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

FEED THE FUTURE INNOVATION LABORATORY FOR SMALL SCALE IRRIGATION (ILSSI)

Year Five (FY 2018) Annual Report
October 1, 2017 – November 30, 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/Abbreviations

AEA	Agricultural Extension Agents
ARARI	Amhara Regional Agricultural Research Institute
ATA	Ethiopia's Agricultural Transformation Agency
BT	Berken Tillage
CA	Conservation Agriculture
CA-CWR	Conservation Agriculture-Crop Water Requirement
CT	Conventional Tillage
DT	Deep Tillage
EAC	ILSSI External Advisory Committee
ERC	ILSSI External Review Committee
FtF	Feed the Future
HIL	Horticulture Innovation Laboratory
IDSS	Integrated Decision Support System
ILSSI	USAID Innovation Lab for Small Scale Irrigation
LSIL	Livestock Systems Innovation Laboratory
ME	Management Entity
NT	No tillage
PD&B	Program Description and Budget
SARI	Southern Agricultural Research Institute
SIIL	Sustainable Intensification Innovation Laboratory
SIPSIN	Sustainably Intensified Production Systems Impact on Nutrition
SSI	Small Scale Irrigation
TDR	Texas Data Repository
WASH	Water Sanitation and Hygiene
WFD	Wetting Front Detector
WRM	Water Resource Management

I. Executive Summary

This report covers the fifth, and final, year of the first phase of the cooperative agreement for ILSSI. A no-cost time extension of the agreement led to a new completion date of the first phase on 30 November 2018. Following a favorable report by the USAID External Review Committee (ERC), year five was highlighted by the decision of USAID to extend the ILSSI agreement for an additional five years, with the potential for total funding over the life of the project of approximately $35 million. A program description and budget (PD&B) for the extension was approved by USAID and partial initial funding was provided for the extension.

Field research and household surveys were completed in all three countries. In year five, field studies led to the completion of studies on: improved irrigation management practices, evaluation of alternative methods of water delivery, tests of tools to access water stress and assessment of shallow groundwater development and use. Livestock-forage studies completed the evaluation of alternative forage species and demonstration of the utility of fodder as a cash crop in multiple countries. Conservation agriculture (CA) as a production method showed positive production, environmental, and economic results. The final endline household surveys were completed in Ghana, wrapping up five-year studies demonstrating the positive impact of irrigation on household income and nutrition, and gender related factors influencing adoption of small-scale irrigation (SSI) by smallholders.

The Integrated Decision Support System (IDSS) capacity was enhanced by adding an agent-based modeling method developed by IFPRI that enabled extrapolation of field study results in national scale modeling. Improved methods for coupling natural resource and population mapping provided decision makers with new planning tools for national and regional planning and evaluation of SSI development activities. Analyses proposing alternatives to overcoming previously identified constraints to adoption of SSI were completed in all three countries.

National stakeholder meetings were held in all three countries, setting the stage for further engagement in the second phase of ILSSI. Capacity development in year five included: customized training requested by government users of the IDSS, continuation of short term IDSS training for university students in all three countries, graduate training for national university graduate and undergraduate students, 90-day training of seven national students in expanded use of the IDSS, and training for farmers and local stakeholders in the application of SSI methods and irrigated fodder. This report also covers an assessment of the levels of readiness to scale technologies, which will serve as a point of departure for the ILSSI extension. The final report for the first phase of ILSSI is being developed during the latter part of this year.

The year five annual report focuses primarily on programmatic activities. Project results from year five will be covered in significant detail in the ILSSI final report (which is currently in development by the management entity [ME]).

II. Program Activities and Highlights

Highlights and activities from ILSSI year five include:

- An International Symposium was held in Washington in conjunction with a related World Bank conference on water use in Africa.
- ILSSI co-sponsored national conferences on irrigation and agricultural development in Ghana and in Ethiopia.

- National stakeholder workshops were held in Ghana, Tanzania and Ethiopia with long-term national planning partners to summarize ILSSI results and set the stage for collaboration in the second phase of ILSSI.
- Partnerships were established with the USAID Feed the Future (FtF) Sustainable Intensification (SIIL) and Livestock Systems (LSIL) Laboratories on analytic methods of assessing production, environmental and economic consequences of farming systems technologies.
- Field studies for SSI technologies, CA practices, and irrigated fodder were completed; the data were analyzed and results reported to stakeholders.
- The final endline household survey was completed for Ghana and results are being processed; irrigators are generally better nourished and have higher incomes.
- National and regional mapping methods were developed to plan and locate country level programs for the application of SSI initiatives.
- Tailored training on IDSS was developed in response to the demand on behalf of government agencies in Ethiopia.
- Training and capacity development were maintained at field/local levels on planning and use of SSI methods developed in the first phase of ILSSI; Training of university students, ministry staff and private sector operators in the use of the integrated decision support system was successfully completed.
- Ex-post and constraints analyses for Ghana and Tanzania were completed along with completion of natural resources mapping in all three countries.
- The integration of IFPRI's agent-based modeling software in IDSS provided national level capacity for application of these methods for planning and evaluation of new initiatives.
- Multi-level stakeholder engagement was continued in all three countries including linkages with national government organizations, USAID Missions and local community and farm. The environmental consequences of agricultural operations in areas where ILSSI research was conducted were evaluated and reported to appropriate regional and national authorities.
- The ILSSI data management plan was implanted in accordance with ADS 579 using the Texas Data Repository built on Dataverse, an open source software package.
- ILSSI is scheduled to complete the final report for the first phase (years one through five) in January 2018.

III. Key Accomplishments

Key accomplishments from year five include:

- Linkages with national and private sector stakeholders generated demand for analytical tools and training for national and sub-national application.
- Initial technology transfer of ILSSI products to other projects (such as Africa RISING, SIIL, and UN Food and Agriculture Organization [FAO]) occurred; increased use of SSI equipment and practices by more farmers after observing SSI results in Ethiopia and Tanzania.
- Deeper engagement across sectors and with private actors during national stakeholder workshops.
- Generated interest from international finance institutions (e.g. World Bank) on results on nutrition and water/irrigation linkages.
- Interest in and feedback from multiple potential users on the dashboard development as a mechanism for employing a user-friendly IDSS format (to explore options for future investment).
- Methodological advances on agent-based modelling enabled national level application of field and household results.

- Methodological enhancement of IDSS to integrate field data on groundwater and modelling to assess potential for irrigation at watershed level.
- The favorable USAID ERC and subsequent decision by USAID to extend ILSSI for five years tops the list of ILSSI accomplishments. The PD&B for the extension were approved by USAID and startup funds provided for the 6th year.

IV. Research Progress by Component and Activity

Component 0: Plan, coordinate, and organize multi-institutional activities

Sub-awardees renewed on-going agreements with national partners to complete field studies and data collection, including: Ethiopia (Bahir Dar University), Tanzania (Sokoine University for Agriculture), and Ghana (University for Development Studies).

Component 1: Identify promising, context appropriate small scale irrigation interventions, management, and practices for poverty reduction and improved nutrition outcomes.

