation Technologies and Tools: Evidence from Northern Ghana. International Conference on Irrigation and Agricultural Development (IRAD) at the University for Development Studies (UDS). Tamale, Ghana, 30-31 October 2017.

Balana B.; Bizimana J.C.; Richardson, J.W.; Lefore L.; Adimassu Z.; Herbst, B.K. 2018. Profitability and Economic Feasibility Analysis of Small Scale Irrigation Technologies in northern Ghana. Conference paper presented at the 'Southern Agricultural Economics Association (SAEA)' 2018 conference Jacksonville, Florida (USA), February 2-6, 2018.

Bezabih, M.; Adie, A.; Gemiyu, D.; Zeleke, B.; Schmitter, P.; Blümmel, M. 2018. Lessons from small-scale irrigated forage production trials: potential of annual oat-vetch mixtures. 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Gebregziabher, G.; Haileslassie, A.; Lefore, A. 2018. The viability of solar irrigation in Ethiopia. 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Gebrehaweria, G.; Hagos, F.; Lefore, N.; Haileslassie, A.; Barron, J. Impacts of household irrigation technologies on poverty reduction: Experience from Innovation laboratory for Small-Scale Irrigation (ILSSI). 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Gedfew, M.P.; Schmitter, P.; Nakawuka, P.; Tilahun, S.; Steenhuis, T.; Langan, S. 2016. Partial Nutrient Balance at Farm plot level under Different Irrigation Water Management for Tomato production. Poster presented on the Small Scale and Mirco Irrigation for Ethiopian Smallholders project. Amhara Agricultural Forum hosted by the Small Scale and Mirco Irrigation for Ethiopian Smallholders, a Canadian-Dutch funded project. Bahir Dar, 8-9 December 2016.

Gedfew, M.; Schmitter, P.; Nakawuka, P.; Tilahun, S. A.; Steenhuis, T.; Langan, S 2017. Sustainable smallholder intensification through improved water management requires adjusted fertilizer recommendation. 19th EGU General Assembly, EGU2017, proceedings from the conference held 23-28 April, 2017 in Vienna, Austria.

Hagos, F.; Gebregziabher, G.; Lefore, N.; Haileslassie, A. 2018. Credit access and adoption of Small Scale irrigation technologies: case of ILSSI sites in Ethiopia. 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Jha, M.K.; Assefa, T.; Reyes, M.R. 2018. Modeling of Commercial Home Gardens under Conservation Agriculture and Drip Irrigation for Small Holder Farming in sub-Saharan Africa. *Annual International Conference of the American Society of Agricultural and Biological Engineers (ASABE)*. July 29 - August 1, 2018. Detroit, Michigan.

Kadyampakeni, D.; Appoh, R.; Barron, J.; Boakye-Acheampong, E. 2017. Analysis of Water Quality of Selected Irrigation Water Sources in Northern Ghana. International Conference on Irrigation and Agricultural Development (IRAD) at the University for Development Studies (UDS). Tamale, Ghana, 30-31 October 2017.

Muche, H.; Abdela, M.; Schmitter, P.; Nakawuka, P.; Tilahun, S. A.; Steenhuis, T.; Langan, S. 2017. Application of Deep tillage and Berken Maresha for hardpan sites to improve infiltration and crop productivity. ICAST conference 2017, Bahir Dar University.

Muche, H.; Abdela, M.; Schmitter, P.; Nakawuka, P.; Tilahun, S.A.; Steenhuis, T.; Barron, J.; Adie, A.; Blummel, M. 2018a. Biological and mechanical techniques to increase infiltration in rainfed agriculture of the Ethiopian highlands. 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Muche, H.; Abdela, M.; Schmitter, P.; Nakawuka, P.; Tilahun, S.A.; Steenhuis, T.; Barron, J.; Adie, A.; Blummel, M. 2018b. Promoting biological and mechanical techniques for enhancing rainwater infiltration and crop productivity in the Ethiopian highlands. 18th International Symposium on Sustainable Water Resources Development on 8-9 Jun 2018, Araba Minch University, Arba Minch, Ethiopia.

