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

INNOVATION LAB FOR
Small Scale Irrigation

Feed the Future Innovation Laboratory for Small Scale Irrigation

ANNUAL REPORT

October 1st, 2018 - September 30th, 2019

Submitted to USAID on Behalf of:

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The Texas A&M University System (Lead Institution)

International Food Policy Research Institute (IFPRI)

International Livestock Research Institute (ILRI)

International Water Management Institute (IWMI)

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Executive Summary

The Innovation Lab for Small Scale Irrigation (ILSSI) vision is to contribute an increase of profitable, sustainable and gender-sensitive irrigation to support inclusive agricultural growth, resilient food systems, and nutrition and health outcomes, particularly for vulnerable populations. Improved management of water and land resources from farm to watershed to basin level is needed to meet the immediate and long-term nutritional needs of growing and urbanizing populations, particularly within the context of changing weather patterns and risks related to natural resources. Research through 2023 focuses on generating evidence for effective scaling – increasing farmer investment in and use of irrigation - and increasing inclusive access to and benefits from irrigation. The project works in Ethiopia, Ghana, Mali, and Tanzania in a collaboration between scientific institutions and private sector actors for applied research within a market systems approach. Evidence is also being generated on small scale irrigation, gender, and nutrition in the context of improving social and ecological resilience. Existing evidence shows that expanding irrigated production will increase the incomes of millions of smallholder producers and actors within irrigated value chains.

ILSSI planned and prepared research activities for the program's extension through 2023, while undertaking outreach based on research undertaken between 2013 and 2018. The Lab developed numerous peer-reviewed publications and end-user knowledge products, which were, in turn, used by institutions such as the World Bank, the International Finance Corporation (IFC), and private companies, as well as for capacity development, such as the Tanzania Irrigation Commission. Increased emphasis was placed on outreach at regional and global levels, creating new and strengthening existing networks with potential users of the Lab's research results. At the national level, several organizations and institutions showed interest in the Lab's research results on irrigation-nutrition linkages; several presentations were provided on demand. The Lab's new emphasis on market systems and the private sector role in scaling included roundtable discussions, initiation of a small-scale irrigation dialogue space with private sector partners, and issuing an RFA for private sector irrigation scaling partners in Ghana and Ethiopia. The project also implemented Net-map activities in Ethiopia, toward understanding the technology supply chain dynamics, which will help to identify entry points to support private sector centric activities.

Research results continue to be generated based on field and survey data. One study examined the constraints to irrigation adoption, analyzing the role of plot, farm, and community-level factors in explaining SSI adoption patterns in Ethiopia, Ghana, and Tanzania. While results vary by country, generally, level of education and access to credit are not determining factors for adoption, which suggests that small scale irrigation can be a democratizing intervention and can reach female and male-headed households, regardless of the level of human capital development. An additional analysis has provided interim results on access to credit and adoption: in Ghana, Tanzania and Ethiopia, about half of the survey households did not attempt to get credit in the preceding 12 months. More analysis is underway to better understand the reasons for 'non-seekers' of credit, which should provide insight on improving financial products/access to small producers, as finance is often given as a policy solution to increasing access to irrigation technologies. Both studies included questions based on the Women's Empowerment in Agriculture Index (WEAI) and offer comparative analysis for men and women farmers. Results from both studies provide valuable information for donor (development interventions) or private sector (market-based) approaches to scaling irrigation access, which ultimately will benefit small, commercializing farmers that want to begin or improve irrigation.

The Lab also produced important suitability maps, suitability analysis, and climate-related analysis, on the potential for solar irrigation. Solar irrigation is drawing increased attention from many donors, public sector institutions and technology suppliers, and the Lab's input is being utilized to manage investments more pragmatically and toward sustainability.

The Lab's efforts to develop networks with potential information users began to show impact. The relationship with global institutions, such as the World Bank, International Finance Corporation (IFC) and Alliance for a Green Revolution in Africa (AGRA), are transforming the Lab's research results into more effective investments and activity design. The World Bank took up the Lab's research to enhance irrigation investments toward strengthened nutritional and gender outcomes, AGRA has now appointed a lead for Farmer-led Irrigation scaling and the Lab's results are informing the United Nations Standing Committee on Nutrition. The Lab's results were also included in a report for the African continent issued by the Malabo Montpellier Panel. The Lab's linkages with USAID projects, such as Power Africa Off Grid, and other donor programs, have expanded the use of research-based evidence; e.g., private sector companies began using the Lab's irrigation suitability maps and economic and market studies to target solar irrigation marketing in project countries. The global and regional knowledge partnerships will be strengthened with small scale irrigation dialogue platforms being established in Ghana and Ethiopia, as we create multi-directional linkages, bringing in private sector technology and irrigated value chain actors. Strong relationships across levels serves to ensure research is relevant, accessible to a range of end users and ultimately, increases the rate and sustainability of scaling. The Lab's value in terms of scientific methods and models, as well as its capacity development efforts, were also recognized through a BIFAD award to a team of Innovation Lab for Small Scale Irrigation scientists; this in turn has increased the trust and interest in Lab research results in Ethiopia. The Lab published 15 peer reviewed papers, 2 discussion papers, 15 conference papers and presentations, three blogs, as well as several capacity development materials and technical reports, during the reporting period.

The Lab received a five-year extension for research, but we were still required to complete final reporting processes for the first phase of the project, while beginning new consultations and project activity design for the extension phase. This created a break in activities, which resulted in the following challenges: few activities 'on the ground', very little reporting on the FTFMS indicators (see Table 1 below), confusion among stakeholders and national partners, as well as high management transaction costs. While the 'break' in activity reflects poorly in terms of Lab performance, the reflection on initial research results and activities was necessary for revised planning of the extension phase, and resulted in a programmatic net benefit . Despite the interruption, the Lab used the year for in-depth engagement and to refocus activities in each project country toward the most promising outcomes for the context.

The Lab developed a broad range of research-based papers and knowledge products between 2013 to 2018, which demonstrated the potential to improve livelihoods of smallholders through small scale irrigation, which could be scalable to millions of farmers. However, the Lab came to recognize that scaling could not be done through typical public sector pathways; to move forward, research must increasingly co-create and share knowledge with private sector companies in frontier markets. In FY2019, the Lab has improved and increased engagement with private sector actors with a positive response; private companies are actively using the Lab's research to inform their market activities. This learning was informed by other USAID programs; networking with existing USAID programs significantly improved our approach and new activities.

Key activities in FY2020 will be related to scaling and engaging the private sector, including selection of private sector partners, completion of Net-map exercises and analysis, initiation of a study on equipment pricing and the technology supply chain (including impact of tariff removal), and data collection on incentives for farmer investment, access to credit and response to prices. Related to irrigated fodder in Ethiopia – a promising irrigated value chain to address human and animal nutrition - the suitability map and natural resource assessment will be completed, as we map out the actors and design a sub-award program for private sector partners, targeting small and medium enterprises. Analysis will continue on the linkages between irrigation, gender and nutrition, based on existing data, including on multiple use systems. ILSSI will also commence work in Mali related to water resource availability at sub-basin scale, water security at household level, potential for scaling vegetable production in irrigated gardens, scope for irrigated seed production for horticulture, and cost-benefit from related investment. The Lab will also continue to strengthen outreach and communications, while ramping up human and institutional capacity development (HICD) – creating demand for research evidence and developing a pipeline of skilled scientists in project countries to deliver research based evidence for decision makers. The dialogue space process will be consolidated in Ghana and Ethiopia, and innovation scholarships will be developed for graduate students in multiple disciplines, including agri-business.

Table 1. Summary of key FTFMS indicators

Indicator	**Description**	**Number**
EG. 3.2-1	Number of individuals who have received USG - supported short term agricultural sector productivicty or food security training	179 Male 33 Female
EG. 3.2-2:	Number of individuals who have received USG - Supported degree-granting non nutrition related food security	1 Male 2 Female
E.G 3-2	Number of Individuals participating in USG food Security Programs	154
EG. 3.2-x41	Number of water resources sustainability assessments undertaken	56
E.G. 3.1-12	Number of agricultural and nutritional enabling polices analyzed, consulted on, drafted on	1
STIR-12	Number of peer reviewed publications	15

1. Activities: Progress toward objectives

A. Objective 0: Effectively plan, coordinate, and organize multi-institutional activities

The primary activity of ILSSI in the first two quarters of the fiscal year was reflecting on the first five years of the project and developing an enhanced impact pathway to contribute to the Feed the Future Theory of Change, and to co-develop activities that would achieve impact. Toward that end, ILSSI held a face to face planning meeting at the end of January 2019 with all cooperative agreement partners, to understand and refine workplans across the multiple partners such that activities support the jointly developed impact pathway of ILSSI phase II. The meeting was hosted by IFPRI in Washington DC.

The ILSSI Management Entity (ME) successfully managed sub-awarded agreements with CGIAR partners and extended sub-agreements to include the World Vegetable Center in Mali. Toward strengthened planning, monitoring and evaluation of activities of sub-agreements, ILSSI contracted with and set up in the Piestar platform.

To further strengthen accountability of ILSSI research, and to support alignment with global and regional development goals, the ME, with input from the sub-agreement partners, identified a list of new potential members for the External Advisory Committee. Two experts have agreed to join (Nuhu Hatibu, Regional Representative of AGRA; Beverly McIntyre, formerly USAID and IWMI, current consultant to IFC). One expert has tentatively agreed to join, to be confirmed based on current contractual requirements. Two more experts are under consideration.

ILSSI ME initiated the process to ensure compliance with ethical human subject research (i.e. Texas A & M Institutional Review Board). An Institutional Agreement is being established with IWMI, which does not have an internal IRB process; this included extending TAMU's trainings and certification to IWMI researchers (without cost). ILRI and IFPRI both have internal IRBs, so each team will complete their own internal processes and submit approvals to TAMU's system, as in the past under ILSSI.

ILSSI successfully expanded the research portfolio with additional funding and buy-in. New funding was awarded by the Office of U.S. Foreign Disaster Assistance (OFDA) for ILSSI activities in Mali, particularly focused on assessing potential for scaling sustainable irrigated production. Research will include cost-benefit analysis, market assessment for irrigated seed production, water accounting of the Black Volta, household water security surveys, and assessment of capacity to scale irrigated commercial gardens.

In addition, ILSSI partners initiated research under additional funding from the Livestock Innovation Lab on irrigated fodder (Ethiopia). TAMU has received a competitively-awarded project to collaborate with the Livestock Systems Innovation Lab to apply IDSS methodologies developed under ILSSI. The aim of the study will be to analyze the productivity of different livestock systems and to supports human and institutional capacity development (HICD) on the use and application of IDSS. All work will be done in Ethiopia. The collaborative project is entitled "Application of Integrated Decision Support Systems to improve livestock systems in Ethiopia: research and capacity development". The project has strong synergies with ILSSI and builds upon the methods developed in Phase 1.

Research funded through the Sustainable Intensification Innovation Lab (Ethiopia) to ILSSI partners in Ethiopia was completed.

ILSSI contributed to two proposals for funding for a global knowledge network on farmer-led irrigation with the Studying African Farmer-Led Irrigation project partners.

B. Objective 1: Identify and test approaches to sustainably scale SSI through reducing constraints and strengthening opportunities for access

Activity 1.1: Identify upscaling opportunities for resilient SSI systems

To set out the private sector partnerships, ILSSI ME consulted extensively with multiple advisors at USAID (virtually and in person) and also received guidance from USAID supported projects, such as Partnering for Agriculture and Power Africa Off Grid. IWMI contributed strongly to the content and presentation of the RFA. Based on the multiple inputs, the ME established a transparent process and issued a Request for Applications for both Ghana and Ethiopia. The RFA was issued according to schedule utilizing PiestarRFX: https://rfx.piestar.com/opportunities/all/rfp/93

ILSSI also prepared the process for Proposal review and established a review committee that includes the ME, IFPRI, IWMI, USAID, and Dalberg. Dalberg's role in the RFA process will be to advise particularly on the finance component, which will be critical to feasibility and sustainability of the private sector activities. Applicants will be required to describe their approach to gender equity. Those sections will be reviewed by IFPRI and compiled for sharing with the USAID Gender Advisor for learning with other Innovation Labs and projects.

