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

FEED THE FUTURE INNOVATION LABORATORY FOR SMALL SCALE IRRIGATION

Annual Report

October 1, 2015 – September 30, 2016

Table of Contents

USAID FROM THE AMERICAN PEOPLE · THE BORLAUG INSTITUTE · TEXAS A&M AGRILIFE RESEARCH · THE TEXAS A&M UNIVERSITY SYSTEM · IFPRI INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE · IWMI International Water Management Institute · ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE · NORTH CAROLINA A&T STATE UNIVERSITY

I. Feed the Future Innovation Lab on Small Scale Irrigation in Ethiopia, Tanzania and Ghana

II. Foreword

This report covers the third year of the five-year cooperative agreement for the laboratory. The first year focused on stakeholder engagement and planning for research in Ethiopia, Tanzania, and Ghana. Small scale irrigation interventions were defined and regional and local engagements were initiated in year two. Research began with field studies; household surveys; and ex ante analyses of the consequences of small scale irrigation interventions using the Integrated Decision Support System (IDSS). This work was further advanced in year 3.

This cooperative agreement is conducting research aimed at increasing food production, improving nutrition, accelerating economic development and contributing to the protection of the environment. The major components of this cooperative agreement are: (1) the assessment of promising small scale irrigation (SSI) technologies; (2) stakeholder consultation at multiple levels of scale to define the interventions to be used in field studies; (3) engagement with national partners and farmers for conducting field studies; (4) surveys of farm families in the region surrounding field test sites; and (5) integrated analysis using the Integrated Decision Support System (IDSS) of the production, environmental and economic consequences of small scale irrigation options, including but not limited to interventions actually studied in farmers' fields. Capacity building and training at multiple levels of scale are also substantive elements of the agreement.

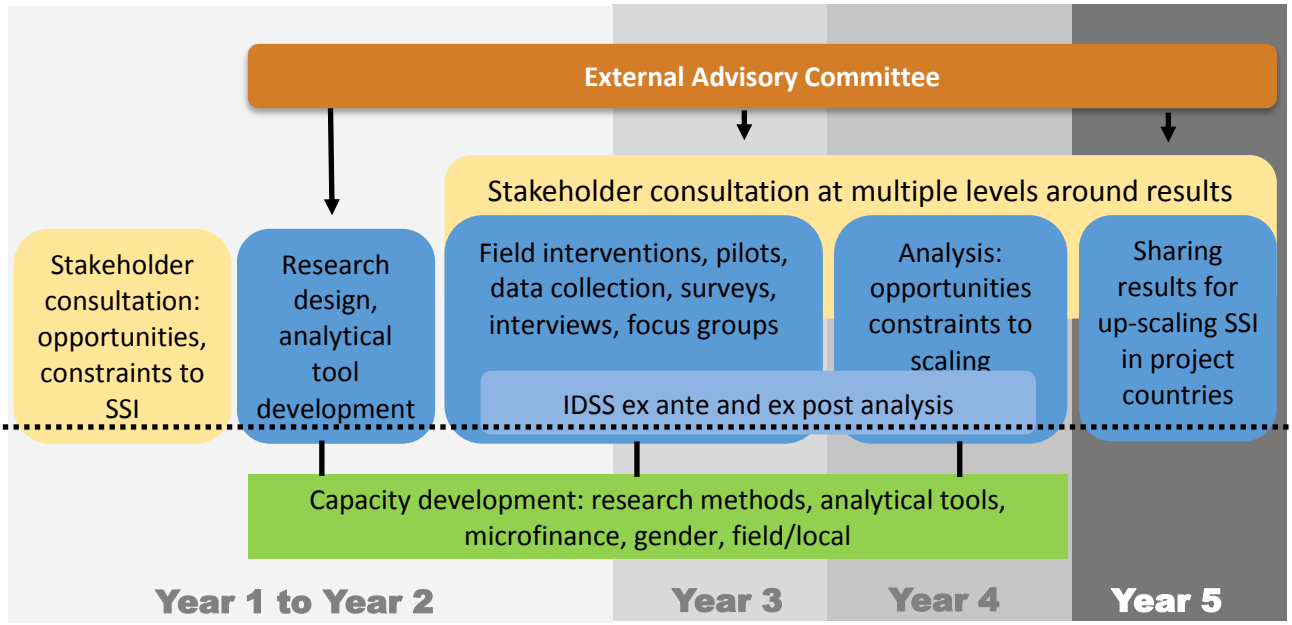
The Borlaug Institute for International Agricultural/Texas A&M University System (BI/TAMUS) is the lead institution. Partners in the cooperative agreement include the International Water Management Institute (IWMI), the International Food Policy Research Institute (IFPRI), the International Livestock Research Institute (ILRI), North Carolina A&T State University (NCA&T) and Texas A&M AgriLife Research (TAMAR).