Nigussie, L.; Lefore, N.; Schmitter, P.; Assefa, T.; Tilahun, S.A. 2018. Gender and water lifting technologies for multiple purposes and Irrigation. 2nd Amhara Agricultural Forum 2017 on 16 Jan 2018, Jacaranda Hotel, Bahir Dar, Ethiopia.

Schmitter, P.; A. Haileslassie; Desalegn, Y.; Chali, A.; Tilahun, S. A.; Langan, S.; Barron, J. 2016. Improving on-farm water management by introducing wetting front detectors to small scale irrigators in Ethiopia. Presentation on the Small Scale and Micro Irrigation for Ethiopian Smallholders project.

Amhara Agricultural Forum hosted by the Small Scale and Micro Irrigation for Ethiopian Smallholders, a Canadian-Dutch funded project. Bahir Dar, 8-9 December 2016.

Schmitter P.; Haileslassie A.; Desalegn Y.; Chali A.; Tilahun S.; Langan S.; Barron J. 2016. Improving on-farm water management by introducing wetting front detectors to small scale irrigators in Ethiopia. Solidarity in a competing world — fair use of resources September 18 - 21, 2016, organized by the University of Natural Resources and Life Sciences (BOKU Vienna), Austria

Tesema M.; Schmitter P.; Nakawuka P.; Tilahun S.; Steenhuis T.; Langan S. 2016. Evaluating irrigation technologies to improve crop and water productivity of onion in Dangishta watershed during the dry monsoon phase. International conference on the advancement of Science and Technology (17-18 July 2016), Bahir Dar University, Ethiopia

Tetteh, R. 2017. Smallholder Irrigation Under Limited Water Supply in selected Communities of Northern Ghana. International Conference on Irrigation and Agricultural Development (IRAD) at the University for Development Studies (UDS). Tamale, Ghana, 30-31 October 2017.

Tilahun, S.; P. Schmitter, P.; Nakawuka, A.; Yimer, D.; Lijalem, T.; Enku, T.; Steenhuis, T.; Langan, S.; Barron, J. 2016. Shallow Groundwater Recharge and its Potential for Smallholder Dry Period Irrigation in Lake Tana Basin Presentation on the Small Scale and Micro Irrigation for Ethiopian Smallholders project. Amhara Agricultural Forum hosted by the Small Scale and Micro Irrigation for Ethiopian Smallholders, a Canadian-Dutch funded project. Bahir Dar, 8-9 December 2016.

Yilak, D. L.; Tilahun, S.A.; Schmitter, P.; Nakawuka, P.; Enku, T.; Tibebu Kassawmar, N.; Steenhuis, T.S. 2015. Determining the groundwater potential for agricultural use in Ethiopian Highlands. 10th Alexander von Humboldt Conference 2015, Water-Food-Energy River and Society in the Tropics, EGU Topical Conference Series, Addis Ababa, Ethiopia, 18–20 November 2015

Yimam, A. Y.; Nakawuka, P.; Schmitter, P.; Tilahun, S. A.; Bekele. 2018, A.M. Rainfall-Runoff Process and Groundwater Recharge in the Upper Blue Nile Basin: The Case of Dangishta Watershed. 6th International Conference on the advancements of Science and Technology (ICAST) on 5-6 Oct 2018, Bahir Dar Institute of Technology, Bahir Dar, Ethiopia

Xie, H.; You, L. Opportunity to invest in dry-season small-scale irrigation to enhance food security in Sub-Saharan Africa: Case studies in Ethiopia, Ghana and Tanzania. AGU annual conference. Washington, DC. December 10, 2018.

Project reports

Abdulai, A.; Balana, B. 2018. Efficiency of Small Scale Irrigation Farmers in Northern Ghana: A Data Envelopment Analysis Approach. ILSSI Technical Report (Ghana).