Activity 1.1.2. Qualitative survey with private and public sectors to assess information requirement and format

IWMI prepared a protocol to collect different types of spatial information requirements that enable public and private sector investment and intervention to SSI scaling. The data will be collected by using (i) semi-structured interview and (ii) qualitative online surveys. Milestones achieved in this activity include:

- A qualitative data collection tool for semi-structured interviews with public and private sector in Ghana and Ethiopia,
- The first draft of the online qualitative survey for both Ghana and Ethiopia, and
- A list of companies participating in the online qualitative survey in Ghana.

Activity 1.1.6.b. Develop irrigated fodder suitability map (Identifying irrigated fodder production areas considering livestock density, feed preference and supply scenarios; biomass national fodder production pot

The IDSS and ILRI teams made substantial progress on an irrigated fodder suitability map. The map refines the existing small scale irrigation suitability map for specific fodder varieties and adds more information related to livestock feed demand and markets. The map will inform where ILSSI works with fodder producing cooperatives and fodder seed producers, to develop scaling business models. The mapping is complex in part due to data and methodology issues, which requires triangulation of methods and results. The result will be reported at the smallest

administrative unit (*Kebele* label), which will provide spatially explicit fodder production potential information in Ethiopia to the policymakers. Stakeholder engagement with the International Fund for Agriculture Development and Ethiopian authorities suggests strong demand and potential use of the irrigated suitability map; ILSSI is the first project to undertake such extensive mapping.

Fodder types were identified by the International Livestock Research Institute (ILRI) through stakeholder engagement exercises; partners in Ethiopia identified potential fodder crops that could be sustainably scaled in Ethiopia. The main criteria to select the fodder crops was the ability to provide high fodder production, thereby improving household income and nutrition. The fodder crops selected were Napier, alfalfa, vetch, oats, and desho grass. Basic characteristics of the selected crops are shown in Table 2.

Table 2: Characteristics of selected fodder crops considered to estimate the potential production area in Ethiopia (Ecocrop 2000).

Fodder	Optimal temperature (ºC)	Altitude (m amsl)	Optimal soil PH	Optimal soil depth (cm)	Rainfall (mm)
Napier	21 – 40	Up to 2000	5.0 – 6.5	> 150	1500 – 2500
Alfalfa	21 – 27	600 – 1200	6.5 – 7.5	> 150	600 – 1200
Vetch	10 – 18	-	6.5 – 7.5	20 – 50	400 – 600
Oats	16 – 20	-	5.0 – 6.0	50 – 150	600 – 1000
Desho	30 – 35	-	5.5 – 7.0	50 – 150	500 – 650

The fodder crops also represent growing niches in different agro-ecologies of Ethiopia and take into account suitability to produce with irrigation. Napier grass grows in mid and low altitude areas in backyards, outfield plots, and on ridges. Alfalfa is a leguminous fodder that grows both in low land and cool highland areas, with a wide agro-ecological adaptation. Oat and vetch are annual fodder crops that are compatible for intercropping and grow well in mid and highland agro-ecologies. Rhodes grass grows favorably in low and mid altitude warmer areas. Detailed climatic and biophysical growth requirements of the selected fodder crops were compiled to be used as input in the mapping process.

The potential suitable area for sustainable fodder production for Ethiopia was studied using a GIS-based Multi-Criteria Evaluation (MCE) technique. In MCE, the major factors affecting the suitability of the land for fodder production will be mapped, weighted, reclassified and overlayed to develop a single-indexes fodder suitability map. The biophysical factors considered were climate (temperature, rainfall, and evaporation), soil, land use, and slope; while the socio-economic factors were access to market and feed demand. The access to the market was represented by proximity to the road, and livestock feed demand was represented by livestock density, which applied the concept of Tropical livestock unit (TLU). TLU aggregates different livestock categories with a standard relative feed requirement. One TLU is referred as a standard feed requirement to metabolizable energy requirements of one cattle with a bodyweight of 250 kg. In addition, suitability analysis for the specific fodder varieties incorporated the crop characteristics from the FAO-EcoCrop database. The general methodology framework of fodder production suitability analysis, input data, and spatial resolution are presented in Table 3. The biophysical factors that determine the suitability of certain land to sustainably scale fodder production system were identified and mapped. The major factors, how each affects suitability for fodder production, and suitable values are as follows:

- ***Climate (rainfall and evaporation)***: Rainfall deficit was considered to identify the potential fodder production area in Ethiopia. Analysis used daily rainfall data from 509 weather stations owned by the Ethiopian National Meteorological Services Agency, and 8-days MODIS potential evapotranspiration data for the period 2000 to 2010.
- ***Slope***: Slope affects land suitability for irrigation through land preparation and irrigation practice. The slope map was prepared using a 30 m resolution Digital Elevation Model (DEM) data from the Shuttle Radar Topography Mission (SRTM) (Figure 2c).
- ***Land-use***: The land-use data were collected from GlobeLand30 (GL). The data is available for 2000 and 2010 and is comprised of ten land-use groups with a spatial resolution of 30 m.
- ***Soil***: The soil data such as soil texture, organic carbon content, drainage class, and soil depth were collected from the Africa Soil Information System (AfSIS, Vågen et al. 2010). The AfSIS data has a spatial resolution of 250 m and has six soil layers. Soil texture was classified according to the USDA soil classification system.

In addition, socioeconomic factors were identified and mapped to evaluate the potential fodder production area sustainability across the country. Two key factors were livestock population and access to a paved road. These factors determined market access to purchase agricultural inputs and sell agricultural produce.

Table 3: Source and spatial resolution of input data used for the land suitability analysis.

Data	Source	Spatial resolution (m)
Land-use	Global Land Cover Datasets (GlobeLand30)	30
Soil	Africa Soil Information Service (AfSIS), 2015	250
Digital Elevation Model (DEM)	Enhanced Shuttle Land Elevation Data from the United States Geological Survey (USGS), 2000 released in 2015	30
Road network	Digital Chart of the World (DCW), 2006	--
MODIS potential evaporation (mm)	MOD16 Global Terrestrial Evapotranspiration Data Set (2000 – 2010)	1,000
Rainfall (mm/year)	Ethiopian National Meteorological Agency (ENMA) from 2000 to 2010	--
Fodder crop characteristics	FAO-EcoCrop database	--
Livestock population density	Ethiopian Central Statistical Agency (ECSA)	--

The major factors determining the suitability of land for fodder production were prepared in accordance with the MCE framework. The overall weights of the factors are determined using a pairwise comparison matrix (Saaty 1977). Thereafter, the weights of the factors are distributed to the different levels of suitability groups. Finally, the reclassified and weighted factors are combined with a weighted overlay analysis to identify the preliminary land suitability for fodder

production in Ethiopia. The most optimal suitable land for fodder production will be identified by applying a user-defined threshold number.

Data sourcing for the suitability mapping process

In addition to the available fodder related data from the ILSSI sites (Lemo and Robit), fodder yield and quality data have been compiled from Africa RISING operational sites in Sinana, Endamehoni and Basona Worena districs, for a better model calibration and analysis of production scenarios. Livestock population data, disaggregated by species, sex, age, and geographical locations have been obtained for the years 2016/17 and 2017/18. The livestock census deta will be used to calculate the overall demand for feed resources across different geographical locations of the country and serve as a criterion in the mapping process. The cattle and small ruminant populations are given special attention in the calculation, as these groups of livestock are directly linked to commercial markets and the probability of success with irrigated fodder production is high with the presence of active dairy and fattening enterprises.

ILRI's FEEDbase tool has been used to estimate the feed supply from land use pattern, crop yield data, and crop harvest indexes on a pilot scale using data from 64 districts. The tool was intended to examine the level of feed balance in a district (i.e., if the available feed is in excess, on par, or in short supply compared to the demand for livestock production). However, the pilot testing of the tool produced unrealistic results, with a large discrepancy between the supply and demand, suggesting some systematic error in the estimation.

To identify the possible source of error and come up with an alternative approach, the TAMU IDSS team have planned to estimate the feed biomass supply using biophysical modeling. To this end, the potential biomass which can be produced from pastureland and agricultural land for livestock consumption will be estimated with the SWAT model. Crop-related parameters will be derived from the APEX model, which will be calibrated using data from the two ILSSI sites and three Africa RISING sites. The level of fodder production will be evaluated considering different scenarios: 1) irrigation scenarios (under, over, and optimal irrigation), 2) fertilizer scenarios, 3) agronomic practices: crop rotation, intercropping crops with forages, single and multiple forage cuts, and 4) the use of improved forages vs. naturally occurring grasses. The demand side will continue to be calculated using ILRI's approach, which considers dry matter and nutrient requirements for maintenance and optimal production levels. The analysis will primarily be done for the 64 districts, for which prior analysis have been done using FEEDbase; the two approaches will be triangulated.

Activity 1.2: Identify constraints and assess impact of policy through analyses and dialogue

1.2.1: Constraints Analysis

During the reporting period, IFPRI completed a paper titled "Hierarchical modelling of the constraints to irrigation adoption in Ghana, Ethiopia, and Tanzania." Using a hierarchical modeling approach, we analyzed the role of plot, farm, and community-level factors in explaining SSI adoption patterns in Ethiopia, Ghana, and Tanzania. Results suggest that irrigation investments targeted at improving household's access to irrigation technologies (e.g., by easing liquidity constraints) can be more effective in Ethiopia, while community-level interventions (e.g., construction of dams and ponds) may promote further irrigation adoption in the areas studied in Tanzania. Results show strong complementary between agricultural labor and irrigation adoption, especially for more labor intensive technologies. Input complementarity is also found in Tanzania and Ethiopia where the use of more chemical fertilizers increases the

likelihood of gravity-based and motorized irrigation. Interaction with only extension agents has a strong positive correlation with the adoption of motorized technologies in Tanzania.

Tenure status also appears to matter in Ghana, where rented-in, as well as inherited plots are less likely to be irrigated, compared to allocated plots. We did not find several of the policy-relevant variables to be significant, including the gender of the plot manager, access to extension services (except for motorized pumps in Tanzania), and membership in non-water related farmers' groups.

Level of education is not a factor determining adoption; and neither is access to credit. The fact that these characteristics are not essential, at least not in the case study sites, suggests that SSI can be a democratizing intervention and can reach female and male-headed households, regardless of level of level of human capital. Moreover, the diverse empirical evidence suggests the importance of local conditions in driving the suitability and profitability of different irrigation technologies and subsequent adoption decisions.

1.2.2: Role of credit constraints

During the reporting period we developed the outline of a paper on the role of credit in accessing irrigation technologies. Even when studies do not directly analyze the role of credit, it is common to see improved access to credit as a benign policy option to boost productivity. However, improving credit access may not directly increase uptake and subsequent modern inputs use if there is no demand for this service. Credit constraints of smallholders are often associated with either absence of accessible credit sources in local areas, absence of credit products in line with smallholder needs or high interest rates (price-rationed credit). Factors other than interest rates could play important roles in the functioning of credit markets and credit-rationing to smallholder borrowers. Credit rationing due to the latter factors is termed as 'non-price credit rationing'.

In this study, we explored the extent to which credit access is a limiting factor for the adoption of small-scale irrigation in developing countries, drawing on a panel data of irrigators and non-irrigators from Ethiopia, Ghana, and Tanzania. Data were collected between 2014 and 2017 under the USAID funded Innovation Lab for Small Scale Irrigation (ILSSI) project. In all the three countries, about half of the survey households did not attempt to get credit in the preceding 12 months (non-seekers). In Ghana, the main reason given by non-seekers included the following: no need for credit (39%), afraid of losing collateral (11%), inability to pay back (29%), and inadequate collateral (8%). In Ethiopia, the reasons given by non-seekers included the following: no need for credit (80%), inability to pay back (12%), and fear of losing collateral (8%). In Tanzania, non-seekers gave the following reasons: afraid of losing collateral (46%), inability to repay (34%), no need for credit (21%), and inadequate collateral (10%). For analytical simplicity, these reasons given by non-seekers were categorized into four main areas: (i) high interest rate– borrowers who are involuntarily excluded from credit market due to too high interest rate; (ii) motivation/aspiration/knowledge – capturing such responses as "I have enough money" or "I do not need any credit", (iii) risk aversion– capturing such responses as "I cannot pay back" or "I am afraid of losing collateral", and (iv) collateral– when non-seeking behavior is due to lack of adequate collateral. Admittedly, the motivation category requires further characterization of the farmers in the group in terms of their socioeconomic status to examine whether the farmers are wealthy enough to afford technologies by themselves or they lack aspirations or knowledge on business opportunities and the return to investing in agricultural technologies.