1.1 Small Scale irrigation interventions, management, and practices

Component 1.1 completed in previous year(s) of project.

Component 2: Evaluating impacts, trade-offs, and synergies of small-scale Irrigation technologies and practices.

2.1 Identify opportunities and constraints related to data availability and quality required for modeling SSI systems

In response to challenges of collecting accurate data in appropriate formats in the field, ILSSI developed a prototype open access, online tool to support detailed data collection for small scale irrigation trials. The tool captures geo-spatial information of the plot, general field conditions, labor, crop performance, amount irrigated, and soul moisture. Additionally, it captures inputs used during the production cycle (fertilizer, seed type). The tool is adaptive for various modes of water lifting (rope and washer, motorized pump, solar), as well as varying application methods (bucket, furrow, drip).

ILSSI also developed an enhanced integrated modeling system to assess the potential of dry-season SSI development for Sub-Saharan African countries. The new modeling system introduces agent-based modeling techniques to simulate the adoption process of dry-season SSI at a national scale and under resource constraints. The new modeling system was applied in Ghana and Tanzania. High-resolution mapping products were also produced to show identified geographic domains with investment opportunities. A beta version for Spatial Production Allocation Model (SPAM) 2010 has been shared between partners (IFPRI and TAMU) and integrated the dataset in IDSS modelling system.

ILSSI completed collection of data from the field, including:

- Data sets for irrigated fodder, notably market surveys on the irrigated fodder value chain
- Biophysical and socioeconomic data compilation in the following watersheds:
    - Robit Bata and Dangishta: irrigation and watershed

- Lemo and Adami-Tulu: socio-economic only
- Lemo, Upper Ghana: watershed
- Bihinayiili and Zanlerigu: irrigation and socio-economic
- Mkindo and Rudewa: irrigation and watershed; limited socio-economic

2.3.1.2 Implementation of household surveys

At the beginning of year five, IFPRI implemented the last endline survey round in northern Ghana, as well as finalized all data collection, cleaning and the majority of analyses. The collaboration with Tufts University on Sustainably Intensified Production Systems Impact on Nutrition (SIPSIN) will continue with several ILSSI households being tested for malaria and anemia under SIPSIN and additional nutritional information being collected as well. These results enrich the ILSSI product and interpretation of SSI interventions.

2.4.1 Field tests for identified technologies and practices

In collaboration with national partner institutions and local line ministries, departments and/or agencies (notably the Extension Service), ILSSI completed field tests of various water lifting technologies and agricultural water management practices and tools. ILSSI also completed fieldwork on shallow groundwater analysis toward identifying the feasibility and sustainability of shallow groundwater use for SSI. This fieldwork included completion of field tests related to the hardpan in Ethiopia, including various approaches and technologies to improving groundwater recharge. Finally, data collected in previous years at field sites was analyzed in response to stated demand from national stakeholders and USAID related to constraints that reduce uptake of SSI technologies and practices, such as willingness to pay, access to credit, and technology supply chains.

Field activities completed include:

Ethiopia

- Field test: Improving farming practices on agricultural land to increase subsurface flow recharge through the treatment of hardpan; tested maize on four tillage treatments (i) no-till (NT), (ii) conventional tillage (CT), plots tilled three times using oxen driven Maresha, (iii) deep tillage (DT), manual digging up to 60 cm using a mattock and (iv) Berken tillage (BT), plots tilled three times using an oxen driven Berken plough.
- Field test of tools to assess water stress: Application of thermal imaging for the assessment of water stress.
- Assessment of feasibility of shallow groundwater development for irrigation: Determine irrigation potential of hillside aquifers in the highlands of Sub-Saharan Africa (Ethiopian case study in Robit watershed).
- Partial nutrient balance (NPK) and pesticide transport assessment: Development of crop coefficient and evaluation of partial nutrient balance under dry period irrigation.
- Upper Gana sub-basin: Runoff measurement and analysis.
- Willingness-to-pay analysis for SSI technologies.
- Credit and SSI adoption analysis: Linking the IWMI qualitative studies and in-depth interviews with the IFPRI survey-based study for synthesis.
- Analysis of private actors vis-à-vis SSI supply chain to be completed. This research consists of: (i) synthesizing government policies related to the irrigation sector; (ii) mapping the main private actors/players in irrigation value chain; (iii) exploring the role of key private actors in SSI supply chain; (iv) examining the constraints and opportunities for private actors in the irrigation supply chain.

- Business model, business case analysis, and suitability mapping for solar irrigation in Ethiopia.

Ghana

- Field study: Assessment of the agronomic performance (e.g., water productivity) of water lifting and application technologies (Bihinaayili and Zanlerigu). Analysis of yield data to understand the agronomic performance of water lifting and application technologies.
- Analysis of dry season vegetable farmers in northern Ghana: Credit access, market participation and constraints.
- SSI under limited water supply in northern Ghana.
- Technical (economic) efficiency analysis (technical efficiency, economic efficiency, and allocative efficiency of small-scale irrigated vegetable production) and identification of constraints to efficiency.
- Analysis of the link between access to credit and irrigation technology adoption among smallholder farmers in northern SSI supply chain to be completed. This research consists of: (i) synthesizing government policies related to the irrigation sector; (ii) mapping the main private actors/players in irrigation value chain; (iii) exploring the role of key private actors in SSI supply chain; (iv) examining the constraints and opportunities for private actors in the irrigation supply chain.
- Business models, case analysis, and suitability mapping for solar irrigation in Ghana.
- Analysis of soil variability for agricultural water management in northern Ghana (spatial heterogeneity of physical and chemical properties).

Tanzania:

- Assessment of the feasibility of small motorized pumps for dry season irrigation of vegetables and improving irrigation water productivity of irrigated vegetables.
- Feasibility of pocket garden on improving water use efficiency and household nutrition.
- Hydrological and water resources assessment, including: Times series of water levels in sites in both downstream and upstream areas, as well as meteorological data for the period up to March 2018; water quality data for the sites within the study collected; cross-sections for a river stretch between the upstream and downstream sites of Rudewa watershed were measured and analysed for flood risk; and, land use and land cover data analyses updated.
- Social economic study: Motor pump irrigation by smallholder farmers in Rudewa and Mkindo wards, Tanzania--Profitability and its impact on income inequality.

2.4.3 Establish and monitor field sites for fodder interventions

The project also continued to work in the three countries on livestock feed interventions (in Africa RISING sites), and conducted economic analyses of proposed fodder interventions in all project countries.

Field activities and related analyses included:

Ethiopia

- Extended irrigated forages to more farmers (increased to a total of 217 farmers), as well as the area allocated.
- Explored multi-use effects of forages, including issues such as improving groundwater infiltration, multi-cut yields, and farmer preferences.

Ghana

- Feed samples of fodder sold at the markets at both project districts were collected, air dried and processed for laboratory analysis. The laboratory analysis will show the fodder quality of

Brachiaria ruziziensis and *Sorghum almum* (two major forages in Ghana) relative to the quality of the fodder; prices for *Brachiaria ruziziensis* and *Sorghum almum* can be extrapolated.