Future Activities: As ILSSI reaches the mid-term of its current cooperative agreement, field research in all three countries will be continued with collaboration on the new SIIL award on SIPSIN in Ethiopia. Second generation household surveys will be initiated in year 4. Application of the IDSS to the ex post studies of constraints and mitigation analyses will be continued. The integrated product of ILSSI component studies will be developed and enunciated in multiple publications. Scaling up small scale irrigation interventions is under way in Ethiopia in collaboration between Texas A&M and IFPRI to regional and then national levels. Stakeholder engagements will be formally continued in all three countries with focus on mitigation of constraints and uptake of SSI interventions. Extensive preparations are being made for the upcoming USAID External Review of the agreement in year four. ILSSI will begin to develop its exit strategy for the current effort and develop the initial strategy for continuation of the effort in a second phase. An international workshop on ILSSI will be planned for year five and conducted in conjunction with another major international water meeting.

Included below for perspective is a figure from the ILSSI Mid Term Report that provides a snapshot of the overall cooperative agreement on the five-year timeline of the effort. Year three of this five year effort involves active field, survey, and analytic activities. It is the last year of research in the field and leads to

major effort in year four to synthesize results across components into a common interactive relationship. Capacity building and stakeholder engagement are ongoing.

Summary of the Major Elements of ILSSI Research, Capacity Building and Stakeholder Engagement



III. Summary of Results

Field Research: In year three, field research involved ongoing research in all three countries with initial results from ongoing studies analyzed and reported. Multi-year field studies continued. In Ethiopia, the second irrigated cropping season was moderately affected by drought. In Tanzania and Ghana, first year dry season field studies were completed. Multiple water delivery and distribution systems, as well as technology financing and cost-benefit analysis, were evaluated in collaboration with national university partners. Data on small scale irrigation systems are being used in modeling results at multiple levels of scale.

Household Surveys: Baseline household surveys involving cohorts of farm families surrounding the areas of field research were completed, providing data on status of family nutrition, economic status of the farming enterprise and factors relating small scale irrigation to gender. Results of the latter initial studies have been presented in multiple international meetings. These studies will be followed by a second round of surveys to evaluate the impact of small scale irrigation at the household level at the beginning of year 4 (and year 5 for Ghana). Surveys in selected households in Ethiopia will be expanded through a collaboration with SIPSIN, a companion project also funded by USAID via SIIL.

Analysis: Ex ante (before field research) studies of the impact of alternative SSI technologies were completed in the first quarter of year three for the regions of all three countries where field research and household surveys are being done. National summaries have been completed for all three countries. These studies provide a quantitative and stochastic estimate of the consequences of introduction of a variety of small scale irrigation interventions. A first set of field survey and observational analyses of the impact of SSI based on emerging field and survey data have been completed. These include a draft paper on the linkages

between small-scale irrigation and nutrition and a draft paper linking small-scale irrigation with gender with a focus on Ethiopia and Tanzania. A third draft paper describes the analysis and results from gendered Focus Group Discussions. The integrated decision support system (IDSS) is being used to assess the consequences of small scale irrigation interventions on production, environmental and economic outcomes. Initial model results have forecasted the availability of water and other natural resource inputs for citing small scale irrigation studies.

Capacity Building: Capacity building was conducted at multiple levels of scale in all countries. At the farm-village level, farmers and those directly involved in the farming system enterprise were provided training that was linked to the ongoing field studies. Special training was provided where experience was lacking in areas such as microfinance and maintenance of irrigation equipment. Ongoing stakeholder engagement at regional and national levels informed audiences at larger levels of scale. Training on the use of the Integrated Decision Support System (IDSS) was provided to large groups of college and graduate students and related faculty along with some government/private sector interests and tracking of their subsequent application of the methodology is being conducted. A key element of capacity building was the involvement of students as primary points of contact with farmers where experience in conducting field research was accompanied by the use of data from ongoing studies as inputs to theses where specific aspects of the ongoing field research was expanded and embellished.