The final analysis will be available at the end of fiscal year 2019 (i.e. by 09/2020).

1.2.3.a. Net-mapping in Ethiopia to understand private sector constraints

During the reporting period, one regional and one national Net-Map workshop were designed by IFPRI together with the Lab Director and IWMI.

In this workshop we were focused on identifying the actors that influence the diffusion of small-scale irrigation (SSI) technologies in Ethiopia (at the national/regional level) and how these stakeholders interact with each other. We started by listing all the actors involved in the diffusion of small-scale irrigation (SSI) technologies at the national level and regional level for Oromia, with a discussion of their role in the diffusion of SSI. We then determined how these actors were linked, examined how influential each actor was, and then discussed ways to accelerate the diffusion of SSI technologies in the country/region.

Net-Map is a tool to explore how things are actually done, not how things 'should be' or how they are 'officially' or in formal documents. The overall guiding questions that framed the participatory activity were:

- National level (Addis Ababa): Who influences the diffusion of improved small-scale irrigation technologies at the national level?
- Regional level (Oromia): Who influences the diffusion of improved small-scale irrigation technologies at the regional level?

More than 15 potential participants were identified for each of the workshops and a national consultant facilitator was hired. The workshops was scheduled for October 8 and 9, respectively, at the ILRI Campus in Addis Ababa.

Activity 1.2.4. Stakeholder analysis and mapping of actors in SSI scaling pathway

IWMI has identified actors in the SSI scaling pathway in Ethiopia and Ghana. IWMI also completed the internal reports on the technology supply chain for those two countries. Initial reports provided an input into the Net-mapping activities noted above.

Activity 1.2.5. Micro-economic study of the effect of loans and tax breaks on the demand for different SSI types

IWMI has developed a literature review note: 'Are subsidies and credit for irrigation sufficient for increasing adoption of pumps in Ethiopia?' and a methodological note on 'Micro-economic study of the effects of tax breaks and loans on the willingness of small and marginal farmers to adopt different types of SSI technologies'. The literature review note highlights the following:

- Farmer-led irrigation - mainly tapping shallow groundwater using solar and diesel pumps – has been increasingly promoted by different stakeholders across Africa due to constraints on public spending, and the agro-climatic challenges that render the development of large public surface-water schemes infeasible.
- Reducing pump prices and providing credits to farmers have been deployed as major instrument to enable the farmers' adoption of irrigation technologies. In Ethiopia, where smallholders typically use their own financing to pay for water pumps to irrigate farms (mostly under 5 hectares), the government has imposed a 37% import duty (tax) on the price of motor pumps 1 to 10 horsepower.
- There is need for better understanding of 1) relationships between access to markets, information, and adoption, 2) respective roles of microfinance institutions (private) and cooperatives (public) in irrigation adoption, and 3) links between public provision of boreholes (with costs shared between farmers and governments) and the farmers' private adoption of pumps

To understand how 'yet-to-be-implemented' financial-incentive policies will affect farmers' willingness to adopt pumps for SSI, the methodological note details: 1) discrete choice experiment (DCE) for identifying attributes determining farmers' utility of pumps, 2) household survey to contextualize the results from the DCE and to better understand how households' willingness to adopt SSI pumps, and 3) sample design for the DCE and the household survey. Based on these documents, IWMI is developing the micro-economic survey questionnaire for data collection in Ethiopia.

1.2.6. Assess impact of change in cost of water lifting technologies (reduction in tariff) on producer revenue

IDSS has worked with the Ethiopian Agricultural Transformation Agency (ATA) to build economic modelling capacity, which is essential for determining efficacy and potential tradeoffs of tax and tariff programs related to irrigation and drainage equipment. Adoption of SSI in Ethiopia has been slow, in part due to high cost of SSI equipment for farmers. A large component of this cost for this equipment is tied up in taxes and tariffs within the value chain; according to an ATA report, taxes or duties accounted for approximately one third of the cost for both motorized and non-motorized irrigation pumps and are considered a major barrier to investing in irrigated agriculture in the country. The ATA report suggested value chain actors would be very responsive to tax incentive structures, invest in irrigation equipment, increase profit and create jobs. The Government of Ethiopia has officially removed the tariff, and is currently evaluating how to roll out the exemption. ILSSI undertook a case study from field level data to evaluate projected benefits.

The impacts of the tariffs were evaluated using the net present value (NPV), benefit-cost ratio (B/C ratio) and the internal rate of return (IRR). B/C ratio and IRR often used to carry out a cost benefit analysis (CBA), inform on the profitability and return on investment of new enterprise, in this case, irrigation technologies (motor and solar pumps) with or without tax exemption. The cost benefit analysis presents the probability distributions of the benefit-cost ratio (B/C ratio) and the internal rate of return (IRR) from 500 iterations (simulations) in FARMSIM.

ILSSI conducted a 5 year forecast using the FARMSIM model and existing ILSSI field data from Robit Bata in the Amhara region. Preliminary results in Robit kebele show an increase in the NPV, B/C ratio and IRR for the equipment purchased free of tax. However, we do not see a change in the average profit. The simulation results for the NPV, which assessed the long-term feasibility of an investment, showed a positive NPV value for all the scenarios considered, including the baseline, which included tax. In general, the NPV, under the tax exemption scenarios (motor and solar) with optimal irrigation, showed superior performance compared to their counterpart with full tax application and the baseline.

The results indicate on average B/C ratios ranging from 1.5 to 4.2 and greater than the threshold value of 1.0 (break-even) and IRR values ranging from 0.3 to 1.2 and greater than the discount rate of 0.1 for all the irrigation technologies (solar and motor pumps) *with or without* tax exemption. This is an indication of the profitability of the alternative technologies (solar and motor pumps) compared to the baseline technology. *Notice that the technologies with tax exemption (motor and solar pumps) have B/C ratios and IRR values greater than those of their counterpart without tax exemption, showing the positive impact of the cost reduction on profitability and rate of return.* Moreover, both metrics have zero probability of falling under their threshold values, meaning that these technologies have no economic constraint in Robit.

In brief, reduction in cost of the irrigation technologies (tools and equipment) can have a positive impact on farmers' ability to invest in the technology, as the reduction in cost of the technology increases the feasibility of investing in the enterprise. The other implication could be the increase in loan access to buy the technology from the banks or microfinance institutions, as the reduction in amount borrowed reduces the uncertainty about the loan repayment.

Activity 1.2.7. Facilitating dialogue between key stakeholders to strengthen SSI scaling

IWMI has consolidated relevant literature and developed a Small Scale Irrigation (SSI) Dialogue Space concept note as a guiding document for the facilitation of multi-stakeholder dialogues. The SSI Dialogue Space concept emphasizes the essentials of establishing a physical and institutional space, where stakeholders come together to exchange ideas and jointly explore opportunities to scale-out/up SSI in specific country or even sub-national contexts, as well as to promote, invest in, and enable the sustainable SSI scaling for smallholder farmers. The Dialogue Space is based on common interests and shared vision which consequently inform membership, participation, and activities of the platform. It aims to raise awareness and interest in SSI scaling, facilitate SSI scaling agenda, foster interactive learning to enhance inclusion in SSI scaling, support irrigation policy and planning processes, capitalize SSI 'good practices' for resource mobilization, drive innovation for SSI scaling, enhance SSI-related institutional memories, and build human and institutional capacity to sustain the Dialogue Space until the close of the project. Moreover, IWMI has prepared for the first meeting of SSI Dialogue Space in Ghana on 24 October 2019 and in January 2020 in Ethiopia.

Activity 1.4: Identify entry points to reduce constraints and strengthen irrigated fodder markets

Despite having Africa's largest livestock population, Ethiopia has not realized the full benefits from the sector due to low animal productivity, which is attributed to many factors, the foremost being poor quality and inadequate feed resources. ILRI made an inventory in August 2019 in the Robit Bata site (Amhara region, Ethiopia) to further document how farmers are expanding their irrigated fodder plots. The irrigated fodder work started with 17 farmers in 2015, each planting an average of 100m^2 of irrigated Napier forage with several farmers choosing to intercrop forage legumes with the Napier grass to increase feed quantity and quality and maintain the soil nutrient base. The number of farmers planting irrigated forages in that area grew to 183 in 2018. The inventory showed that a total of 42 farmers expanded their fodder plots by 25-1300m^2 each. As a result of this expansion, a total area of 6312m^2 new irrigated fodder was established. In addition to farmers expanding their plots, a total of 9 new farmers accessed planting materials through farmer to farmer seed transfer and planted forages on a total of about 3408m^2. It has been reported that demand for planting materials increased dramatically and farmers are repeatedly asking for cuttings. To address the demands of farmers, ILRI plans to support forage seed producer cooperatives in the district.

Significantly, before the introduction of cultivated forages, farmers in the area used water resources to grow khat – a stimulant perennial crop, which, though socially and religiously unacceptable, earned them a good profit. Some have now abandoned the crop in favour of forage farming. Farmers explained the change in crop selection that since adopting forage farming, they make more money from the sale of milk and have other benefits from their better fed livestock such as calves, manure for soil fertilization and biogas. Moreover, they said that khat farming required the use of large amounts of pesticide, which forage farming does not need. They added that irrigating forages uses less labour and water compared to khat. Researchers have yet to determine the extent of increased benefits.

The improved forage supply has increased milk yields helping farmers secure dairy-based food sources for their families and led to an emerging milk market in the area. Information from 10 farmers indicated that their milk yield has increased from 2.3lt to 4.6lt/day/local cow resulting from the use of irrigated forages. Current farm-gate price of milk is ETB13 (USD0.46)/lit and some farmers who have 3–4 milking local cows make ETB1,170–1,560/month. The income grows to ETB4,000-5,000/month for farmers owning 3-4 crossbred cows. These results have drawn the attention of other farmers and government officials who have expressed interesting in scaling up the intervention to other areas of the Ethiopia.

Napier-desmodium fodder in Robit, Amhara Region, Ethiopia. Photo courtesy of ILRI.

C. Objective 2: Component 2: Identify and test approaches to scale SSI to be sustainable and support resilience

Activity 2.1.: Assess tradeoffs between environmental and human resilience to climate shocks and stressors

2.1.2: Irrigation/Water pollution modeling analysis (Evaluating the impact of agricultural inputs (e.g. pesticides, fertilizer, etc.) on the environment, i.e. water and soil)

IFPRI completed an initial design of the methodology for this activity. The major data gap identified for this activity was the lack of water quality monitoring data to characterize water quality conditions in the base year. In view of this challenge, a downscaling analysis was launched, in which national statistics on fertilizer consumption were downscaled to the pixel level to inform the re-construction of agricultural nutrient loading estimates in the base year, using modeling approaches. Efforts were also made to collect fertilizer use data at the subnational level to support the downscaling analysis.

2.1.3. Assess future climatic risk on water availability and crop production

The water resources analysis mainly focused in Ethiopia in establishing the baseline condition to estimate impacts of climate change; 12 basins were assessed. Particular attention was given

to the potential to scale irrigated fodder production across the country. The analysis, therefore, estimated green and blue water resources. Blue water is the amount of water flowing into rivers, lakes and deep groundwater, while green water is the water stored in soils and evapotranspired from the soil and plant canopy.

A grid-based Soil and Water Assessment Tool (SWAT) was developed to estimate the blue-green water resources in Ethiopia. This model discretization provided 14,314 subbasins and 57,256 Hydrological Resource Units for Ethiopia and the 20 km buffer area. The land management data (e.g. irrigation command area, cultivated crops and crop management for the large-scale irrigation projects) were obtained from Girma and Awulachew (2007). The model was fine-tuned to represent the agroecology of the different regions. The evaluation of the model was conducted using observed streamflow data from ten river gauging stations that represent meso-scale watersheds in the Upper Blue Nile basin. The calibration of the model generally indicated satisfactory performance. This initial study helped to refine the methodology and approach that will be used in future suitability analysis; a publication is in preparation related to data and methodology based on this activity.