- Irrigation of six fenced farmer plots continued to determine the regenerating capacity of fodder grasses *Brachiaria ruziziensis* and *Sorghum almum* during the dry season. Collection of biomass and dry matter data for the regenerated fodder is ongoing. Some areas are not suitable for forage production under irrigation given limited water availability.
- The project assessed the seasonal availability, quality and prices of the livestock feeds being sold.

Tanzania

- Evaluated the performance of Napier grass cultivars under different irrigation technologies: Evaluated four Napier cultivars – ILRI 16835, ILRI 16937, Ouma and Kakamega 2 (KK2) cultivars under pump irrigation technology and rainfed conditions (control); findings suggest that the relative performance of Napier hybrids versus Napier varietis is highly location specific
- Assessed socioeconomic feasibility of irrigated fodder: Assessed the socioeconomic feasibility of irrigated fodder technologies in Tanzania. One activity was a participatory farmer evaluation of Napier grass accessions in Mawemairo, Matufa and Gichemeda villages in Babati district. The parameters evaluated by farmers included greenness as an indicator of feed quality, growth vigor, tallness, disease and pest tolerance, and capacity of forage yield. Another activity was the implementation of a household survey covering 67 farm households residing in Babati, Kilosa and Mvomeor districts In Tanzania.

Component 3: Identifying key constraints and opportunities to improve access to small-scale irrigation technologies

3.4.1 IDSS application to improve access to SSI technologies

ILSSI developed an enhanced integrated modeling system to assess the potential of dry-season small-irrigation development Sub-Saharan African countries. The new modeling system introduces agent-based modeling techniques to simulate the adoption process of dry-season SSI at a national scale and under resource constraints. The new modeling system was applied in Ghana and Tanzania. Significant potential for investing in dry-season SSI over the next decade (~1 million hectares) was identified. High-resolution mapping products were also produced to show identified geographic domains with investment opportunities.

IDSS activities also focused on field scale ex-post research in Ethiopia and Ghana to evaluate the profitability and nutrition outcomes of the SSI technologies, including potential constraints of adopting SSI technologies at the household level. Scale up analysis was also conducted in Ghana and Tanzania to estimate the biophysical and economic potential of expanding SSI in these countries. Conservation agriculture practices were considered in Ethiopia against CT.

Analysis for field and scale up included:

Ethiopia

- CA practices assessed: The biophysical analysis considered field data collected from 34 field plots (i.e. 10 m by 10 m) of small-holder farmers in the Dangesheta watershed. Farmers, who also participated in the field research, cultivated Red Bombay Onion variety (Allium cepa L.) in the dry season from December 2016 to March 2017 using irrigation water from shallow wells. The field experiments were designed into: 1) CA, particularly mulch, throughout the crop growing period and irrigated based on crop water requirement (CA-CWR); 2) CT with irrigation based on crop water requirement (CT-CWR); and 3) CA with irrigation based on farmer's existing or own

irrigation practice (CA-FTP). The socio-economic analysis considered four scenarios comprising a baseline scenario with current farming conditions (non-intervention farmers) and three alternative scenarios (intervention farmers). Two rainfed crops (maize and teff) and one irrigated vegetable crop (onion) were analyzed at the farm household. The baseline scenario considers no or minimal irrigation based on the information for the existing irrigation practice from the household surveys while the alternative scenarios consider the irrigation of onions during the dry season using the pulley system to minimize the investment costs. Results show that CA practice coupled with irrigation management based on climate-based crop water requirment practices increased crop yield, reduced yield variability while improving soil health and reducing negative environmental consequences. In addition, the practice provided maximum profit and nutrition outcome.

- Evaluated three categories of constraints in Robit watershed, including: 1) water lifting technology costs, 2) water availability and use of drip and furrow irrigation, and 3) fertilizer costs. Five crops that include three grains (maize, teff and millet), one vegetable (tomato), and one fodder (napier grass) were analyzed at the farm household. All the alternative scenarios take into account the total input labor costs to carry out the farming and irrigation activities at the household level. Yields for the different irrigation levels and conditions (optimal and under-irrigation) were determined based on a tomato and napier grass water production function generated. (Note: Napier grass was evaluated not as a livestock feed but as a commodity for its market value.) Results indicate that nutrition improvement can be achieved in optimally irrigated systems and in under-irrigated systems that employ drip irrigation by using the sale profits to purchase supplementary foodstuffs, especially animal source products that would increase the intake in fat and calcium.
- Based on data from 2015 to 2017, project partners defined scenarios and evaluated the economic and nutrition benefits of adopting sustainably intensified production systems of onions in Dangeshta kebele. Management practices to reflect the intensified production of onions included irrigation, fertilizer application, tillage practices (CA and CT) as well as application of mulch. SSI technologies (rope and washer, pulley) were considered for water lifting. The results showed profitability of onion production under intensified systems in comparison to the baseline system, as well as improvement in nutritional well-being at the family level through use of profit to purchase supplemental foodstuffs, mainly animal products; deficits in calcium and fat were observed for both the baseline and alternative systems (SIPS) scenarios.
- Evaluated the potential nutrition and economic impacts of SSI technologies through an increase in animal feed production in Lemo. SSI technologies along with fertilizer application were used to grow and improve yields of fodder and napier grass with the purpose of feeding animals and generating income. Livestock production technologies (feeding fodder from a mix of oats and vetch) were aligned with water lifting irrigation technologies (rope & washer and solar pumps). In the baseline scenario, fodder crops (oats and vetch) are grown on limited land with minimal irrigation and fertilizer applications and all the fodder produced is sold at the market for revenue generation. However, in the alternative scenarios, more land is allocated to fodder where a portion of the total production of fodder is fed to cows and bulls to increase the production of milk and meat, while the remainder is sold to generate income. Results show that a representative household under the alternative scenarios performed better than the baseline scenario in terms of profit and nutrition.

<u>Ghana</u>

- Compared baseline scenario with current fertilizer application rates and no or minimal irrigation to two alternative scenarios where recommended fertilizers rates and various SSI technologies used to grow vegetable crops in the Bihinaayili and Zanlerigu communities in North and Upper East regions of Ghana. Results suggest trade-offs between technologies related to

investment/return risks. Nutrition consumption improved significantly in two alternative scenarios studied (the application of fertilizer and irrigation technologies) compared to the baseline scenario as a result of the improvements in crop yields. Results reveal that capital and financial constraints related to initial investment and operational costs, particularly fuel cost, are the key limiting factors to farmers.

- Scale up analysis: ILSSI studied the scalability of SSI showed that the available water resources met the irrigation water requirement in most parts (~68%) of the country (except in the northwest and small pockets in the southwest). The estimated national SSI development potential in Ghana was found 211,000 ha. Northern region has the largest identified SSI development potential (115,000 ha) and accounts for more than half of the total SSI development potential in the country.