Adimassu, Z.; Appoh, R.; Bizoola, Z.; Balana, B.; Lefore, N.; Ayambila, S. 2017. Land and water productivity of small-scale irrigation system in the Northern and Upper East Regions of Ghana. ILSSI Technical Report (Ghana).

Addimassu, Z. 2018, Crop and Water Productivity of Onion (Allium cepa) and Corchorus (Corchorus olitorius) under Wetting Front Detector and Farmers' Practices Irrigation Scheduling Methods in Northern Ghana. ILSSI Technical Report (Ghana).

Akudugu, M. A. 2017. Financing Irrigated Agricultural Production in Northern Ghana: An Innovative Financing Model for Action. ILSSI Technical Report (Ghana).

Balana, B.; Appoh, R.; Adimassu, Z.; Lefore, N. 2017. Profitability and Economic Feasibility Analysis of Small Scale Irrigation Technologies in Zanlerigu and Bihinaayili, northern Ghana. ILSSI Technical Report (Ghana).

Balana, B.; Appoh, R. 2018. Assessment of private actors in irrigation supply chain in Ghana. ILSSI Technical Report (Ghana).

Balana, B.; Abdulai, A. 2018. Access to Credit and Adoption of Small-Scale Irrigation Technologies: Evidence from Northern Ghana. ILSSI Technical Report (Ghana).

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W. 2016. Small-Scale Irrigation Applications for Smallholder Farmers in Ghana: Ex Ante Analysis of Options.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W.. 2016. *Ex Ante* Analysis of Small-Scale Irrigation Interventions in Bihinaayili, Ghana.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W. 2016. *Ex Ante* Analysis of Small-Scale Irrigation Interventions in Nimbasinia, Ghana.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W. 2016. *Ex Ante* Analysis of Small-Scale Irrigation Interventions in Zanlerigu, Ghana.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W. 2015. Small-Scale Irrigation Applications for Smallholder Farmers in Tanzania: Ex Ante Analysis of Options.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W. 2015. *Ex Ante* Analysis of Small-Scale Irrigation Interventions in Babati, Tanzania.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W. 2015. *Ex Ante* Analysis of Small-Scale Irrigation Interventions in Mkindo, Tanzania.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W. 2015. *Ex Ante* Analysis of Small-Scale Irrigation Interventions in Kilosa, Tanzania.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W. 2015. Small-Scale Irrigation Applications for Smallholder Farmers in Ethiopia: Ex Ante Analysis of Options.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W... 2015. Ex Ante Analysis of Small-Scale Irrigation Interventions in Adami Tulu, Ethiopia.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W... 2015. Ex Ante Analysis of Small-Scale Irrigation Interventions in Robit, Ethiopia.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W... 2015. Ex Ante Analysis of Small-Scale Irrigation Interventions in Dangila, Ethiopia.

Bizimana, J.C.; Clarke, N.; Dile, Y.T.; Gerik, T.J.; Jeong, J.; Osorio Leyton, J.M.; Richardson, J.W.; Srinivasan, R.; Worqlul, A.W... 2015. Ex Ante Analysis of Small-Scale Irrigation Interventions in Lemo, Ethiopia.

Bizimana, J.C.; Richardson, J.W. 2016. Farm level economic and nutritional analysis on how to reduce hunger at the household level: A Case study of Robit in Amhara region.

Gebregziabher, G.; Hagos, F. 2017b. Economic feasibility of water lifting technologies for small scale irrigation in Ethiopia. ILSSI Technical report (Ethiopia).

Gebregziabher, G.; Hagos, F.; Lefore, N.; Haileslassie, A. 2017a. Analysis of poverty impacts of household level water lifting irrigation technologies. ILSSI technical report (Ethiopia).

Gebrehaweria Gebregziabher, G.; Hagos, F.; Haileslassie, A. 2018a. Disaggregated Analysis of Farmers' Willingness to Pay for Household Irrigation Technologies. ILSSI project report (Ethiopia).