Activity 2.2.: Assess approaches to reducing risks associated with irrigation investments

2.2.4. Examining how credit and yield-based index insurance can increase resilience

The crop insurance study by the IDSS team identifies areas in Ethiopia susceptible to rainfall variability and vulnerable to the risk of crop failure. The objective of the study is to identify potential areas where crop insurance could provide a cost-effective risk management strategy in building resilience. The study tests the effectiveness of rainfall and simulated yield-based indexed insurance in Ethiopia in an area vulnerable to crop failure, which has a long period record of climate and crop yield data. The study was done for maize, one of the dominant rainfed crops in Ethiopia. The crop insurance research activity is an integrated approach involving mainly two models: Agricultural Policy/Environmental eXtender (APEX) model and the farm simulation model (FARMSIM). The study also seeks to determine crop indemnities and premiums for indexed insurance products.

To date, researchers identified appropriate regions for case study modelling, which are reflective of representative samples of areas to target for a crop index insurance. The case study areas chosen are areas in Ethiopia with three distinctly different rainfall regimes, which also have high quality historical rainfall data and maize yield records. Historical rainfall, temperature, and soil moisture data from the selected location are used with the APEX model to produce a simulated yield history for a specific crop and cropping practice, in this case, maize. The agricultural management practices were collected through communication with the local agricultural extension agents and farmers in the areas. Appropriate data was collected for simulating the primary crop in APEX (planting and harvest dates, current seed variety, and fertilizer types and amounts, soil type, and slope, location (altitude and climate data), and weather station data.

Results from the initial study revealed that the probability of crop failure due to rainfall stress was minimal in one area, while rainfall was well below the crop water required for maize and the probability of crop failure due to rainfall scarcity was much higher in the other two areas. These results indicated that there is indeed a need for transferring or managing risk. In addition, researchers – particularly the Texas A & M researcher currently based in Addis –identified and met with several insurance service providers and other projects working on crop insurance, including those led by the CGIAR. ILSSI is engaging with various companies to gather feedback

on the approach and to explore potential partnerships to develop and pilot improved insurance products in Ethiopia.

The next steps in this study require understanding the relationship between maize yield and rainfall to analyze the appropriateness of a rainfall-indexed approach to calculating crop insurance needs. This will require using APEX to simulate relationships between 30 years of actual weather data in combination with a 30-year crop yield history under the current farming practices. Researchers are also considering losses related to pest and disease, with input from the Government of Ethiopia, the Integrated Pest Management Innovation Lab and International Center of Insect Physiology and Ecology. Researchers will then estimate a crop yield probability distribution for maize, while also estimating the insurance premiums for a number of crop yield insurance coverage levels using FARMSIM.

Activity 2.3.: Assess the potential for innovative technology and scheduling tools (f.ex. solar, sensors) to contribute to social-ecological resilience

2.3.1: Solar irrigation assessment, sub-national Ghana and Ethiopia

IFPRI conducted a systematic review of methodologies for sizing PV solar systems. The study concluded that the current sizing tools, which were widely used to size standalone PV solar system for residential energy supply, have limitations in reflecting the variability of energy demand of irrigation caused by climate variability in the sizing process. To address this challenge, IFPRI is considering coupling the PV sizing model with SWAT/APEX in IDSS or other crop models for better irrigation scheduling in the next step of the analysis.

IWMI continued refining the solar irrigation suitability mapping for Mali; preliminary results are presented in a technical brief (Mali potential solar suitability mapping). The preliminary results were shared during a roundtable meeting facilitated by Power Africa Off Grid in Senegal in April 2019; that project has also shared the technical report and related slidedeck to their network. The methodology and results have generated interest from the private sector, who noted their interest in water resource susintabilty and their demand for such detailed, biophysical reports.

Solar pump irrigation in Mali. Photo courtesy of IWMI.

2.3.2. Estimating the potential of solar pumps in improving irrigation access vis a vis energy intensity

IFPRI is preparing a manuscript titled “Solar or diesel: a cost comparison analysis for groundwater-fed smallholder irrigation in Sub-Saharan Africa under two energy solutions,” which is based on a technical note completed in early 2019. This publication is fully funded by CGIAR WLE. However, lessons from this work will be used for sub-national solar irrigation studies in Ghana and Ethiopia under ILSSI.

In addition, the presentation “Last Mile Energy Access for Productive Energy Use in Agriculture in Sub-Saharan Africa – What and Where is the Potential?” will be presented by IFPRI at the AGU Annual meeting in December 2019.

IFPRI also finalized the upscaling paper titled “Mapping development potential of dry-season small-scale irrigation in Sub-Saharan African countries - an integrated modeling approach with a case study on Ethiopia” for *Agricultural Systems.* ILSSI fully funded this paper preparation.

D. Objective 3: Identify and test approaches to maximize inclusivity, effective governance, women’s empowerment, and involvement of youth for nutrition-sensitive irrigated production

Activity 3.1: Institutional and policy analysis & strengthening of governance

3.1.1.a Pilot experiential learning Ethiopia (IFPRI)

In year 6, we focused on the identification of potential sites for groundwater governance work and we identified potential implementers of the groundwater governance work. We also expanded the team for this work and now include Dr. Wei Zhang, who has worked with Ruth Meinzen-Dick on forest and other games in India before.

Activity 3.2: Analysis of approaches for equity (along value chains), focused on women and youth

Activity 3.2.2. Gender and inclusivity (across research activities with emphasis on private sector, business models).

In the sub-component of '*Analysis of approaches for equity along value chains', focused on women and youth*', milestones achieved in this activity include (I) the integration of gender inclusivity and youth mainstreaming into the RFA development and (ii) the detailed implementation plan and roadmap for data collection and engagement in dialogue with private sector along the piloting of SSI scaling pathways.

Activity 3.3: Assess approaches for more nutrition- and health-sensitive SSI

3.3.1: Assessment of Multiple Use Systems in GHA, ETH and TAN

For the MUS paper, IFPRI completed a literature review that found that 1) Diarrhea burden in children and WASH - WASH is still one of the highest risk factors for diarrhea; 2) Water quantity and quality - crucial components of the impacts of WASH on health; and 3) Irrigation could be a pathway to decrease diarrhoeal diseases in children in Sub-Saharan Africa (see also Passarelli et al. 2018).

We also completed data analysis of the Ghana survey nutrition data, and submitted a paper on “Irrigation-Nutrition Linkages: Evidence from Northern Ghana” to Food Policy. The paper was rejected, so it was submitted as an IFPRI working paper (to be published in 10/2019).

2. Data and publications

A. Datasets

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. 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.

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. Data Sets uploaded to the ILSSI Dataverse during this reporting period are in Annex 1.

IWMI Water Portal

In addition to those datasets that were uploaded to the ILSSI dataverse, the International Water Management Institute has also uploaded 23 datasets to the IWMI Water Portal from Phase 1. The IWMI Water Portal is open access and a well-known resource for water-related datasets. A list of the data uploaded to the IWMI Water Portal can be found in Annex 1.

B. Publications

As ILSSI completed Phase 1, research partners consolidated datasets and completed analysis from initial activities. This has resulted in numerous publications and related knowledge products. The summary list for each category is in Table 4, while the full list and publication information can be found in Annex 2.

Table 4. Summary of publications for reporting period

Category of publication and/or knowledge product	**Total number across project (i.e. all research partners)**
Peer reviewed publication	15
Discussion/Working paper	2
Technical reports	3
Conference paper, poster, or presentation	15
Capacity development material or product	1
Submitted and under review or accepted with revisions	3

3. Outreach and communications

The ILSSI workplan matrix includes an objective (Component 4) related to outreach and communications. This section reports on progress against Component 4 of the workplan matrix. Toward improving outreach and impact, ILSSI ME appointed a communications specialist in September 2019, who refined the communications plan and began developing improved

outreach materials, such as a newsletter and updated website. New materials and platforms will be active in FY2020.

Moreover, within ILSSI's impact pathway, the project targets change in policy and investment at multiple levels toward achieving the project vision. As indicated in Figure 1, ILSSI aims to share its research to influence global thinking and communities of practice related to water, agriculture, health and nutrition, as well as cross-cutting issues such as gender, while also influencing policy and investment at global and national levels. ILSSI's scientific outputs (peer-reviewed papers, scientific conferences, and global symposiums) influence the broader debates that involve global and bi-lateral organizations, ultimately shaping future research and investments in agriculture.

During FY2019, ILSSI's outreach emphasized sharing research with global and regional level based on research evidence from Phase 1, while engaging with stakeholders at the national level, particularly around activity planning for Phase 2. Less emphasis was placed on local level producers, value chain actors, and other stakeholders during this year, as this is prior to the roll out of the private sector and irrigated value chain activities that will entail more direct, local engagement. That shift is represented in the relatively lower numbers in the FTFMS indicators. This section describes efforts at the multiple levels to engage and influence.

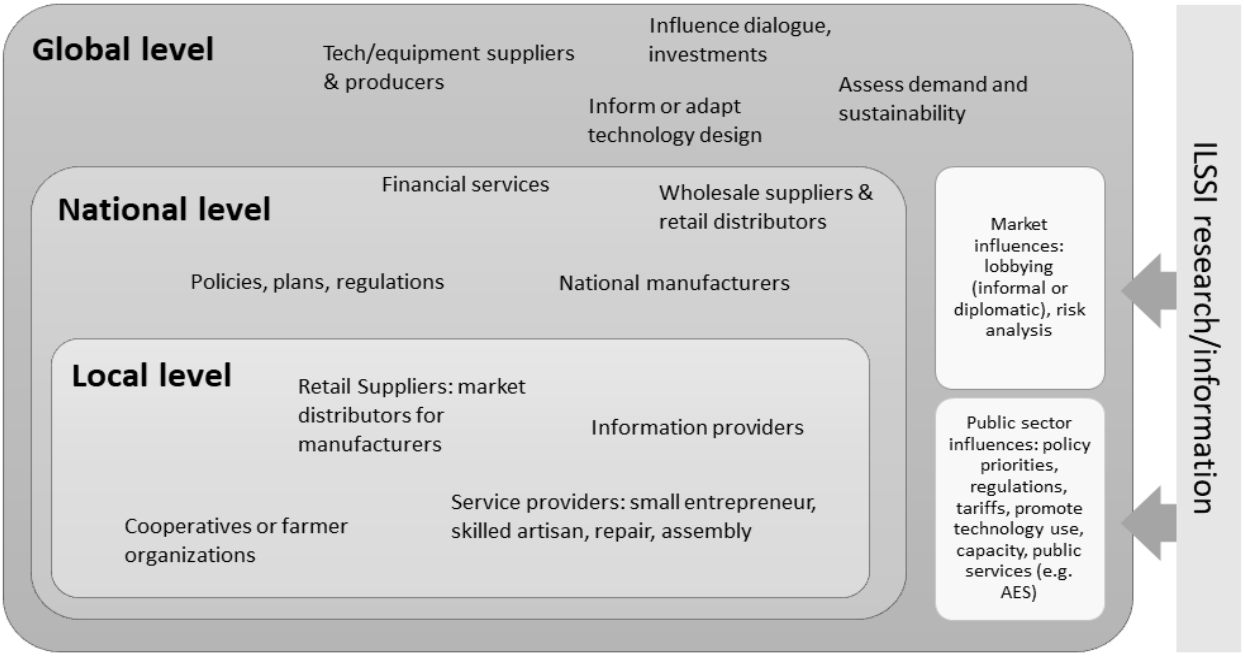

Figure 1. Targets of influence across levels

A. Global level outreach

- World Bank on farmer-led irrigation: ILSSI met with two key officers of the World Bank regarding the farmer-led irrigation efforts. ILSSI updated the World Bank on research results from Phase 1 and intended research program and focus countries for Phase 2. Potential areas for collaborating, particularly outreach, were discussed. The World Bank's emphasis was noted as advocacy, though they are exploring potential

approaches to integrate small scale irrigation into field activities; an initial case will be in Uganda.