Tanzania

- Scale up analysis: The preliminary land suitability for SSI in Tanzania suggests nearly 4% of the Tanzanian landmass is suitable for surface irrigation. The Rufiji basin system has the largest area of suitable land (19%) followed by Lake Tanganyika Basin (18%) and Wami Ruvu Basin (17%). The most productive areas for SSI during the dry season are located in the central and southern parts of Tanzania, as well as pockets of land in the northern parts of Tanzania. The available water resources met the irrigation water requirement for optimal production in more than ~40% of the irrigable land, while in more than 70% of the irrigable land the irrigation water demand for average production can be met. The border strip of Arusha/Kilimanjaro region to Mbeya region has a high adoption probability of SSI in Tanzania. Economically and biophysically suitable area for SSI was estimated to be 573,886 ha. The return in investment to the farmers was about 1,310 million USD per annum benefiting 2 million smallholder farmers.

Component 4: Capacity Development and Stakeholder Engagement and Dialogue

4.1.1 Facilitate extended IDSS training

Training was provided for six participants selected from Ethiopia, Ghana, and Tanzania for the period March 18, 2018 to May 18, 2018. The trainees were provided hands-on trainings on IDSS, participated in seminars, and attended courses at Texas A&M University.

4.1.2 Provide customized IDSS workshops to the Ethiopian Agricultural Transformation Agency

ILSSI provided tailored IDSS training to the Ethiopian Agricultural Transformation Agency (ATA). The customized training activities included GIS Application to Water Resources Management, Integrated Biophysical and Socio-economic Modeling (i.e. SWAT, APEX and FARMSIM), AutoCAD Application for Engineering Design, Agricultural Policy and Environment eXtender, and Farm Income and Nutrition Simulator). The IDSS modeling team educated researchers and practitioners at ATA and its partners on the application of IDSS to study the impacts of water management interventions on agricultural production, environmental sustainability, and household income and nutrition. More than 55 participants engaged in different components of the 2-weeks long IDSS training, namely SWAT, APEX, FARMSIM, GIS Application to Water Resources Management, AutoCAD Application to Engineering Design, and Advanced SWAT. The participants were selected from the public and private sectors, as well as academia. Post-training feedback reports indicate that the participants received the necessary skillset to make an integrated analysis for informed policy formulation and evidence-based planning in their respective institutions.

4.1.8 Training for farmers and local stakeholders

Irrigated fodder: In Ethiopia, field-level trainings (including establishment and management techniques of irrigated forages, intercropping, and their utilization by livestock) were facilitated and conducted in collaboration with local partners, the Southern Agricultural Research Institute (SARI) and the Amhara Agricultural Research Institute (ARARI).

In Tanzania, farmers participated in agronomic evaluation of irrigated forages under different irrigation technologies. Farmers were trained on Napier establishment and management e.g. cutting regimes, chopping, optimum forage amounts for different animals, pasture production and grazing management. The projected mobilized and trained fodder traders. In northern Ghana, training (CSIR - Animal Research Institute, Agricultural Extension Agents (AEAs) of MoFA and farmers) was conducted on fodder planting, plot management and harvesting and feeding trials.

***Irrigated production practices and monitoring*:** As the first phase of ILSSI began to close field activities, fewer trainings were provided at field level; however, some training continued on data collection and analytical methods (including training on laboratory methods and equipment). A full list of training participants is found in Table 1 below, but is summarized as follows:

- Total trained: 40 (Females: 19; Males: 21)
  Private sector: 2; Producers: 32; Students/researchers: 2; Civil servants: 4

Table 1. Trainings conducted under ILSSI in Component 4

Country of Training	Purpose of Training	Who was Trained	Number Trained M	Number Trained F	Total
Ghana (10-13 January 2018)	Irrigation scheduling, including wetting front detector	Farmers/producers	16	16	32
Ghana (10-13 January 2018)	Data collection methods and templates	Private sector/youth	2		2
Ethiopia (6 Aug 2018 to 10 Aug 2018)	Gas Chromatograph (GC)-Mass Spectrometer (MS) [Jije Analytical Testing Service Laboratory at Abbay Basin Autority laboratory] • Basic concepts and principles for operation, preventive maintenance, and troubleshooting of GC MS/MS and libraries interpretation • Basic concepts and principles for operation, preventive maintenance, and troubleshooting of MS/MS instrument hardware • Mass hunter software, NIST library and application of MRM	Students and civil servants: PhD student (Feleke Kuraze, M), MSc student (Elsabeth Tsegaye, F); Abbay Basin Autority lab technicians (Alemtsehay Tsega, F; Hasen Muhabaw, M; Asres Tsega, F, Yibeltal Amlak, M; and Melaku Tarekegn, M).	3	3	6

	database. • GC-MS/MS calibration, method development and sample preparation with an interactive demonstration of pesticide residue in water samples.				

4.1.9 Develop graduate education programs

Selected students at various levels remain engaged with ILSSI in the final year of data collection and analysis. While students do not receive any financial support from ILSSI to cover their graduate program fees, they receive funds through the national university sub-agreements with IWMI, or through a direct internship agreement, to conduct field work and collect data. The project works with the national university to ensure students have training and support for research design, data collection and thesis writing; ILSSI partner researchers act as co-supervisors and mentor promising graduate students in prepation of abstracts for conference presentations and publication manuscripts.
Number of students trained is summarized as follows:

- BSc: 8 (4 female and 4 male)
- MSc: 4 (1 female and 3 male) [1 new in FYR 5; female; completed MSc]
- MPhil: 2 (2 male)
- PhD: 3 (3 male) [1 new in FYR 5; collected data for dissertation]

ILSSI also conducted training on agent-based upscaling analysis at Texas A&M during August 2018, as well as training on household survey implementation. Numbers trained are as follows:

Table 2: Training on agent-based upscaling analysis

Location	Date	Number Trained	Gender
Texas A&M University	August 27th - August 28, 2018	4	M

Table 3: Training on household survey implementation

Location	Date	Number Trained	Gender
University for Development Studies in Tamale	December 4 - December 9, 2017	12	F
		30	M
Sokoine University of Agriculture, Morogoro, Tanzania	June 26th -July 27th. 2018	14	F
		11	M

4.2.3 Stakeholder engagement and dialogue at global and national levels

- Water for Food International Forum held in Washington, D.C. from 29-30 January 2018. Results from the ILSSI research informed the contribution to the discussion paper and panel organization.
- ILSSI International Symposium 31st January 2018 in Washington, D.C. shared results to date.