Collaboration with other FtF and related Programs: In Ethiopia, there is active collaboration with Africa RISING (AR) at several sites involving field studies and plans for applying the IDSS to AR results. ILSSI partners and the FtF Nutrition Innovation Laboratory, along with Bahir Dar University in Ethiopia were awarded a contract by the FtF Sustainable Intensification Laboratory to study the impact of sustainably intensified production systems on household nutrition. As part of this collaboration, ILSSI is also collaborating with the SIIL Appropriately Scale Mechanization Consortium (ASMC). A pilot study was initiated with the FtF Horticulture Innovation Laboratory to apply the IDSS to the analysis of results of farm level studies in Uganda. ILSSI is collaborating with the ILRI's Canadian funded study on Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) in the application of the IDSS to field and survey results. Initial discussions are underway with the FtF Soybean Innovation Lab for collaboration to evaluate the IDSS in assessing the impact of their genetic research in Ghana.

Mission Engagements: Meeting with staff of the Ghana Mission in February 2016 resulted in follow up to determine if ILSSI or its partner IWMI could assist/advise on irrigation for dry season production of seed – IWMI has an ongoing effort for the Mission and will continue to support this need. The Ethiopia Mission has an active program as part of their Productive Safety Net Program (PNSP) that involves evaluating several techniques for control soil erosion. To evaluate the possibility of improving the assessment methods, a preliminary pilot study was done to compare SWAT as an analytic tool to the currently used universal soil loss equation. Results suggested SWAT would provide more detailed and dynamic assessment of these options. Mission staff are investigating the actions needed to further evaluate and incorporate the SWAT method into their ongoing program.

External Advisory Committee: ILSSI's External Advisory Committee met jointly with its Program Management Committee in Accra, Ghana in February 2016. Status reports and plans for ongoing ILSSI projects were presented and discussed and faculty from the University of Development Studies in Tamale briefed the committee on field studies underway in that region of Ghana. The committee provided

substantive feedback and advice on current and future programs and committed themselves to active participation in the upcoming preparations for the USAID External Review.

Engagement with stakeholders and partners: External Stakeholder Meetings on Constraints and Gaps to Application of Small Scale Irrigation were held in all three countries. Following up with previous stakeholder engagements, meetings were held in the period June-July 2016 to present the results of field, survey, and analysis studies to invited stakeholders. Participants provided a prioritized list of constraints to application of SSI methods in their countries. Analysis of the impact of these constraints and possible mitigations was initiated using the Integrated Decision Support System. Reports of stakeholder engagements are available on the ILSSI website. ILSSI also held meetings with key institutions in each country to share preliminary results, e.g. the Savannah Accelerated Development Authority and the Irrigation Development Authority in Ghana, the Agricultural Transformation Agency in Ethiopia and the National Irrigation Commission in Tanzania.

Mid Term Report: Concurrently with the preparation of this report, ILSSI continued to develop background papers and concept notes that will be referenced in its mid-term report which will be provided to USAID in December 2016. This will be a brief but comprehensive report with multiple references to research results and other analyses pertinent to the assessment of the use of small scale irrigation in the three countries where ILSSI is working. Initial preparations for this report began with an all partners meeting at Texas A&M in December 2015 and continued during the program management committee meeting in February. The mid-term report is intended to be the principle input provided to USAID for informing the External Review of ILSSI early in 2017.

Outreach Events: In year 3, ILSSI focused significant resources on outreach. This included presentations at various USAID, national, regional and international venues to ensure that early findings are communicated to large audiences and that feedback on these early findings can be incorporated into final research results. Selected events included:

- Panel on "Agricultural Water Management" at the Dupont Summit, in Washington, DC, Dec 2015.
- Panel on “Opportunities and Challenges of Expanding Smallholder Irrigation in Sub-Saharan Africa” at Nebraska Water for Food Conference, April 2016.
- Panel on irrigation and gender at Africa Water Week, Tanzania, July 2016.
- Sessions at Stockholm World Water Week on "Enabling investment in irrigation in sub-Saharan Africa" and Session at Stockholm World Water Week on "Beyond the Drinking Glass: Expanding our Understanding of Water-Nutrition Linkages", Aug/Sep 2016.
- Professional presentations at American Agricultural Economics Association Annual Conference in Boston, July 2016.
- Seminar at USAID headquarters, October 2015.
- Panel on water at USAID's Global Learning and Evidence Exchange (GLEE) on Climate-Smart Agriculture in Lusaka, Zambia, March 2016.

Other activities included the writing of blogs, such as on gender and small-scale irrigation, on micro-finance and on The Goldilocks Dilemma of Balancing Irrigation Technologies, Policies and Institutions.