Gebrehaweria Gebregziabher, G.; Hagos, F.; Haileslassie, A.; Lefore, N. 2018b. A Multivariate analysis of factors influencing adoption of smallholder irrigation technologies. ILSSI Technical Report (Ethiopia).

Gebregziabher, G. 2017c. Economic feasibility of diesel/petrol pumps for small scale irrigation in Tanzania. ILSSI Technical report (Tanzania).
Hagos, F.; Gebregziabher, G.; Lefore, N.; Haileslassie, A. 2017. Credit access and adoption of irrigation technologies by smallholder farmers: Evidence from Ethiopia. ILSSI project report. ILSSI Technical Report (Ethiopia).
Hagos, F.; Lefore, N.; Gelgo, B.; Haileslassie, A. 2018. Rapid assessment of supply chain of agricultural water management technologies in Ethiopia. ILSSI Technical Report (Ethiopia).
Katic, P. 2017. Evidence for upscaling of dry season irrigation technologies: Market opportunities. ILSSI Technical Report (Ghana).
Lukuyu, B., Mwilawa, A, Ngunga, D and Mangesho, W. 2015. An assessment of feed and forage resources in Morogoro, Kilosa and Babati districts in Tanzania. ILSSI project report.
Lukuyu, M.; Njehu, A.; Mwilawa, A.; Lukuyu, B.; Omore, A.; Rao, J. 2017. The role of fodder markets in meeting the year-round forage requirements of smallholder dairy farmers in Tanzania. ILSSI project report.
Richardson, J.W.; Bizimana, J.C. 2017. Agricultural technology assessment for smallholder farms in developing countries: An Analysis using a farm simulation model (FARMSIM).
SUA. 2018. Effect of deficit irrigation on tomato production under drip system. ILSSI Technical report (Tanzania).
SUA. 2018. Motorized pump sharing dynamics under small scale irrigated vegetable producers. ILSSI Technical report (Tanzania).
SUA. 2018. The efficacy of thermal imaging in managing irrigation water in African eggplant production. ILSSI Technical report (Tanzania).
SUA. 2018. The Potential of Agronomic Practices on Rice Production to Food Security and Household Income: A Case of Wami Ruvu Basin, Tanzania. ILSSI Technical report (Tanzania).
Tilahun, S.; Steenhuis, T.; Lijalem, D.; Yimer, A.; Mamo, A.; Schmitter, P. 2017. Observations and Parameter Efficient Distributed modeling of Surface runoff, and Groundwater recharge in Northern Ethiopia Highlands: the Case of Robit Bata and Dangishta Watersheds. ILSSI Technical report (Ethiopia).

Select student thesis papers

Belete, B. Impact of small-scale irrigation technology on farm household welfare in Amhara Region: Evidence from Dangila and Bahir Dar Zuria Districts. Bahir Dar University. Thesis submitted toward requirements for a MSc degree.
Gedfew, M. 2017. Comparing the effect of soil moisture and climate based irrigation scheduling strategies on tomato production and partial nutrient balances: Case study in Robit watershed. Bahir Dar University. Thesis submitted toward requirements for a MSc degree
Getachew, Tamrat. 2018. Evaluation of full nutrient balance for garlic & inter cropped Napier grass under different water management during the dry season at Robit Bata watershed. MSc. (Bahir Dar University)
Mwalonde Johnson, P. 2018. Motor pump irrigation by smallholder farmers in Rudewa and Mkindo wards, Tanzania: Profitability and its impact on income inequality. MSc. (Sokoine University of Agriculture)
Tesfaye, Tigist. 2018. Determinants of Access to Credit among Small Scale Irrigation User Farmers in Dangla Woreda, Amhara National Regional State, Ethiopia. MSc. (Bahir Dar University)
Tetteh, R. 2018. Smallholder irrigation under limited water supply in northern Ghana. Mphil. (University for Development Studies)
Workie, Anteneh. 2018. Application of thermal image or thermograph for the determination of water stress in case of Tomato. MSc. (Bahir Dar University)

Zakaria, N. 2018. Credit access, market participation and constraints: Analysis of dry season vegetable farmers in northern Ghana. Mphil. (University for Development Studies)

Annex 6. Short-term trainees

Summary of IDSS trainings.