- ILSSI partners organized an event on 26 August at the Stockholm World Water Week, *Small-Scale Irrigation—The Answer to Ecosystem Health?* ILSSI funds supported the participation of partner institution (Bahir Dar University).
- U.S. Congressional staff to visit the ILSSI project site in Bihinaayili in Feburary 2018, as part of their Feed the Future programs in Ghana in February to assess progress, meet partners, and inform strategy. The delegation interacted with farmers, in a discussion facilitated by Prof Saa Dittoh of University for Development Studies, a national partner in the project. The farmers showed the delegation the rapid uptake of SSI technologies and practices in the site since the project inception. Women farmers from the project described the lower risk and higher income benefits from SSI, as they previously foraged for firewood during the dry season.
- IFPRI, though the ILSSI project, developed a session for the December AGU meetings on "Water for Food: Enhancing Food Security in the Developing World Through Improved Agricultural Water Management" at AGU 18 Fall conference (to be held on 10-14 December 2018).
- ILSSI organized national stakeholder workshops for each project country in May 2018 to contribute to a smooth transition to the extension and to post-exit impact, e.g. through identification of key stakeholders, synthesis of key messages prepared in communications materials in user-friendly format, and convening of workshops with national partners and stakeholders, including additional private sector actors.
- ILSSI co-sponsored the first annual International Conference on Irrigation and Agricultural Development (IRAD) at the University for Development Studies (UDS), Tamale, Ghana, 30-31 October 2017. ILSSI results were shared at a special symposium organized by IWMI on "Small scale irrigation: A Colloquium on improving livelihoods through enhanced land and water productivity in Ghana".
- ILSSI co-sponsored 2nd Annual Amhara Agricultural Forum in Bahir Dar on 16 January. The theme was "Small Scale Irrigation and Agricultural Technologies for Sustainable Development in Amhara Region". The event brought together research institutions, government agencies and other agriculture related projects, including the Small Scale and Micro Irrigation Support project. ILSSI research results were shared with farmers and FtF in Fenote Selame in the Amhara region of Ethiopia on 27 January 2018. Graduate students prepared posters in Amharic and explained the potential for use of the wetting front detectors (WFD) and Berken plow.
- In Tanzania, ILSSI convened and facilitated stakeholder meetings in the fodder value chains. These meetings brought together producers (farmers), fodder traders, transporters, consumers, and research and extension officers. Meetings explored issues that could trigger and/or deter production and engagemenet in fodder marketing. Opportunities identified include: policies that seek to reduce conflict between crop and livestock that would encourage demand for irrigated fodder; availability of improved animals that require higher quality fodder; climate change that increases fodder scarcity with longer dryer periods; and urbanization that stimulates demand for fodder in larger cities and peri-urban areas. Stakeholders also identified challenges related to: water scarcity and prioritization of food crops for people; perishability of some fodder; erratic fodder prices and lack of information on fodder pricing; and, transportation.
- In Ghana, ILSSI held a consultation with national stakeholders to share research results and project outcomes related to irrigated fodder. This gathering highlighted potential fodder species, economic potential, agronomic practices and information on the market.
- ILSSI supported the second official meeting with the relevant line ministries and institutions in Amhara region in Ethiopia to share results from SIPSIN on water quality on 30 October 2018. IWMI presented on both ILSSI and SIPSIN, and a graduate student presented the water quality analysis results. Government institutions have committed to monitoring the situation related to agro-chemical pollution from intensified production.

4.2.8 Engage Communities to assess needs related to interventions and practices

- ***Farmer to Farmer***: ILSSI factiliated 'farmer to farmer' knowledge exchange visits in two sites in Ghana. Farmers from Bihinaayili visited farmers at Zanlerigu on 9 March 2018. Farmers from Zanlerigu paid a returned visit to Bihinaayili on the 10 March 2018. These exchange visits provided an opportunity to share research results with farmers, as well as the chance for farmers and researchers to discuss the opportunities and challenges related to SSI interventions.
- ***Farmer Forums***, in conjunction with Farmer Exit Interviews, were conducted in year five of the project. Focus group discussions and key respondent interviews were used to document experiences of ILSSI supported farmers in all countries and field sites. Project coordinators were also interviewed at the district level to better understand the overall implementation process, as well as how the implementation contributed to development plans of the district and the livelihoods of project participants. (Ethiopia: March 2018; Ghana: April, October 2018; Tanzania: October 2018).
- ***Municipality/District Training***: ILSSI continues to foster collaboration and partnerships with line ministries for agriculture at the various district and municipality/village levels. This collaboration occurs through training and involvement of AEA in all field activities; AEAs and other subject matter specialists share information from the project to other colleagues and with farmers that are not part of the project through their formal and informal interactions.

4.2.12 Publications and knowledge products

During year five, ILSSI partners had several papers published in peer reviewed publications, as well as multiple publications under review. ILSSI partners supported students to participate in conferences. A list of publications, conference papers and other knowledge products (at various stages of development) from year five can be found in Annex 1.

ILSSI disseminated findings from research through Agrilinks, Agrilinks webinars, and blogs; the project also produced a practitioner's brief to support impact from results.

V. Innovation Transfer and Scaling Partnerships

Evidence for technology feasibility (biophysical and economic)

ILSSI built upon previous projects that had identified the potential for SSI in a few African countries. ILSSI aimed to fill a gap in knowledge and sought to identify specific technology and practice packages, and their trade offs, at field level; this began with water lifting technologies and tools that would improve water productivity in certain value chains. In the course of field tests, ILSSI came to recognize the constraints related to scaling technologies off field, notably critical infrastructure such as technology access (i.e. weak technology supply chains) and credit access. In short, scaling high potential technologies that had been tested in the field required research on factors that limited the willingness and ability of farmers to invest in the technologies.

Policy analysis that would support identification of investment opportunities and potential for commercial scaling

Policies influence various factors such as incentives for global and local technology suppliers, technology supply chain market constraints, access to credit for both technology suppliers and producers, regulatory environments that either increase or reduce risk, among others. Policy analysis focused on the following: a) two country specific studies on private sector opportunities and constraints in the overall irrigation technology supply chain development (Ghana, Ethiopia); b) two country specific studies on potential business models and private sector case studies for small scale solar irrigation, including mapping potential areas highly suitable for the technology (Ghana and Ethiopia); c) two country specific studies on

microfinance constraints and opportunities for irrigated agriculture (Ghana, Ethiopia); and d) one general microfinance study for irrigation in sub-Saharan Africa with recommendations for potential approaches to increase access to smallholder farmers and small entrepreneurs.

Continuous engagement with a range of stakeholders

The various steps in the research process (from initial consultation on research needs to field studies to policy studies) were conducted in partnership and in collaboration with national universities, relevant line ministries, research institutions, and to a lesser extent NGOs and sector relevant associations. Research results have been shared at multiple levels, as noted above. ILSSI's continuous engagement provided the basis for ensuring demand, generating interest and raising awareness. ILSSI held national workshops in May 2018 to share results, including private sector technology suppliers and financial service providers.

A. Technologies at various stages of readiness for scaling

Technology tested in field during reporting period:

- Cameras to assess water stress in plants (to strengthen water productivity) shows potential for research and evaluation or advising purposes, but requires further research to understand costs and potential end users for application.
- In Ethiopia opportunities emerged for scaling of irrigated forages. This, however, can only be facilitated by ILSSI. Consequently, discussions are currently going on with public (ATA) and developmental (NGO) actors of how to bring this scaling about.
- ILSSI partners have observed that the multi-purpose forage use promoted by the ILSSI project, such as intercropping and use of biological treatments (pigeon pea use for penetration of hard pans), piqued the interest of the national systems, which have subsequently initiated their own experiments along those lines.