- World Water Week (Stockholm) on multiple subjects:
    - Nutrition-gender-irrigation

    In relation to nutrition and irrigation linkages, ILSSI, with partners UN Standing Committee on Nutrition, World Bank, FAO WASAG and SIWI, organized a session at Stockholm World Water Week titled: "The multiple bridges connecting the water-nutrition divide: What's new?"

    Messages:

    - Globally, one in three people are malnourished, while every third person lives in a water-stressed environment—in just three decades, one in two people might be malnourished, while half of the world's population will live with water stress. As such, SDG 2, SDG 6, and SDG 12 are interlinked, but not on track.
    - Much work needs to be done to understand the interlinkages between water, food, and nutrition security. New results on "dietary water productivity" showed huge variations in diets, and the volume of water used to produce these diets, between low- and high-income households in several developing countries.
    - Several actions can be implemented now to improve progress on these SDGs. These include: 1) Increasing coordination across the water and nutrition communities at all levels to avoid nutrition strategies that harm water ecosystems or food security strategies that convert wetlands to waste areas; 2) Ensuring the nutrition-sensitivity of all water investments; 3) Making dietary guidelines work for people and the planet; and 4) Enabling women's empowerment through individual and joint water and nutrition interventions."

    Outputs:

    - The WASAG working group on water and nutrition has welcomed additional members as a result of the session and plans to hold an Expert Group Meeting in the first half of 2020 to discuss a larger set of case studies and associated policy action.
    - The UNSCN will publish a working paper on the topic directed at nutrition audiences.
    - The World Bank will test a new guidance on nutrition-sensitive irrigation development in Uganda
    - The AU will carry the results from the session to the Africa Green Revolution Forum in Accra.
    - An IFAD supported project will further study the concept of dietary water productivity in 5 countries.

    - Farmer-led irrigation

    ILSSI led the organization of a co-convened sessions with Robert B. Daugherty Water for Food Global Institute (DWFI) at the University of Nebraska; The World Bank Group; Alliance for Green Revolution in Africa (AGRA); and the International Water Management Institute: Innovation, Entrepreneurship, and Inclusion: Africa's Farmer-led Irrigation Revolution. SAFI was also represented. The session combined three submissions to the event organizers and brought together key players in the small scale, farmer-led irrigation space. Speakers from USAID (Biniam Iyob), International Finance Corporation (Richard Colback), Alliance for a Green Revolution in Africa (John Jagwe), and DWFI provided reflections and next steps.

    Messages:

    - Increased interest and momentum around the potential for farmer-led irrigation.

- Farmers successfully self-organize, including in small groups, without interventions from government or donors; interventions need to be designed carefully to avoid disruptions and creation of disincentives.
- Women farmers have specific interests, preference and potential benefits, which need to be considered for external interventions.
- Interventions in some value chains, such as fodder, could have multiple benefits related to resilience and conflict mitigation.
- Suitabilty mapping for technologies such as solar can be beneficial for planning and natural resource sustainability.
- Need to understand more issues, e.g. roles for various actors, private sector, and how to design activities to support inclusivity.

Outputs:

- The session had a video station that showcased work by the World Bank and ILSSI (irrigated fodder video from ILRI; farmer-led irrigation video from IWMI in Ghana on "Not want, but need" found here).

B. Regional level outreach

- SAFI – Studying African Farmer-led Irrigation Development, Arusha, Tanzania, March 2019. Dawit Mekonnen of IFPRI participated in the launch event for a research network on behalf of ILSSI. Dawit Mekonnen presented ILSSI's research experience to understand the wider welfare effects of small scale and farmer-led irrigation, including effects on nutrition and women's empowerment.
- Roundtable meeting on the private sector and scaling solar pump irrigation in and the West Africa region, Dakar, Senegal, April 2019. The meeting was convened by the USAID Feed the Future implementer, Power Africa Off-Grid (managed by TetraTech). Several private sector companies were represented, including Bonergie (supplier of Lorentz pumps), Nadji.BI Group, Aggrico, and a representative of SunCulture. In addition, GIZ and public/donor-funded projects also participated, including Energy 4 Impact and Enda Energie. A separate meeting was held with PEG Africa, for both Senegal and Ghana. Across the meetings, participants expressed demand for technical information on water resource availability and mapping of high potential areas for solar irrigation. Some partners have had high success with Pay-as-You-Go systems for payment (notably Lorentz). Concern over different customs charges in the region were noted, particularly the lack of duties/tariffs in Mali that undercut the market in Senegal through illegal import of pumps. ILSSI committed to sharing the results of the mapping activity for Ghana and Mali, following additional activities in Senegal and in the West Africa region, which would be explored jointly with Power Africa Off Grid. This developed into a stronger relationship with Africa Off Grid regional and country offices for West and East Africa; the project has participated in ILSSI meetings in Ghana and has shared the RFA with its network. ILSSI is exploring potential collaboration with Power Africa Off Grid to explore market dynamics for solar pumps in Mali.
- African Union Workshop, Ouagadougou, Burkina Faso, July 2019. Dawit Mekonnen participated in a validation workshop regarding the African Union's "Framework for Irrigation Development and Agricultural Water Management in Africa" at AU-SAFGRAD.

C. National level outreach

- Consultative meetings, Ghana, March 2019: TAMU ME, IWMI, and IFPRI held consultative meetings with Ghana Irrigation Development Authority, Ministry of Food and Agriculture, and several other stakeholders to inform them that ILSSI research had been extended and to discuss future research collaboration. In addition, ILSSI held a seminar on 26 March, 2019 involving about 30 participants from public, private, and development

organizations working in the area of small scale irrigation value chain. The seminar discussed the future research for small scale, farmer-led irrigation, as well the potential to empower women. ILSSI director Dr. Lefore presented on new research areas, and IFPRI's Elizabeth Bryan shared research results from a multi-project effort on small scale irrigation and women's empowerment in Ghana. Ms. Bryan presented on 'Linkages between small-scale irrigation and women's empowerment: Evidence from the Upper East Region of Ghana'.

- Consultative meetings, Ethiopia, March 2019: ILSSI's ME and IWMI met with national institutions and related project to discuss their interests as they align with the ILSSI Phase 2 workplan. Institutions and project visited include: Basin Development Authority (newly formed); Ethiopia Irrigation Commission (newly formed); Agricultural Transformation Agency; Ministry of Agriculture and Natural Resources Small Scale Irrigation Directorate; LandPKS initiative in Ethiopia; CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS); IFAD Ethiopia Country Program and the Participatory Small-Scale Irrigation Development Programme (PASIDP). On request, the IDSS team presented research results and methodology to the World Bank.

D. Engage stakeholders on nutrition, health, and gender as related to irrigation

- IFPRI presented irrigation-nutrition work on Irrigation-Nutrition Linkages in Ethiopia. Presented by Dawit Mekonnen at the National Information Platform for Nutrition – Ethiopian Public Health Institute, Addis Ababa. 7th December 2018.
- IFPRI presented irrigation-nutrition work at the USAID Mission Ethiopia, 11 February, 2019, Addis Ababa. Dawit Mekonnen presented preliminary findings on Ethiopia ILSSI data to USAID mission.
- IFPRI presented irrigation-nutrition work at the Pennsylvania State University, 20 September, 2019. Claudia Ringler presented 'Achieving nutrition outcomes through improved agricultural water management.'
- IFPRI prepared a powerpoint on gender and irrigation for training of irrigation engineers in Arusha, Tanzania. The powerpoint was used to train 12 people in December 2018 (2 women and 10 men) and 22 people in March 2019 (8 women and 14 men). The powerpoint has been shared and used by other projects, including the Studying Africa Farmer-led Irrigation Project.
  See: https://www.youtube.com/watch?v=_ojHjmaM2yw&feature=youtu.be
- ILSSI's work on irrigation-nutrition linkages inspired the World Bank to draft a guidance on nutrition-sensitive irrigation and water management. See: *Bryan, Elizabeth; Chase, Claire; and Schulte, Mik. 2019. Nutrition-sensitive irrigation and water management. Washington, DC: World Bank. http://hdl.handle.net/10986/32309*.

E. Scientific outreach events

- Horticulture Innovation Lab scientific conference, Washington D.C., March 26–27, 2019: In response to an invitation to *Colorful Harvest: From Feeding to Nourishing a Growing World*, ILSSI was represented by Dr. Tom Gerik, in a panel discussion on innovations and challenges in water management for Nutrient Dense Foods.
- Water for Food Conference, Nebraska, April 2019: IWMI presented findings from ILSSI at the farmer-led irrigation session titled: *Integrated solar irrigation solutions for resilient and equitable smallholder farming;* results were shared on groundwater and highlighted the solar business models in a Business Models for Smallholder Irrigation.
- Water for Food Global Conference, April 2019: IWMI contributed to the Technical Expert Meetings on Mitigation at UNFCCC in a session led by IRENA. The session was titled

"Making Water-Energy-Food Integrated Policies Work for Food Security and the Climate". In the introduction of relevant research, IWMI highlighted the workaround suitability mapping to guide irrigation investments and business models to reduce up-front costs. The discussions also highlighted the need for innovative financing to support inclusive access and safeguard groundwater resources.

- American Geophysical Union (AGU) Conference, December 2018. Building on ILSSI research methods and results, IFPRI with the IDSS team co-organized a session *Opportunity to invest in dry-season small-scale irrigation to enhance food security in Sub-Saharan Africa: Case studies in Ethiopia, Ghana and Tanzania*. The session was organized by Xie, H., L. You, Dile, Y., Abeyou, W., Bizimana, J.C., Srinivasan, R.

F. Outreach knowledge products and communications

- Technical brief on solar suitability in Mali: IWMI produced a technical brief for Mali on potential solar suitability mapping, which has been positively received by related projects in Africa. In addition, IWMI developed a blogpost in collaboration with WLE on the release of the solar suitability maps for Mali.
- Video on irrigated fodder in Ethiopia: ILRI developed a six minutes video documentary that was prepared to document and communicate achievements of the ILSSI irrigated fodder project. The video has been edited and posted online and presented in different forums to donors and policymakers. The video shows how the ILSSI irrigated fodder project changed the attitude and livelihood engagement of farmers by increasing the availability of quality feed for their livestock and improving milk productivity. A blog was posted with the video by ILRI: https://www.ilri.org/news/irrigated-forages-improve-livestock-productivity-and-livelihoods-ethiopia.
- Success Story on solar pump irrigation. IWMI's research under the ILSSI project yielded a major conclusion: solar-powered pumps can offer an inexpensive and effective irrigation solution when shallow groundwater or surface water resources are available. IWMI incorporated ILSSI these research results as part of the Success stories 24: Revolutionizing Smallholder Irrigation in Africa
- Nutrition feature: Ringler, C. 2019. Why irrigation is key to feeding Africa south of the Sahara's growing population. Based on Can Sub-Saharan Africa Feed Itself? A New Entry Point to An Old Question. *African Leadership Magazine*.
- Gender and farmer-led irrigation blog: Lefore, N. and C. Ringler. 2019. The unfulfilled promise of farmer-led irrigation: How to include those left behind. Thrive Blog.
- Gender and irrigation blog: Bryan, E. and H. El Didi. 2019. Guest Commentary - Considering Gender in Irrigation: Technology Adoption for Women Farmers.

4. Human and Institutional Capacity Development

This section reports on activities under the ILSSI workplan matrix Component 4 related to capacity development activities. In FY2019, ILSSI developed a HICD plan that integrates multiple trainings and capacity development efforts into a more cohesive, agricultural innovation systems approach (adapted from the USAID HICD strategy). During FY2019, ILSSI had fewer graduate students, indicating the focus on project planning for Phase 2.

A. Short term training

ILSSI's efforts in short-term IDSS training in particular, led to more requests for support in Ethiopia and West Africa than the project had planned, which is under discussion with USAID. In addition, the IFPRI video on gender and small scale irrigation was used in multiple fora in

Africa for trainings and workshop; this exceeded expectations by the project. ILSSI organized and/or planned short-term trainings are found in Table 5.