Country	Hosting institution	Duration	Training	Number of Participants	
				M	F
Ethiopia	ILRI	June 9 - 13, 2014	IDSS	43	8
	Bahir Dar University	February 2-6, 2015	IDSS	73	9
	ILRI	February 8-12, 2016	IDSS	58	9
		February 15-19, 2016	Advanced SWAT/SWAT-clinic	29	2
	Addis Ababa University	January 30 - February 3, 2017	IDSS	48	9
	Ethiopian Agricultural Transformation Agency (ATA)	December 18-20, 2017	GIS	45	2
		December 21-27, 2017	IDSS	49	3
		December 28-29, 2017	Advanced SWAT	8	1
		December 28-29, 2017	AutoCAD	22	1
Ghana	Water Research Institute	February 1-5, 2016	IDSS	40	10
	Kwame Nkrumah University of Science and Technology	July 24-28, 2017	IDSS	43	24
Tanzania	Sokoine University of Agriculture	July 27-31, 2015	IDSS	41	10
	Arusha Nelson Mandela	June 6-10, 2016	IDSS	33	13
			Advanced SWAR	16	8
	University of Dar Es Salaam	January 23-27, 2017	IDSS	53	20

Short-term training on gender-irrigation

In 2016, IFPRI with IWMI worked with 150 experts from government, practitioners, and universities in three gender-irrigation trainings in Ethiopia, Ghana and Tanzania. As part of this training, IFPRI and IWMI developed two tools to integrate gender into irrigation programming. The two tools are: A diagnostic that assesses the key drivers of gender inequality in access to irrigation technologies and water and control over benefits in a given community, helping practitioners identify entry points to improve women's access to and control over irrigation; and An assessment tool that measures the extent to which women were effectively included in collective irrigation scheme development (the Gender in Irrigation Learning and Improvement Tool - GILIT) that serves as a reflection on women's participation in community-level decision-making. These tools can be used for a range of purposes: to inform qualitative and quantitative research instruments and approaches; for training and capacity strengthening for program managers on themes of gender in irrigation; and to guide program design, monitoring, and evaluation. They help to propose ways of measuring and supporting gender equality in this sector.

- *Ethiopia:* March 2016 (IFPRI, IWMI, Ministry of Agriculture and Natural Resources) Information is available on the ILSSI website.
- *Ghana:* April 13-14, 2016 (IFPRI, IWMI, Ghana Irrigation Development Authority) Information is available on the ILSSI website.
- *Tanzania:* April 20-21, 2016 (IFPRI, Sokoine University of Agriculture, Ministry of Agriculture, Livestock, and Fisheries) Information is available on the ILSSI website

Annex 7. Long-term training: Students and post-doctoral scholars

Students supported by ILSSI

M/F	Univ	Degree	Major	Subject	Program end date	Degree granted	Country
M	BDU	MSc	Hydraulic Eng'g	Improving subsurface recharge through breaking restrictive layers by mechanical Means	06/2016	Yes	Ethiopia
M	BDU	MSc		Evaluating Simple Irrigation Technologies to Improve Crop and Water Productivity of Onion in Dangishta Watershed	2015	Yes	Ethiopia
F	BDU	Msc.	Hydraulic Eng'g	Comparing different water management and technology for vegetable crop(onion , pepper and tomato) in Dangishta	10/2019	No	Ethiopia
M	NCAT	PhD		Experimental modeling: Conservation agriculture	2018	Yes	Ethiopia
M	BDU	Msc.	Economics	Impact of Small Scale Irrigation Technology on Farm Household Welfare In Amhara region: Evidence from Dangila an Bahir Dar Zuria Districts	06/2017	Yes	Ethiopia
M	Arba Minch	PhD	Water Resource Irrigation Engineering	Adaptive capacity of community to drought in the Upper Gana watershed	06/ 2019	No	Ethiopia
M	BDU	MSc	Economics	Cost-Benefit Analysis of small scale irrigation technologies: In Bahir Dar Zuria and Dangela Experimental Projects	05/2015	Yes	Ethiopia
M	BDU	MSc	Hydraulic Eng'g	Assessing the performance of manual water lifting technologies and irrigation scheduling based on measured soil moisture and farmers practice on irrigated tomato production, and comparing soil moisture measuring and	11/2015	Yes	Ethiopia