Technologies ready to scale

- ILSSI's suitability assessments, cost-benefit analysis, and business cases analysis suggest high potential for solar irrigation pumps in Ghana and Ethiopia. ILSSI developed business models for Ghana and Ethiopia that suggest potential approaches to profitable investment given the contextual constraints.
- 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 international projects, including one project led by FAO (note: IWMI is a partner in that FAO project). In addition, the Ghana Irrigation Development Authority expressed interest in the WFD, though for use outside Feed the Future zone of influence; at 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, Sokoine University of Agriculture 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.
- Studies have also shown potential for the Berken plow to improve yields and groundwater recharge that would strengthen water productivity at multiple scales. Separate studies and support is provided to national partners to examine commercialization; relevant public sector institutions have been invited to see demonstrations and have received evidence generated through ILSSI. A national private sector partner is involved.

VI. Success Stories

1. Uptake of ILSSI gender and nutrition results by World Bank

"ILSSI influences global nutrition-sensitive irrigation investments" – Based on the results emerging from the ILSSI project on nutrition and irrigation linkages, 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. IFPRI is developing a guidance note in response to the request from the World Bank, which will draw on the work completed 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 this initiative is to ensure that World Bank irrigation activities are implemented in a nutrition-sensitive fashion. The objectives of the guidance are to: (i) summarize the evidence on irrigation-nutrition linkages; (ii) sensitize irrigation managers to nutrition outcomes; and (iii) 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 at the World Bank over the next few months. A larger convening of project leaders is currently being planned during the World Bank's Water Week.

2. Irrigated fodder production expands in Amhara, Ethiopia based on ILSSI intervention

Feed is the number one constraint for livestock production in the highlands of Ethiopia. Irrigated production of supplemental green fodder under smallholder conditions appears to be a suitable solution to feed shortages. ILSSI is examining how irrigated fodder can enable households to diversify income while securing adequate animal-based food for families in Ethiopia.

ILRI in collaboration with the Amhara Region Agricultural Institute (ARARI) introduced Napier grass - a perennial forage - to only 17 farmers who planted an average of $100m^2$ each in 2015 in one sub-kebele in Robit Bata of the Amhara region. Legume forages were intercropped with Napier grass to improve feed quantity and quality while maintaining the soil nutrient base. The forages were distributed by ILSSI in 5 sub-kebeles in the Robit-Bata kebele.

The number of farmers growing the forages in the Robit-Bata kebele grew from only 17 farmers in 2015 to 183 in 2017. The number of irrigated forage producers is 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 3 trained farmers showed that they in turn shared the technology to 7 more 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 state that they have a better income source from the sales of milk when feeding their cattle irrigated fodder and they can also improve the family's food security with their dairy products. Farmers are realizing more milk yield from better-fed cows. This has helped them secure dairy-based food for their families. They also sell the surplus milk to the emerging market for dairy products, which has grown alongside the increased milk production in the area due to improved feed supply. Average milk yield information from 10 farmers indicates that milk yield has increased from 2.3 liters to 4.6 liters per day per local cow with feeding Napier and legume forages. Some farmers who have 3-4 milking (local breed) cows are collecting around Birr 4000 – 5000/month. The current farm-gate price of milk is Ethiopian Birr 13 per liter.

Moreover, 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 that they do to khat. They also claim that forage production requires less irrigation water compared to khat.

Farmers and the government officers express commitment to development of irrigated forages. ILSSI has provided evidence that improved feed can increase incomes and provide the basis for improved household food security through dairy-based products. There are additional benefits from providing cows with high quality irrigated forages, for example, improved calves, manure for soil fertilization, biogas production, among others. Irrigated fodder also provides an environmentally and socially healthier alternative to some existing crops, such as khat. Farmers and government in the Amhara region are beginning to scale irrigated fodder production to more communities in the region.

VII. Lessons Learned

Three significant lessons learned during this reporting period include:

1. Delayed budget disbursement led to postponement of sub-sub-contracting and implementation of some activities. More notably, IWMI had to cancel the intended 'write shops' to strengthen student and partner institution capacity in publication writing and submission processes; this undermined the trust with sub-contracted researchers and slowed data sharing to IWMI.
2. ILSSI's approach to capacity development became more strategic based on lessons learned over the course of the project. ILSSI identified the need to simultaneously ensure both demand and supply of information for sustained evidence-based decision making beyond a single project. This requires creating awareness of decision makers on the value of the analytic tools available and the robustness of research results, while also developing capacity of a range of scientist across institutions on those tools. Generating high-level demand for information needs to be complemented by the sustained supply of evidence by national and research institutions, as well as relevant NGOs. Therefore, ILSSI focused more effort this year on sharing the IDSS tools with decision makers, delivering tailored capacity development on the IDSS, and continuing to develop capacity of early and mid-career scientists and graduate students on good quality data collection and application of analytical methods. ILSSI applied this approach to capacity development to sustain the impact on informed planning and monitoring related to SSI in natural resource management and agriculture.
3. Data transfer between partners is complex; requirements to upload to multiple repositories (USAID, lead partner and Field Partners) slows data sharing and compliance on open access.

VIII. Environmental Management and Mitigation Plan (EMMP)

ILSSI continued to ensure that the field interventions had no adverse effects on the environment. ILSSI continued to follow the EMMP for each country with context relevant indicators developed under USAID guidance in year one. Within the scope of the EMMP, ILSSI continued in year five to have no role in the promotion of pesticide intensive crops or in the field application of agrochemicals. Farmers engaged in final year field studies were advised on agrochemical use only by the national extension services directly and without ILSSI support or intervention. Further, ILSSI and its national partners did not involve or commit project resources to support any demonstration or intervention that endangered the environment as per the EMMP indicators. All the participating researchers in national partner institutions also agreed to uphold the EMMP. While the project does not collect data for each indicator in the EMMP, it monitored key components and continued to raise awareness of farmers and local partners on those indicators. Interventions were reviewed with farmers and research scientists in year five and no new issues emerged. It may be noted that ILSSI, through a related project in the Amhara region of Ethiopia

funded by the SIIL, conducted more extensive water quality tests in the basin beyond the scope of ILSSI; tests identified pollutants in groundwater and surface water bodies from unrelated agricultural activities in the Blue Nile Basin, and therefore ILSSI duly informed the relevant regional government authorities.

IX. ILSSI Data Management Plan/USAID Requirements

The ILSSI project operates in accordance with ADS 579, USAID's policy on sharing Agency-funded data for public benefit. ADS 579 defines USAID's data governance structure; establishes the Development Data Library (DDL) as the Agency's repository of USAID-funded data; creates Data Stewards in each USAID operating unit; outlines the process for USAID staff and implementing partners to submit data to the DDL; defines the data clearance process; and outlines special considerations for research data.