Table 5. List of short-term trainings and trainees by gender

Subject	Location	Date	Number Trained	Gender
IDSS/data	Bahir Dar University, Ethiopia	March 7-8, 2019	3	F
			35	M
IDSS	Abbay Basin Authority, Bahir Dar, Ethiopia	March 11th – 15th, 2019	7	F
			78	M
IDSS	Water Resources Institute, Accra, Ghana	August 12-16, 2019	13	F
			42	M
Gender	Arusha, Tanzania	December 2018	2	F
			10	M
Gender	Tanzania	March 2019	8	F
			14	M
	Sub-Totals		33	F
			179	M
	Total (aggregated)		**212**	**F+M**

- IDSS trainings

  Three short-term trainings were held on methods related to the Integrated Decision Support System (IDSS). The general objective of the training is to equip the participants with a tool to evaluate the integrated impact of agricultural management practices on production, household income, nutrition, and environmental suitability. The trainings utilize local data, which was collected under the ILSSI project. Trainings are on the suite of three models: the Soil and Water Assessment Tool (SWAT, http://swat.tamu.edu), the Agricultural Policy/Environmental eXtender (APEX, http://epicapex.tamu.edu), and the Farm Income and Nutrition Simulator (FarmSIM, http://afpc.tamu.edu). Participants are provided with a detailed description of the capabilities of each of the three components of the IDSS models, and were trained hands-on the application of the models for natural resources and irrigation management. The participants are also trained how to use the three models in an integrated manner. By the end of the training, the participants are able to evaluate the integrated impact of water and land management practices on agricultural production, environmental suitability, and household income and nutrition.

  - Ethiopia, Bahir Dar University, March 7-8, 2019. ILSSI partnered with Bahir Dar University to provide a training on biophysical data preparation.
  - Ethopia, Abbay Basin Authority, March 11-15, 2019. In response to a request, an IDSS training was provided to the Abbay Basin Authority. A total of 72 participants came from 26 institutions. Priority was given for the experts of the hosting institution, Abbay Basin Authority (ABA). From three ABA branch offices in Assosa, Bahir Dar and Nekemite, 32 participants attended. About 33 participants came from 9 universities across Ethiopia. The remaining participants came from different

government MDAs (e.g. Agricultural Transformation Agency, ATA), quasi-government (e.g. Amhara Design and Supervision Work Enterprise), and private institutions. The participants came from regional (e.g. Amhara National Region State Water, Irrigation and Energy Bureau) and federal (e.g. Ethiopian Environment and Forest Research Institute) government offices working in research, planning, design, and construction sectors. Participants also came from donor agencies such as the USAID and World Bank.

- Ghana, Water Resources Institute, August 12-16, 2019: Advanced SWAT training was provided on August 17 based on request from the local host.

IDSS Training in Accra. Photo credit: Texas A & M

- Gender and irrigation trainings:

- IFPRI's online training module on gender and irrigation has used in a training of irrigation engineers in Tanzania.
- The resource was used to train 12 people in December 2018 (2 women and 10 men) and 22 people in March 2019 (8 women and 14 men).
- The narrated PowerPoint can be found here: Making Small Scale Irrigation Work for women.

B. Long term training

Post-graduate research training/mentoring

Two graduate students completed their thesis papers under the ILSSI project through IWMI at Bahir Dar University (BDU) and Arba Minch University (AMU) in Ethiopia, seen in Table 6. These students had begun studies during the first phase of ILSSI.

Table 6. List of long-term degree related trainees

M / F		Univ	Degree	Major	Subject	Program end date	Degree granted	Country

F	Asnakew, Talake	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	Beshaw, Kassaw	AMU	PhD	Water Resource, Irrigation Eng'g	Adaptive capacity of community to drought in the Upper Gana watershed	06/2019	No	Ethiopia

IFPRI's Elizabeth Bryan developed one of her dissertation papers on a GAAP2 project, which is linked with ILSSI. She presented the results in the March 2019 stakeholder workshop in Accra, Ghana.

Other training - interns and related trainees

IFPRI hired Emma Davies as an intern under ILSSI in 2019. She is a MA student at Harvard University. Emma led the final data cleaning for the baseline surveys in Ethiopia and Tanzania and she contributed to the ILSSI data paper:

> *Mekonnen, Dawit Kelemework; Bryan, Elizabeth; Choufani, Jowel; Davies, Emma; Ringler, Claudia; and Passarelli, Simone. 2019. A user guide to the Innovation Lab for Small Scale Irrigation (ILSSI) baseline survey data: Ethiopia and Tanzania. Washington, DC: International Food Policy Research Institute (IFPRI).*

Emma also contributed to the ILSSI related paper under SIPS, with the following citation:

> *Baye, Kaleab; Choufani, Jowel; Mekonnen, Dawit Kelemework; Bryan, Elizabeth; Ringler, Claudia; Griffiths, Jeffrey K.; and Davies, Emma. 2019. Irrigation and women's diet in Ethiopia: A longitudinal study. IFPRI Discussion Paper 1864. Washington, DC: International Food Policy Research Institute (IFPRI). https://doi.org/10.2499/p15738coll2.133399*

5. Technology Transfer and Scaling Partnerships

A. Progress made for scaling technologies

Application and/or transfer of analytical methods developed under ILSSI

IFPRI applied the agent-based planning model developed in the ILSSI project to complete an analysis of the potential of small-scale irrigation development in two West African countries, Mali and Niger, for a project funded by BMZ called PARI.

IWMI has received funding from BMZ (100,000 Euro) to extend the solar suitability framework developed under ILSSI and the CGIAR Research Program for Water, Land and Ecosystems; completed for Ethiopia and validated for Ghana and Mali. This project aims to develop an online interactive interface that meets the expectations and requirements of the public and private sector to support their efforts to scale of solar based irrigation technologies. Within the project IWMI partners with a private sector solar manufacturer and GIZ supported Powering Agriculture to for outreach and use of the online tool.

Use of ILSSI research for scaling irrigation solutions

Upon successful demonstration of irrigated fodder production in the ILSSI sites, farmers have been asking for improved animals. In the Amhara region of Ethiopia, Andasa Agricultural

Research Center is working to help farmers access improved crossbred animals. This support is expected to encourage farmers to adopt irrigated fodder cultivation and utilization practices at scale. Local forage seed/planting material multiplication and marketing is an important factor for scaling irrigated forages. Good awareness has been created among the extension system about the need to strengthen the local capacity in seed/planting material production and distribution. Organizing women and youth groups/farmer cooperatives in producing and supplying forage planting materials appear to be an important area of engagement that needs further piloting.

The forage intervention at Robit Bata has particularly paved a way to income generation for farming families through sales of increased milk production. This has attracted a private milk processing enterprise in Bahir Dar. The enterprise is collecting milk every morning and evening from Robit farmers at its collection center established in the Kebele. This has motivated the re-vitalization of the once existed but died dairy cooperative in the kebele to come back to the business.

Use of ILSSI research to influence policy and future investments in SSI

IWMI prepared outreach material for the World Bank on farmer-led irrigation, which contains examples and lessons from ILSSI Phase 1. The slide deck will be used by the World Bank and provided a wider reach of ILSSI results in the donor and public sector community.

As noted above, IFPRI's work supported by ILSSI on irrigation-nutrition linkages inspired the World Bank to draft a guidance on nutrition-sensitive irrigation and water management. Knowledge products were developed for use by the World Bank to improve the nutrition outcomes of their irrigation investments. See Annex 3 for the related Success Story.

IFPRI supported the development of the Malabo-Montpellier report on Irrigation in Africa: Malabo Montpellier Panel. 2018. Water-Wise: Smart irrigation strategies for Africa. Dakar, Senegal: International Food Policy Research Institute (IFPRI) and Malabo Montpellier Panel. This knowledge product – which has lessons and publications supported by ILSSI - is influencing policy and investments at a regional level.
https://www.mamopanel.org/media/uploads/files/Water-Wise_Smart_Irrigation_Strategies_for_Africa.pdf

6. Issues, Concerns and Lessons from the Reporting Period

A. Issues and concerns

While there has been value in evaluating progress after five years of ILSSI research, significant investment in time and resources was required to develop a research program and constitute teams (of our sub-awardees) for the extension period - most of year six was needed for this process. We underestimated the effort and time/resources required.

ILSSI's approach to partnering with the private sector on scaling research is new among Innovation Labs; few instances are documented of lessons from research programs. In developing the approach for the partnerships and for setting up the Request for Proposals (RFAs), expertise had to be sought from Partnering4Innovation, Power Africa, and other initiatives with experience with the private sector. This extended the time required to set up the RFA, though it helped to ensure a more effective process.

ILSSI has influenced World Bank activities and publications, but this is not attributed to our program. Recent World Bank publications on irrigation, water, and nutrition are based on IFPRI publications and presentations supported through ILSSI, but ILSSI is not acknowledged and in

some cases, the researchers are also not properly acknowledged. Similarly, IWMI prepared slides for use by World Bank on farmer-led irrigation, but it is unclear if ILSSI was acknowledged in presentations later. This suggests a need for a strategy to support proper acknowledgement of USAID and Feed the Future investments.

ILSSI is receiving more requests for HICD than available funding. ILSSI's ME has informed USAID advisors and is seeking potential ways to support valid requests that originate from project country institutions.

B. Lessons

One lesson that may be highlighted from this period is that research projects of five-year duration in the subjects related to agricultural development, natural resource management, and nutrition, often require extended periods to develop and publish. As a result, ILSSI is still finalizing the analysis for and publication of research results. This points to the lesson that continuity between the initial five-year award and an extension period is critical to achieve development impact based on research evidence generated.

C. Gender-Related Progress

ILSSI continued to place emphasis on gender in it second phase research plan and activities. In addition to gender disaggregation of data collected, ILSSI has mainstreamed gender issues into research protocols on the irrigated value chain (including fodder), private sector scaling mechanisms and business models, economic and credit-related analysis, among others. Targeted studies included the above-mentioned multiple use analysis and irrigation-gender-nutrition linkages.

To further highlight the importance of gendered analysis for informing policies and investments, ILSSI undertook the following specific outreach activities around gender:

- Support for participation in the Feed the Future Innovation Lab gender workshop in Washington, DC, convened by the Horticulture Innovation Lab. In addition to the participation of IFPRI, the ILSSI ME supported development of the presentation by Appropriate Scale Mechanization Consotium, which was on tools that can support other Innovations Labs to conduct assessments of the links between gender and technology adoption.
- Amplified the research results from the irrigation-nutrition-gender research produced by ILSSI sub-awardee IFPRI.
- ILSSI Director published an invited piece in a special issue of *Water Alternatives* on inclusivity and farmer-led irrigation in 2019. Key findings and lessons have been shared on social media and in other fora.
- Included a section on gender in the ILSSI RFA, in consultation with the USAID gender advisor. The ILSSI ME will review all submissions for the gender module and share with USAID's gender advisor (based on feedback and suggestions from Krista Jacobs during meeting in August 2019).

7. Future Work

As indicated in the five year and the Year 7 workplan, activities shift toward understanding how to scale small scale irrigation in a way that is economically and environmentally sustainable, while enhancing resilience. Activities are outlined in the separate document, Year 7 Workplan Matrix. Some highlights are described below.

Objective 0: Effectively plan, coordinate, and organize multi-institutional activities

- Select private sector partners and manage sub-awards; an extensive evaluation process will be underway through February 2020.
- Implement the updated communications plan and activities with comms specialist, e.g. migrate and update website, regular postings on social media, develop success stories, develop new briefs, knowledge products, and issue quarterly newsletters.
- Hold annual face to face meeting with program management committee of ILSSI to share research and ensure alignment of activities; meeting will include the new External Advisory Committee.
- Explore potential for ILSSI research, particularly in response to requests from the USAID supported AgDiv project in Malawi.