				estimation methods: The case of Western Amhara sub- region			
M	Arba Minc h	MSc	Economics	Impact of small scale irrigation technologies on farm production and productivity		Yes	Ethiopia
M	SUA	BSc	Irrigation and water resources engineering			Yes	Tanzania
M	BDU	MSc	Hydrology	Partial Nutrient Balance at Farm Plot level under Different Irrigation Water Management for Tomato Production	11/2016	Yes	Ethiopia
M	BDU	MSc.	Hydraulic Eng’g	Evaluation of full nutrient balance for garlic & inter cropped Napier grass under different water management during the dry season at Robit Bata watershed	06/2018	Yes	Ethiopia
M	BDU	MSc	Hydraulic Eng’g	Improving Subsurface Recharge By Breaking Hardpans Through Mechanical Means	2016	Yes	Ethiopia
M	SUA	MSc	Food and Resource Economics	The impact of motor pump irrigation technology on vegetable production and household income: case of Rudewa and Mkindo wards in Tanzania	11/2018	Yes	Tanzania
F	SUA	BSc	Irrigation and water resources engineering			Yes	Tanzania
M	BDU	PhD	Hydraulic Eng’g	Optimizing use of groundwater for irrigation in the dry season in the Robit-Bata watershed located in the Lake Tana basin (Robit)	June 2017	Yes	Ethiopia
M	SUA	BSc	Irrigation and water resources engineering			Yes	Tanzania
M	SUA	BSc	Irrigation and water resources engineering			Yes	Tanzania

M	SUA	BSc	Irrigation and water resources engineering			Yes	Tanzania
M	AMU	MSc		Evaluation Of Wetting Front Detector To Determine Water Demand, Water And Crop Productivity Of Selected Fodder Varieties Under Supplemental Irrigation (Case Studies In Lemo And Angacha Areas Of SNNP Region)	2015		
M	BDU	Msc	Hydraulic Eng'g	Development of crop coefficients and evaluating the productivity and water use for Napier grass under small- scale irrigation: the case of Robit Kebele	11/2015	Yes	Ethiopia
F	SUA	BSc	Irrigation and water resources engineering			Yes	Tanzania
F	SUA	BSc	Irrigation and water resources engineering			Yes	Tanzania
M	BDU	MSc.	Hydraulic Eng'g	Application of Berken and deep tillage systems for hardpan sites to improve hydrological processes and crop productivity		Yes	Ethiopia
M	SUA	PhD	Irrigation and water resources engineering		11/2021	No	Tanzania
M	BDU		Hydraulic Eng'g	Analysis of Technical Efficiency of Small Scale Irrigation Technologies: The case of Robit and Dangeshita	2015	Yes	Ethiopia
M	AMU			Farmers willingness to pay and choice of smallholder water lifting technologies: Evidence from Adami Tulu, Lemo, Dangila and Bahir Dar Zuria woredas, Ethiopia	06/2015	Yes	Ethiopia