The following areas provide an overview of how the ILSSI project is meeting the requirements of ADS 579:

A. Texas Data Repository

ILSSI has partnered with the Texas Data Repository (TDR), an online platform for Texas A&M University researchers to publish and archive datasets and data products. 30 The TDR is built on Dataverse, an open-source software developed by Harvard University. The TDR is hosted by the Texas Digital Library, a consortium of Texas academic libraries focused on long-term access and preservation of digital content. The TDR is committed to preserving and providing ongoing access to research data for at least 10 years after submission.

Through the TDR, data files are uploaded to datasets and organized in a consistent manner using metadata tags such as title, creator, and date created. Each dataset receives its own webpage and a Digital Object Identifier (DOI).

B. Dataverse

Dataverse is the name of the software running the Texas Data Repository as well as the name of the container that holds datasets. The dataverse container is similar a directory or folder in a computer file system and may hold one of more datasets into collections based on a project or other criteria. The dataverse container can also hold sub-dataverses or sub collections of datasets. As of June 2017, ILSSI has begun working with the Texas A&M Library System to design a Dataverse unique to ILSSI needs.

The ILSSI Dataverse is organized by country and region. It contains sub-dataverses named after countries; these country dataverses contain sub-dataverses named after regions. Each regional sub-dataverse includes datasets relevant to that region. Each dataset may be based on a different model and analysis conducted in a region. More information on the on the structure of the ILSSI Dataverse can be found Here. ILSSI worked with the researchers at Texas A&M to upload the IDSS dataset to the Dataverse.

C. Field level data storage

In addition to the data created and stored at within the TAMU Dataverse, it is also recognized that the data storage requirements for our field level partners are like those required by USAID. As such, the data generated by our partners is being stored in Dataverses and other web spaces unique to each institution and datasets. For example, IFPRI stores data on a Dataverse hosted by Harvard University, while IWMI stores data on an open access Water Portal. Links to these data sets will be included in the Digital Data

Library. In addition, ILSSI has explored the option of linking these data sets to a central repository for all ILSSI data within the ILSSI Dataverse.

X. Project Management Activity

A. Primary engagement by the PMC for year five:

- Annual work and budget plans for year five were solicited, aggregated, and approved by USAID. A no-cost time extension for year five of ILSSI extended the agreement to 30 November 2018.
- Support was provided to the USAID ERC team during their review of ILSSI.
- Plans and assignments were made for the preparation of the year five annual and final reports for the initial phase of ILSSI.
- An international symposium highlighting the introduction of ILSSI technology in Africa was organized and conducted in Washington, DC at the Ronald Reagan Building.
- Meetings of the PMC and the EAC were successfully conducted for program planning and implementation.
- Background material for the renewal decision was provided to USAID and, based on sponsor guidance, the Concept Note and PD&B for the ILSSI Extension were prepared and accepted.
- Following notification of the ILSSI Extension, plans and schedules were put in place to develop a detailed scope of action for the remainder of year five and for year six of the project. Furthermore, initial planning commenced to begin developing the five-year work plan for the extension (years 6-10).
- Meetings with USAID staff were held in Washington in September receive input for the Extension scope of work. Meetings with USAID Mission staff were held in May and June 2018.

B. ILSSI External Advisory Committee (EAC)

The EAC is comprised of one representative from each of the three countries, one regional representative and one representative from the private sector. The primary purposes of the EAC are to provide advice and counsel on program priorities, strategy and plans, evaluation of results, communication and linkages with relevant national and regional stakeholders and governmental agencies, and to help assure continuity of purpose and outcomes across the three countries. The EAC meets annually (in person or electronically). Some members of the EAC attended and provided leadership in the international symposium held in Washington in January 2018. All members of the committee reviewed and provided input on the materials provided to the USAID ERC.

C. ILSSI Program Partners by Country

The ILSSI project is actively engaged with national and sub-national partners including government agencies, NGOs, research institutions, and tertiary educational institutions in implementing research, analyzing data, writing reports, and sharing results. In addition to these partners, ILSSI works to closely collaborate with local farmers and village leaders. A detailed list of ILSSI partners is located in Annex 2.

XI. Other Topics

Proposals were submitted for ongoing collaborations with SIIL, Horticulture Innovation Laboratory (HIL), and LSIL. LSIL accepted the proposal and formal award is expected in December 2018.

The IDSS was successfully applied to multiple government analyses for planning of initiatives on irrigation and water management. Results on the role of gender in SSI were presented in multiple national and international venues and at USAID.

XII. Issues and How They Are Being Addressed

The impact of late obligation of year five funds was mostly offset by carry over of prior year funds and loans made by Texas A&M. USAID provided partial funding of year six of ILSSI, enabling continuity of operations for the extension and early initiation of planning for years six through ten of the agreement. Political unrest in Ethiopia curtailed travel of international scientists with resulting delays in completing field studies. To compensate, field studies were extended past their planned completion into the final year of the ILSSI project. No serious impacts resulted from issues arising during the first five years of the ILSSI agreement.

XIII. Future Directions

USAID extended ILSSI for an additional five years with the ten-year funding totaling approximately $35 million. The PD&B submitted in August 2018 describes the general approach for the extension, which will involve active support to national stakeholders in both government and private sectors to enable application and adoption of research results from years one through five of ILSSI. An indicative year six and overall five-year budget were provided for initial planning. The period from 1 December 2018 through 30 April 2019 will be utilized to develop final expanded plans and budget for the extension. Final selection of countries for years six through ten will be made and engagement with national players and USAID country and regional missions will guide the agenda and identify potential areas of funding.

Annex I: Publications

Peer Reviewed

1. 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; doi:10.3390/w10020120
2. Worqlul, A. W., Jeong, J., Dile, Y. T., Osorio, J.,Schmitter, P., Gerik, T., Srinivasan, R., Clarke, N. Assessing potential land suitable for surface irrigation using groundwater in Ethiopia. *Applied Geography* 85 (2017) 1-13.
3. Bezabih M., Adie A., Gemiyu D., Zeleke B and Blümmel M. 2018. Lessons from small scale irrigation forage production trials: potential of annual - oats vetch mixtures. *Books of Abstracts* p. 13
4. Adie, A., Bezabih, M., Yitayew, A., Demeke, B., Yeheyis, L., Blümmel, M. 2018. Lessons from small scale irrigation forage production trials in the Amhara region: potential of integrating the perennial forage Napier grass with Desmodium and Pigeon Pea in cropping systems. *Books of Abstracts* p. 14
5. Kadyampakeni, D., Appoh, R., Barron, J., Boakye-Acheampong, E. 2017. Analysis of water quality of selected irrigation water sources in Northern Ghana. *Water Science and Technology: Water Supply*. s2017195; **DOI: 10.2166/ws.2017.195** http://ws.iwaponline.com/content/early/2018/01/11/ws.2017.195
6. 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* https://doi.org/10.1007/s00704-018-2412-x
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9. Moges, M.A., Schmitter, P., Tilahun, S.A. et al. 2018. Watershed modeling for reducing future non-point source sediment and phosphorus load in the Lake Tana Basin, Ethiopia. *J Soils Sediments* 18: 309. https://doi.org/10.1007/s11368-017-1824-z
10. Otoo, M., N. Lefore, P. Schmitter, J. Barron, G. Gebregziabher.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
11. 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*. https://doi.org/10.1016/j.gfs.2017.10.003
12. Schmitter, P., et al. 2018. "Suitability mapping framework for solar photovoltaic pumps for smallholder farmers in sub-Saharan Africa." Applied Geography 94: 41-57.
13. Schmitter, P., N. Lefore, J. Barron and M. Giordano. 2018. "Improving on-farm water management through irrigation information for climate-smart agriculture in sub-Saharan Africa", In "Case Studies", 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/3/CA1726EN/ca1726en.pdf