Area of Inquiry 1: Identify and test approaches to sustainably scale SSI through reducing constraints and strengthening opportunities for access

- Initiate the 'scaling small scale irrigation' dialogue platform meetings in Ghana and Ethiopia.
- Organize the Net-map workshps in Ghana and Ethiopia
- Complete the irrigated fodder suitability mapping for Ethopia; identify sites for private partnerships in irrigated fodder

Area of Inquiry 2: Identify and test approaches to scale SSI to be sustainable and support resilience

- Implement activities in Mali: Focus Group Discussions; surveys; irrigated seed market assessment; Water Accounting assessment.
- Initiate local level water governance activities in Ghana and Ethiopia
- Implement survey on farmer investment incentives in Ethiopia

Area of Inquiry 3: Identifying and testing approaches to maximize inclusivity, effective governance, women's empowerment, and involvement of youth for nutrition-sensitive irrigated production

- Assess gendered implications of the irrigated fodder value chain
- Complete study on multiple use systems, irrigation and gender

Outreach, communications, engagement and HICD

- Participate in outreach events that amplify ILSSI research, including at the AGU in December 2019, Water for Food Conference (University of Nebraska) in 2020, among others.
- IDSS training co-organized with ICRAF in Ivory Coast; IDSS trainings in Ghana and Ethiopia; Targeted IDSS training on irrigated fodder in Ethiopia
- Initiate competitive process for innovation scholarships in Ghana and Ethiopia

Annex 1. Data sets made open access (FY2019)

ILSSI Dataverse

1. Ex-ante studies - Tanzania
2. Ex-ante studies - Ethiopia
3. Nutritional quality and price of irrigated fodder and other feed resources in Lemo area
4. Biomass yield of irrigated oat-vetch forage and desho grass in the Lemo district of southern Ethiopia.
5. Yield and fodder quality of irrigated Napier grass inter-cropped with either Sesbania, Desmodium or Pigeon pea

IWMI Water Portal

1. Standard Climatic Data Rudewa-Tanzania
2. Watershed Delineation, Sub-Watershed & River in SWAT-Tanzania: 2017
3. Production Analysis Commodities-Ghana 2014-2015
4. Rice Production Northern Region-Ghana 1991-2008
5. Maize Production Northern Region-Ghana 1991-2008
6. Market Prices Kasenanankana District Monthly 2016
7. Food Production of Northern Ghana Kasenanankana District
8. Biophysical Data on Irrigation Experiments-Ghana
9. Evaluation of Irrigation Scheduling Strategies on Partial Nutrient Balance for Tomato Production During the Dry Season at Robit Bata Watershed
10. Improving Subsurface Recharge through Breaking Restrictive Soil Layers by Mechanical Means
11. Evaluation of Wetting Front Detector to Determine Water Demand, Water and Crop Productivity of Selected Fodder Verities Under Supplemental Irrigation-Climate Data
12. Evaluation of Wetting Front Detector to Determine Water Demand, Water and Crop Productivity of Selected Fodder Verities Under Supplemental Irrigation-Desho Agronomic Data
13. Evaluating Simple Irrigation Technologies to Improve Crop and Water Productivity of Onion in Dangishta Watershed-Climate

14. Evaluating Simple Irrigation Technologies to Improve Crop and Water Productivity of Onion in Dangishta Watershed

15. Evaluation of Wetting Front Detector to Determine Water Demand, Water and Crop Productivity of Selected Fodder Varieties Under Supplemental Irrigation

16. Optimizing Use of Groundwater for Irrigation in the Dry Season: The Case of Robit Watershed, Lake Tana Basin Stream Flow Data

17. Optimizing Use of Groundwater for Irrigation in the Dry Season: Th Cause of Robit Watershed, Lake Tana Basin

18. Assessing the Performance of Manual Water Lifting Technologies and Irrigation Scheduling Based on Measured Soil Moisture and Farmers Practice on Irrigated Tomato, and Comparing Soil Moisture Measurement and Estimation Methods: Case Study of Western Amhara Sub Region

19. Evaluation of Wetting Front Detector to Determine Water Demand, Water and Crop Productivity of Selected Fodder Varieties Under Supplemental Irrigation

20. Optimizing Use of Groundwater for Irrigation in the Dry Season: The Case of Robit Watershed, Lake Tana Basin

21. Development of Crop Coefficients and Evaluating the Productivity and Water Use for Napier Grass Under Small-Scale Irrigation: The Case of Robit Kebele

Annex 2. Publications ILSSI (FY2019)

Peer-reviewed publications

Abidela Hussein, M.; Muche, H.; Schmitter, P.; Nakawuka, P.; Tilahun, S. A.; Langan, S.; Barron, J.; Steenhuis, T. S. (2019). Deep Tillage Improves Degraded Soils in the (Sub) Humid Ethiopian Highlands. *Land*, *8*(11), 159.

Assefa, T.; Jha, M.; Worqlul, A. W.; Reyes, M.; Tilahun, S. (2019). Scaling-Up Conservation Agriculture Production System with Drip Irrigation by Integrating MCE Technique and the APEX Model. *Water*, 11(10), 2007.

Assefa, Tewodros; Jha, Manoj; Reyes, Manuel; Tilahun, Seifu; Worqlul, Abeyou W. (2019). Experimental Evaluation of Conservation Agriculture with Drip Irrigation for Water Productivity in Sub-Saharan Africa. *Water* 11(3), 530 (March).

Ayana, Essayas K.; Dile, Yihun T.; Narasimhan, Balaji; Srinivasan, Raghavan. (2019). Dividends in flow prediction improvement using high-resolution soil database. *Journal of Hydrology: Regional Studies* 21, 159-175 (February).

Balana, B. B., Bizimana, J. C., Richardson, J. W., Lefore, N., Adimassu, Z., & Herbst, B. K. (2019). Economic and food security effects of small-scale irrigation technologies in northern Ghana *Water Resources and Economics*, 100141 (March).

Bayabil, H.K.; Yihun T. Dile; Tebebu, T.Y.; Engda, T.A.; Steenhuis, T.S. (2019). Evaluating infiltration models and pedotransfer functions: Implications for hydrologic modeling *Geoderma* 338, 159-169 (March).

Belay, S. A., Schmitter, P., Worqlul, A. W., Steenhuis, T. S., Reyes, M. R., & Tilahun, S. A. (2019). Conservation Agriculture Saves Irrigation Water in the Dry Monsoon Phase in the Ethiopian Highlands *Water*, *11*(10), 2103.

Bizimana, J.C.; Richardson, J.W. (2019). Agricultural technology assessment for smallholder farms: An analysis using a farm simulation model (FARMSIM). *Computers and Electronics in Agriculture* 156, 406-425 (January).

Dersseh, M. G., Kibret, A. A., Tilahun, S. A., Worqlul, A. W., Moges, M. A., Dagnew, D. C.; Abebe, W.B.; Melesse, A. M. (2019). Potential of Water Hyacinth Infestation on Lake Tana, Ethiopia: A Prediction Using a GIS-Based Multi-Criteria Technique. *Water* 11(9), 1921.

Desta, M.; Zeleke, G.; Payne, W.; Shenkoru, T.; Taddele, Y. D. (2019). The impacts of rice cultivation on an indigenous Fogera cattle population at the eastern shore of Lake Tana, Ethiopia *Ecological Processes* 8(1), 1-15 (May) doi:doi.org/10.1186/s13717-019-0167-7

Lefore, N., Giordano, M., Ringler, C., & Barron, J. (2019). Viewpoint–Sustainable and Equitable Growth in Farmer-led Irrigation in Sub-Saharan Africa: What Will it Take?. *Water Alternatives* 12(1), 156-168.

Teklay, A., Dile, Y. T., Asfaw, D. H., Bayabil, H. K., & Sisay, K. (2019). Impacts of land surface model and land use data on WRF model simulations of rainfall and temperature over Lake Tana Basin, Ethiopia. *Heliyon*, *5*(9), e02469.

Walker, D., Parkin, G., Schmitter, P., Gowing, J., Tilahun, S. A., Haile, A. T., & Yimam, A. Y. (2019). Insights From a Multi-Method Recharge Estimation Comparison Study. *Groundwater*, *57*(2), 245-258.

Worqlul, A. W., Dile, Y. T., Jeong, J., Adimassu, Z., Lefore, N., Gerik, T., ... & Clarke, N. (2019). Effect of climate change on land suitability for surface irrigation and irrigation potential of the shallow groundwater in Ghana. *Computers and electronics in agriculture* 157, 110-125 (February).

Worqlul, A. W., Dile, Y. T., Schmitter, P., Jeong, J., Meki, M. N., Gerik, T. J., ... & Clarke, N. (2019). Water resource assessment, gaps, and constraints of vegetable production in Robit and Dangishta watersheds, Upper Blue Nile Basin, Ethiopia. *Agricultural Water Management*, *226*, 105767.

Discussion/Working Papers and reports

Baye, K.; Choufani, J.; Mekonnen, D.; Bryan, E.; Ringler, C.; Griffiths; J. K.; Davies, E. (2019). *Irrigation and Women's Diet in Ethiopia A Longitudinal Study.* Washington, D.C.: International Food Policy Research Institute (IFPRI). (IFPRI Discussion Paper 1864).

Merrey, D. J.; Lefore, N. (2018). Improving the availability and effectiveness of rural and "Micro" finance for small-scale irrigation in Sub-Saharan Africa: a review of lessons learned. Colombo, Sri Lanka: International Water Management Institute (IWMI). 46p. (IWMI Working Paper 185). doi: 10.5337/2018.225

Technical Reports

Mekonnen, D. (2019). A User Guide tothe Innovation Lab for Small Scale Irrigation (ILSSI) Baseline Survey Data: Ethiopia & Tanzania.. IFPRI, Washington DC.

Lefore, N., Gebregziabher, G., Hagos, F., & Haileslassie, A. (2019). A. Credit constraints, adoption of modern agricultural technologies and agricultural income in Ethiopia.. IWMI, Addis, Ethiopia.

Lefore, N., Hagos, F., Gelgo, B., & Haileslassie, A. (2019). Rapid assessment of the agricultural water management technology supply chain: Ethiopia case study. IWMI, Addis, Ethiopia.

Capacity development materials

Theis, S. 2018 (December). Making small-scale irrigation technology work for women.

Conference papers and posters; Presentations

Balana, B. & Appoh, R. (2019). Assessment of private actor participation in the irrigation technology supply chain: Ghana case study. IWMI, Accra, Ghana.

Balana, B., Gebregziabher, G., Mul, M., Owusu, A., Kodua, T., & Closas, A. (2019). Solar PV Technology for Small-Scale Irrigation in Ghana: Suitability and Business Cases. IWMI, Accra, Ghana.

Bryan, E. (2019). Linkages between small-scale irrigation and women's empowerment: Evidence from the Upper East Region, Ghana. Presentation at ILSSI Stakeholder Consultation, Accra, Ghana.

Dile, Yihun T.; Worqlul, A. W.; Xie, H.; Ayana, E. K.; Bizimana, J.C.; Srinivasan, R.; You, L.; Lefore, N.; Gerik, T.; Richardson, J.W.; Clarke, N. (2018, December). Potential of Small-scale Irrigation to Improve Livelihoods in Ethiopia. American Geophysical Union (AGU) Conference.

IFPRI. (2018, December). Solar Irrigation Potential Poster. American Geophysical Union (AGU) Conference.

Mekonnen, D. (2018). Irrigation-Nutrition Linkages. Presentation at National Information Platform for Nutrition – Ethiopian Public Health Institute, Addis Ababa, Addis Ababa.

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Ringler, C. (2019). Achieving nutrition outcomes through improved agricultural water management: What are the options?. Presentation at Pennsylvania State University.

Schmitter P. (2018) Prospects of Solar Irrigation to accelerate Farmer-led irrigation in Sub-Saharan Africa. Presentation at the session: Accelerating Farmer-led Irrigation in Sub-Saharan Africa, at the Building Climate Resilience for Doubling Farmer's Income, IWMI-TATA Partners Meet 2018, Anand, India, 4th – 5th of December 2018.

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Tesfaye, M., Daba, T., Bizimana, J., Balana, B., & Gebregziabher, G. (2019). Farmers Willingness to Pay for Smallholder Water Lifting Technologies: Evidence from Ethiopia. Presentation at Agricultural & Applied Economics Association (AAEA), Atlanta, Georgia – USA.