F	BDU	MSc.	Economics	Determinants of Access to Credit among Small Scale Irrigation User Farmers in Dangla Woreda, Amhara National Regional State, Ethiopia		Yes	Ethiopia
M	UDS	MPhil	Irrigation engineering	Soil and water conservation and management	11/2018	Yes	Ghana
M	UDS	MSc	Environmental Engineering	Assessment of Pesticide residual contamination of soil and water resources: Case of Robit Bata	01/2017	Yes	Ethiopia
M	BDU	Msc.	Hydraulic Eng'g	Application of thermal image or thermograph for the determination of water stress in case of Tomato.		Yes	Ethiopia
F	SUA	BSc	Irrigation and water resources engineering	Rainfall-Runoff processes in the upper Blue Nile Basin. The case study of Dangishta watershed	07/2016	Yes	Tanzania
M	BDU	MSc					Ethiopia
M	UDS	MPhil	Agricultural economics	Credit access in small scale irrigation	11/2018	Yes	Ghana

Post-doctoral scholars supported through ILSSI

M/F	Organization	Subject	University
F	IFPRI	Water-nutrition linkages	U. Barcelona/Spain
M	IFPRI	Household survey development and analysis	U. Georgia

Annex 8. Outreach

Blog Posts

Domènech, Laia. 2015. How can reliable water access contribute to nutrition security in Africa south of the Sahara? IFPRI, March 20, 2015.

Domènech, Laia. 2015. How can irrigation water improve women's empowerment and nutrition? An untapped potential for Africa south of the Sahara. CGIAR Research Program on Agriculture for Nutrition and Health, June 1, 2015.

ILRI Communications. 2016. Irrigated fodder opportunities for small-scale farmers in Ethiopia. Africa RISING, July 25, 2016.

Bizimana, J.C and J.W. Richardson. June 2017. Farm Level Economic and Nutritional Analysis in Ethiopia: A Case Study in Reducing Hunger. https://www.agrilinks.org/blog/farm-level-economic-and-nutritional-analysis-farmsim-case-study-robit-village-amhara-region

ILSSI. Can Irrigation Both Empower and Exclude Women? Agrilinks. January 2, 2018.

Lefore, N.; Merrey, D. "Uber for Irrigation" and Other Novel Ways to Finance a Farmer-Led Revolution in Africa. Agrilinks, December 134, 2018.

Lefore, N., S. Theis, E. Bryan, C. Ringler and R. Meinzen-Dick. 2018. What's the truth about the role of women in agriculture today? Let's start asking the right questions about women in agriculture. Thrive, CGIAR Research Program on Water, Land and Ecosystems.

Ringler, C. 2016. The Goldilocks Dilemma of Balancing Irrigation Technologies, Policies and Institutions. Thrive, CGIAR Research Program on Water, Land and Ecosystems.

Webinars/Online trainings

October 31, 2017: Can small-scale irrigation empower women? By B. Iyob, C. Ringler, E. Bryan, S. Theis and N. Lefore. Agrilinks Webinar.

Making Small-Scale Irrigation Work for Women, by S. Theis, narrated for an African Union training for irrigation engineers. December 10, 2018. https://www.youtube.com/watch?v=_ojHjmaM2yw&feature=youtu.be

Annex 9. Global conferences, symposia and events

Africa in Soil conference 2015. The importance of Ethiopian soils in irrigation and overall watershed management. Leuven Belgium, 4 December 2015.

European Geosciences Union Conference 2017. Sustainable smallholder intensification through improved water management requires adjusted fertilizer recommendation, by graduate student (Muluye Gedfew). Austria. 23-28 April 2017.

Stockholm World Water Week 2017. Session contribution: *African smallholder irrigation: Double yields with half the water!* Stockholm, Sweden, 30 August 2017.

Tropentag Conference 2017. Assessing the Effects of Smallholder Intensification through Improved Water Management Beyond "Business as Usual": a Multi-Facet Lens on Sustainability, by P. Schmitter, G. Gebrehaweria, S. A. Tilahun, N. Lefore and J. Barron. Bonn, Germany, September 2017

Advancing Canada's Feminist International Assistance Policy through Agriculture and Food Systems, **Presentation,**

Enabling resilient, equitable smallholder farming systems through improved agricultural land and water management by Meredith Giordano (IWMI). Ottawa, Canada. 6 -7 September 2017.