14. 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
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16. Walker, D., Parkin, G., Schmitter, P., Gowing, J., Tilahun, S.A., Haile, A.T. and Yimam, A.Y., 2018. Insights from a multi-method recharge estimation comparison study. *Groundwater*. https://onlinelibrary.wiley.com/doi/10.1111/gwat.12801
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1. Lefore, N., Giordano, M., Ringler, C., Barron, J. 2018. Sustainable and equitable growth in farmer-led irrigation in sub-Saharan Africa: What will it take? Accepted with revisions in *Water Alternatives*, Special Issue on Farmer-led Irrigation Development in Sub-Saharan Africa.
2. Bedru Balana, Jean-Claude Bizimana, James W. Richardson, Nicole Lefore, Zenebe Adimassu and Brian K. Herbst (2018). Economic Analysis of Small Scale Irrigation Technologies in northern Ghana. Accepted with revisions in *Water Resources and Economics.*

In preparation

1. IFPRI. Mapping development potential of dry-season small-scale irrigation in Sub-Saharan African countries - an integrated modeling approach with a case study on Ethiopia.
2. Gebregziabher, G., Hagos, F., Lefore, N., Haileslassie, A., Barron, J. Analysis of impacts of household level water lifting irrigation technologies on poverty: An example from Ethiopia. IWMI Working Paper.
3. Tilahun, S. A., Yilak, D. L., Schmitter, P., Langan, S., Barron, J., and Steenhuis, T. S. Determining irrigation potential of hillside aquifers in the highlands of sub-Saharan Africa. *In preparation.*
4. Muche,H., Abdela, M., Schmitter, P., Nakawuka, P., Tilahun, S. A., Steenhuis, T.S., Barron, J., Adie, A., Blummel, M. Modified plow and biological means to break hardpan in the Ethiopian degraded highlands: Case study with plots in Robit Watershed. *In Preparation*.
5. Hussen, M.A., Muche H., Schmitter, P., Nakawuka, P., Tilahun S.A., Steenhuis, T.S., Langan, S., Barron, J. Effects of tillage on runoff and recharge of degraded soils in the Ethiopian Highlands. *In preparation.*
6. Abdela, M., Muche, H.,Schmitter, P., Nakawuka, P., Tilahun, S. A., Steenhuis, T.S., Barron, J., Adie, A., Blummel, M. Management Options for Reducing Runoff and Enhancing Recharge of Degraded Soils in the Ethiopian Highlands. *In preparation.*

7. Adimassu, Z., Ghansah, B., Appoh, R., Mul, M. Understanding soil variability for agricultural water management in northern Ghana. *In preparation.*

IWMI Working Papers

1. Merrey, D.; N. Lefore. 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.

Project reports

1. Gebrehaweria Gebregziabher, Fitsum Hagos, Nicole Lefore, Amare Haileslassie. 2018. A Multivariate analysis of factors influencing adoption of smallholder irrigation technologies.
2. Hagos, F., Lefore, N., Gelgo, B., Haileslassie, A. Rapid assessment of supply chain of agricultural water management technologies in Ethiopia.
3. Abdulai, A., Balana, B. 2018. Efficiency of Small Scale Irrigation Farmers in Northern Ghana: A Data Envelopment Analysis Approach.
4. Balana, B., Appoh, R. 2018. Assessment of private actors in irrigation supply chain in Ghana.
5. Balana, B., Abdulai, A. 2018. Access to Credit and Adoption of Small-Scale Irrigation Technologies: Evidence from Northern Ghana.
6. SUA. 2018. Effect of deficit irrigation on tomato production under drip system
7. SUA. 2018. Motorized pump sharing dynamics under small scale irrigated vegetable producers
8. SUA. 2018. The efficacy of thermal imaging in managing irrigation water in African eggplant production
9. SUA. 2018. The Potential of Agronomic Practices on Rice Production to Food Security and Household Income: A Case of Wami Ruvu Basin, Tanzania

Conference presentations

1. Bizimana, J.C. and J.W. Richardson. Agricultural technology assessment for smallholder farms in developing countries: An Analysis using a farm simulation model (FARMSIM). Paper presented at the Southern Agricultural Economics Association (SAEA) conference held in Jacksonville, Florida from Feb. 2-6, 2018.
2. Bedru Balana, Jean-Claude Bizimana, James W. Richardson, Nicole Lefore, Zenebe Adimassu1 and Brian K. Herbst. Profitability and economic feasibility analysis of small scale irrigation technologies in Northern regions of Ghana. Paper presented at the Southern Agricultural Economics Association (SAEA) conference held in Jacksonville, Florida from Feb. 2-6, 2018.
3. Tilahun, S. A., Sishu, F. K., Schmitter, P., Steenhuis, T. SSI and risks of intensification: Case study on water quality in the Ethiopian Highlands. Event on Small Scale Irrigation: The answer to ecosystem health? At Stockholm World Water Week. Stockholm, Sweden, 26 August 2018. https://programme.worldwaterweek.org/Content/ProposalResources/PDF/2018/pdf-2018-7891-4-SWWW2018_Tilahun_SSI%20and%20ecosystem%20health_Final.pdf
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5. Kadyampakeni, D., Appoh, R., Barron, J., and Boakye-Acheampong, E. 2017. Analysis of Water Quality of Selected Irrigation Water Sources in Northern Ghana. International Conference on

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- Zakaria, N. 2018. Credit access, market participation and constraints: Analysis of dry season vegetable farmers in northern Ghana. Mphil. (University for Development Studies)
- Tetteh, R. 2018. Smallholder irrigation under limited water supply in northern Ghana. Mphil. (University for Development Studies)
- Mwalonde Johnson, P. 2018. Motor pump irrigation by smallhoder farmers in Rudewa and Mkindo wards, Tanzania: Profitability and its impact on income inequality. MSc. (Sokoine University of Agriculture)
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- Workie, Anteneh. 2018. Application of thermal image or thermograph for the determination of water stress in case of Tomato. MSc. (Bahir Dar University)
- 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)

Annex 2: ILSSI Program Partners by Country

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) • Blue Nile Water Institute • Abay Basin Authority • Ministry of Water, Irrigation and Electricity • Africa RISING • Productive Safety Net Program (PSNP) • Private sector • 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) • Northern Accelerated Development Authority • Water Resources Institute • Africa RISING • FINGAP • Additional national, regional, and local government agencies
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