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Xie, H. (2018). Opportunity to invest in dry-season small-scale irrigation to enhance food security in Sub-Saharan Africa: Case studies in Ethiopia, Ghana and Tanzania. American Geophysical Union (AGU) Conference, Washington, DC.

You, Liangzhi; Xie, Hua; Dile, Yihun; Worqlul, Abeyou Wale; Bizimana, Jean-Claude; Srinivasan, Raghavan. (2018, December). Opportunity to invest in dry-season small-

scale irrigation to enhance food security in Sub-Saharan Africa: Case studies in Ethiopia, Ghana and Tanzania. American Geophysical Union Conference.

Blogs

Ringler, C. (2019). Why irrigation is key to feeding Africa south of the Sahara's growing population. Based on Can Sub-Saharan Africa Feed Itself? A New Entry Point to An Old Question. African Leadership Magazine.

Lefore, N. and C. Ringler. (2019). The unfulfilled promise of farmer-led irrigation: How to include those left behind. Thrive Blog.

Bryan, E. and H. El Didi. (2019). Guest Commentary - Considering Gender in Irrigation: Technology Adoption for Women Farmers.

Papers under review

Assefa, T., Reyes, M., Jha, M., Tilahun, S., & Worqlul, A. W. Conservation Agriculture with Drip Irrigation: Effects on Soil Quality and Crop Yield in Sub-Saharan Africa. *Journal of Soil and Water Conservation* **Awaiting publication**

Ibrahim, K.; Richardson, J.; Mutabazi, K.; Philip, D.; Bizimana, J.; Mourice, S.; Waized, B. Forecasting farm productivity and profitability as probability distributions for main cereal crops in Tanzania: a multivariate empirical (MVE) approach. Agricultural Systems Accepted

Schmitter, P., Tilahun, S., Langan, S., Barron, J., Steenhuis, T., & Yilak, D.. Establishing irrigation potential of a hillside aquifer in the African highlands. *Hydrological Processes* **Under review**

Annex 3. Success Stories

New research puts development partners and policy makers on path toward nutrition-sensitive irrigation investments

It is well recognized that small scale, farmer-led irrigation can increase farm production, profitability, and climate resilience. However, until recently, the link between irrigation and nutrition has been surprisingly under explored. New research supported by USAID through the Feed the Future Innovation Lab for Small Scale Irrigation (ILSSI) has found linkages between irrigation and improved nutrition of women and children. These insights have also informed a new World Bank guidance note on nutrition-sensitive irrigation and water management investments.

Fruit and vegetables provide key nutrients for children. Photo: Information Services Department of Ghana, 2011.

ILSSI partners, notably the International Food Policy Research Institute (IFPRI), have found that irrigation has a strong positive effect on a household's economic access to food and dietary diversity as well as on nutritional outcomes for women and children. Irrigation allows smallholders to fill dietary gaps during the dry season and to consume more nutritious foods, such as vegetables and eggs, which are key for child growth and overall health.

These findings have important implications for future investments in water management and irrigation, for which improved nutritional status can now be added and tracked as an explicit goal. Understanding the pathways and context in which irrigation can improve nutrition is of particular importance because the linkages and their strength vary depending on context. It also matters because irrigation could risk undermining nutrition and health goals, if not carefully designed, by causing water pollution and water-related diseases.

Therefore, understanding precisely how irrigation and nutrition are linked is essential to achieve global development objectives, such as outlined under the UN Decades for Action on Nutrition and for Action on Water for Sustainable Development, while avoiding adverse trade-offs.

Pathways from irrigation to improved nutrition

According to research carried out under ILSSI, irrigation can be considered to contribute to nutrition outcomes through four different pathways: increases in agricultural production, increases in income, empowerment of women, and provision of water for domestic and sanitation purposes. While all four aspects are highly relevant, differences in context determine which pathway makes the strongest contribution to nutrition.

Empowering women to influence decision making may lead to greater spending on health care and nutritious foods. Photo: Apollo Habtamu, ILRI, 2018.

Drawing on data collected through household surveys in Ethiopia and Tanzania, IFPRI researchers found that irrigating households in both countries produced more vegetables, fruits and cash crops, had a higher production diversity and dietary diversity compared to non-irrigating households, and were more food secure. What's important is that these positive outcomes were achieved in different ways.

The study indicated that in Ethiopia, irrigation resulted in improved dietary diversity through an increase in agricultural incomes. In other words, increased income allowed smallholders to spend more money on more diverse food products, but also on health care, which is likely to improve their nutritional status and health. Results from Ethiopia, however, also indicated that dietary diversity was greater in female-headed households, supporting the notion that women prefer to allocate spending toward nutritious diets.

Global development partners take on ILSSI's research results

Inspired by and leveraging the findings of ILSSI, The World Bank in August 2019 published a guidance note on nutrition-sensitive irrigation and water management investments. The guidelines describe the four irrigation-to-nutrition pathways (production, income, women's empowerment, and water, sanitation and hygiene) identified by IFPRI researchers. **The guidelines highlight entry points for improving the nutritional outcomes of irrigation and water management investments, such as incorporating nutritional considerations in project design and engaging women in irrigation decisions. They also provide practical guidance on indicators to support monitoring and evaluation of such investments.**

Claudia Ringler, IFPRI's Deputy Director of Environment and Production Technology Division, presented ILSSI research at World Water Week, August 2019. Photo: Niroshini

Publication of the guidelines in August 2019 coincided with World Water Week**, where ILSSI results were presented in several sessions.** One session **discussed how water and agricultural strategies can contribute to improved nutrition outcomes, as** informed **by ILSSI's findings**. A second session focused on how to bridge the water–nutrition divide, and its answers included ensuring that all water investments are nutrition sensitive. Following these discussions, the African Union reported that it would communicate the session results to the Africa Green Revolution Forum in Accra, Ghana; The World Bank committed to testing its new guidelines on nutrition-sensitive irrigation development in Uganda; and a project supported by the International Fund for Agricultural Development (IFAD) said it would further study the concept of dietary water productivity in five countries.

These commitments suggest that the World Bank-issued guidelines and the ILSSI research that contributed to these guidelines may not only inform The Bank's own irrigation investments and initiatives, but may also impact other irrigation and water investors working to end malnutrition.

Ethiopian interest indicates further potential for change

National partners and policy makers in Ethiopia are also showing significant interest in ILSSI's recommendations on how irrigation can improve nutritional status. Following a presentation by IFPRI researchers during a National Information Platform for Nutrition seminar at the Ethiopian Public Health Institute, the USAID Mission in Ethiopia and other national stakeholders have expressed interest in strengthening linkages between irrigation and nutrition. IFPRI researchers working on irrigation and nutrition linkages have been invited to present to a wider audience at the Ethiopia National Nutrition Conference in December 2019.

This interest demonstrates potential for shifting to nutrition-sensitive irrigation investments in Ethiopia. Like many other countries in sub-Saharan Africa, Ethiopia tends to focus on increasing production for household consumption to achieve food and nutrition security. ILSSI findings indicate opportunities for increasing nutrition security by commercializing irrigated production. In addition to raising incomes of irrigating households, this approach would also increase the availability of diverse and nutritious foods in local and national markets.

Responding to the major threat that climate change and weather variability pose to nutrition security in sub-Saharan Africa, ILSSI is now continuing research to identify the linkages between nutrition, human resilience, and weather extremes to better understand how irrigation might contribute to resilience – particularly food and nutrition security – during droughts.

Revolutionizing smallholder irrigation in Africa

Expanding small scale irrigation to intensify production is urgent for Sub-Saharan Africa, where scarce or variable rainfall severely impedes agriculture growth, curbing productivity and ultimately the resilience of poor farmers. The Innovation Lab for Small Scale Irrigation, through its partners including the International Water Management Institute (IWMI), have taken steps to tackle the challenge of how to increase the use of irrigation through smallholders' own investments. ILSSI's research is gaining attention from bi-lateral and global development partners, who are now increasing their investments in small scale, farmer-led irrigation development.

Solar-powered pumps offer an inexpensive and effective irrigation solution. Funded by ILSSI, researchers at IWMI developed a methodology for mapping the suitability of solar irrigation across Mali.

Putting technologies to the (field) test

In partnership with smallholders, ILSSI supported scientists at IWMI to test a wide range of manual and motorized water-lifting options in farmers' fields. The research looked at how to improve agricultural production, water use efficiency and water productivity. Research also addressed constraints related to wider adoption, such as gender, access to credit and the technology supply chain. IWMI's research under the ILSSI project yielded a major conclusion: *solar-powered pumps can offer an inexpensive and effective irrigation solution when shallow groundwater or surface water resources are available.* Farmers in rural areas experience high running costs with petrol-powered pumps, which erode their profits and increase their risks. Access to fuel as an input acts as an additional constraint. Solar powered pumps open up opportunities for farmers who are off the grid, while freeing the farmers from the fuel related constraints. According to a recent report from Dalberg, "these solar water pumps have the potential to reach up to 1.6 million households in sub-Saharan Africa by 2025 and as many as 2.8 million households by 2030—a value of approximately USD 1.6 billion by 2030". ILSSI also identified the importance of combining irrigation technologies with suitable agriculture value chains.

IWMI researchers – partially funded by ILSSI and the Water, Land and Ecosystems Research Program of the CGIAR - developed a methodology for mapping the suitability of solar irrigation. It has now generated maps for Ethiopia, Mali, and Ghana. During roundtable meetings, private companies have shown interest in using the maps to support initial assessments of potential market growth for irrigation technologies based on available resources and infrastructure. ILSSI held round table meetings with the private sector in three countries in Sub-Saharan Africa; the technology supply companies noted that they have a stake in water resource sustainability, and welcomed maps that considered agro-ecological zones, water resource availability and sustainability, as well as market factors, such as demographics and infrastructure. Companies have an interest in both economic and natural resource sustainability, but often lack the resources to individually develop such complex maps.

In addition to the solar suitability mapping, USAID funding enabled IWMI – through ILSSI and the Africa RISING project – to test irrigation scheduling tools. Introduction of irrigation scheduling enables farmers to achieve higher water productivity – farmers could reduce their labor input by knowing when and how water to use, and also increased their yields and produce quality. While the impact of using the tools varied by country - related to capacity and information access - evidence suggested the potential for improving farmer income and enhancing water resource management.

Global development partners invest in expanding ILSSI's research results

Leveraging the initial funding through USAID and ILSSI, IWMI is now scaling out the use of an online interactive tool for solar suitability mapping throughout sub-Saharan Africa. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) found the mapping tool to be a good investment. The open access, interactive tool will enable companies to know where solar pumping would be suitable and thereby, reduce the risks of investing in frontier markets. The tool can also be used by donors and NGOs to target their interventions and activities in solar powered irrigation. For example, the Food and Agricultural Organization (FAO) is requesting national suitability analysis in West Africa to inform their Regional Programs.

The irrigation scheduling tools also drew the attention of development partners. The research under ILSSI and Africa RISING suggested that these tools provide a learning and communication platform influencing when and how much farmers irrigate. This has led to a larger assessment funded by FAO in Ethiopia to build local communication networks for water user associations (WUA) around ICT and non-ICT based scheduling tools, reaching over 602 farmers on 240 ha. The low cost ICT scheduling sensor is currently being considered for scaling to other African countries through the Water Enabler Compact under the Technologies for African Agricultural Transformation program funded by the African Development Bank. In addition, promising tools and technologies explored under ILSSI will be incorporated into a Swiss Development Cooperation funded project with Wetlands International (WI) and IWMI to reduce the ecological footprint of food production, in Ethiopia and Mali on Improving Food Security and Nutrition in the Sahel by Safeguarding Wetlands through Ecological Sustainable Agricultural Water Management (ESAWM).

Future efforts toward outcomes

The initial investments of USAID through ILSSI to field test with farmers a broad range of technologies across the agricultural water management spectrum, which generated evidence that led to a better understanding of barriers and opportunities. This has informed new ideas on how research could help private and public sector target investments in expanding small scale irrigation access. Private sector companies, donors and development partners are using the results of research to guide their investments in irrigation. Over the coming years ILSSI will continue to act as a catalyst for investment in farmer-led irrigation – enabling irrigation investors to scale and expand - contributing to USAID's vision for the journey to self-reliance.