Stockholm World Water Week 2018. Overview of frameworks for irrigation and water resource management impacts on child nutrition. Water For Wellbeing: From Framework to Action session. August 29, 2018:

Stockholm World Water Week 2018, Stockholm, Sweden. *Irrigation—The Answer to Ecosystem Health?* Session: https://programme.worldwaterweek.org/event/7891-small-scale-irrigation-the-answer-to-ecosystem-health

Water for Food Global Conference 2016, University of Nebraska. Panel on "Opportunities and Challenges of Expanding Smallholder Irrigation in Sub-Saharan Africa" by C. Ringler and IWMI participants. Lincoln, Nebraska. April 2016.

Water for Food Global Conference 2017, University of Nebraska. Women's Empowerment in (Irrigated) Agriculture, by R. Meinzen-Dick: "Upscaling Solutions: Expanding access to irrigation for smallholders in sub-Saharan Africa", Lincoln, Nebraska. April 2017.

Stockholm World Water Week 2017. Beyond the Drinking Glass: Expanding our Understanding of Water-Nutrition Linkages (IFPRI/ILSSI session). Presentation: Irrigation-nutrition linkages: Insights from the ILSSI project and beyond, by D. Mekonnen. August 31, 2017:

Stockholm World Water Week 2017. Enabling Investment in Irrigation in Sub-Saharan Africa Presentation: Small-scale irrigation: how to ensure equity and nutrition benefits—insights from ILSSI and beyond, by D. Mekonnen. August 28, 2017.

Water for Food International Forum. World Bank/University of Nebraska. Washington, D.C. 29-30 January 2018.

ILSSI International Symposium. Washington, D.C. 31 January 2018.

AGU annual conference. Water for Food: Enhancing Food Security in the Developing World Through Improved Agricultural Water Management. Session convened by Xie and L. You. Washington, DC. December 10, 2018.

USAID Global Learning and Evidence Exchange (GLEE) on Climate-Smart Agriculture. Panel on water, by E. Bryan. Lusaka, Zambia. March 2016.

Annex 10. National conferences and events

1st Amhara Agricultural Forum 2016. Small Scale and Micro Irrigation for Ethiopian Smallholders. Bahir Dar, Ethiopia. 8-9 December 2016.

2nd Amhara Agricultural Forum 2017. Small Scale Irrigation and Agricultural Technologies for Sustainable Development in Amhara Region. Bahir Dar, Ethiopia. 16 January 2018.

International Conference on Irrigation and Agricultural Development (IRAD). University for Development Studies (UDS). Tamale, Ghana. 30-31 October 2017.

Youth Entrepreneurs, drip and solar irrigation. Small Scale and Micro Irrigation for Ethiopian Smallholders (SMIS). Addis Ababa, Ethiopia. **23 August 2017.**

Agricultural Water Management for Attainment of SDGs in Ghana: A knowledge-sharing event. Knowledge sharing event co-convened with the CSIR. Accra, Ghana. 20 September 2017.

Enhancing research into policy and practice, 2016. ILSSI and the Savannah Accelerated Development Authority. Tamale, Ghana.

National Information Platform for Nutrition – Ethiopian Public Health Institute. Irrigation-Nutrition Linkages, by D. Mekonnen. Addis Ababa . December 7, 2018.

American Agricultural Economics Association Annual Conference 2016. Presentation on ILSSI work, by D. Mekonnen. Boston, USA. July 2016.

Dupont Summit Event, "Agricultural Water Management: Confluence of Policies, Institutions and Technologies" organized by C. Ringler, M. Giordano and R. Meinzen-Dick. December 4, 2015. ILSSI presentations include:

M.A. Giordano, IWMI: Unlocking the Potential for Smallholder Agriculture in Sub-Saharan Africa and South Asia

S. Passarelli, IFPRI: Tapping Irrigation's Potential for Women's Empowerment

World Food System Conference 2015. Reliable Water Access: The Solution to Undernutrition?. Oral presentation by Simone Passarelli, Ascona, Switzerland. June 26, 2015.