IV. Small Scale Irrigation Interventions

Interventions selected and used in these "research for development" studies involve active planning and selection by stakeholders down to the farm level. Farmers wishing to participate in the studies are given options from which they select the actual intervention used. Farmers receive training on the use of the system and advice on other parts of their farming system such as crop varieties to use in making best use of irrigation. ILSSI does not purchase pesticides or fertilizer as part of these studies but advises farmers on safety and environmental concerns where they are used. Both farmers and national partners, usually graduate students from national universities are trained in collection of data and ongoing engagement is maintained throughout the growing season. The following are illustrations of the interventions currently being evaluated in the three countries.

Ethiopia

Interventions

- **Manual/motorized water-lifting devices:** pulley, R&W pump, diesel pump, solar pump
- **Irrigation management:** CWR. WFD
- **Crops:** vegetables, fruit trees, fodder species
- **Groundwater recharge improvement**
- **Credit access:** revolving fund

Implementation in Year 3 developed further upon Year 2 activities with some modifications based on field-level learning of farmers. In year 3, farmers showed preference for selected lifting technologies over others in some sites. Ethiopia began with trying to meet farmers' preferences which saw some technology transfers between sites. Specifically, Robit farmers preferred pulley/tank system to Rope & Washer (R&W) pumps, thus they gave up all the R&W pumps for pulley/tanks systems. These R&W pumps were transferred to Dangishta, where new farmers were selected to take these pumps. The farmers in the various sites agreed to grow crops indicated in the table below. To assist the farmers, field books were adjusted, made simpler to fill and also shorter from the ones that were used in the previous year.

Year 3 also saw exchange of information on SSI technologies between farmers as Robit farmers visited Dangishta to share experiences. The Robit farmers were surprised to see that the R & W were preferred in Dangishta and working well. (The water levels in the wells in Dangishta are shallower, thus less effort is needed to lift water as compared to the deeper wells in Robit.) Farmers trained at the start of the previous year succeeded in helping other farmers with repair services. This suggests that farmers can be successfully trained to provide services in remote for repairs and installation services.

Demonstration of a pulley system to new irrigators

In addition, measuring/monitoring equipment was installed in the various sites to gather data on crop performance. At the end of Year 2, the number of farmers changed: 5 farmers dropped out and 11 new households requested to join the project. The new irrigators tended to be youth farmers that were able to acquire 'test' plots for the irrigation of tomato in Year 3. While this suggests that potential interest of youth to adopt SSI where success is demonstrated, the change in farmers further complicated data collection and analysis across households. During the farmer-to-farmer field visits, the Dangishta farmers were especially impressed with the commitment of Robit

youth in the project who acquired land from their parents to begin producing irrigated tomato. This further suggests the potential for diffusion of technology and adoption by youth where exposed to SSI technology and provided support and land access.

Farmers trained on the use of WFDs

Research on the Wetting Front Detector (WFD), a simple and inexpensive method to estimate soil moisture at the root zone of the plant, in Dangashita continued, with results showing that farmers doubled yields with an on-field water use increased by 30 %. The research results suggested that farmers had tended to under-irrigate due to labor constraints and low capacity for lifting water. However, the TDR and the WFD showed farmers the need to increased water consumption. At the same time, the work on partial nutrient balances in relation to irrigation in Robit showed need to adjust fertilizer application; when scheduling advice is given, higher yields lead to higher nutrient removals.

In the Southern Lemo site, through the on-going collaboration with Africa RISING (AR), solar pumps and tractor mounted water delivery were added to the variety of water lifting technologies being tested and adapted. In addition, unlike previous years, farmers paid for their own inputs (seeds and fertilizer) in 3 out of the 4 sites (Lemo being the exception).

Support and mentoring for students continued in Ethiopia to strengthen capacity in field research on small scale irrigation. New students were selected to undertake research activities for this season in Robit and Dangishta, as the ones for last year had completed their studies. PhD students are ongoing (see annex for updated list of students across sites).

Table 1: Intervention sites and interventions for households

Technology	No. of target households being monitored in year 3 dry season				No. of target households in original research design			
	Robit	Dangishita	Bochesa	Upper-Gana	Robit	Dangishita	Bochesa	Upper-Gana
Rope and Washer	0	22	1	11	13	12	6	11
Pulley	24	11	0	0	9	12	0	1
Drip	0	0	0	3	0	0	0	0
Solar pump	0	0	0	3	0	0	0	2
Diesel pump	0	0	12		0	0	20	0

Crops	Tomato (1st dry season Year 3) Green pepper (2nd dry season Year 3)	Onion (1st dry season Year 3) Green pepper (2nd dry season Year 3)	Mix of cabbage, tomato, onion, green bean, maize, etc.	Avocado, fodder, carrot, cabbage (only one season in Year 3)	Tomato	Onion	Tomato	Avocado, fodder,

Ghana

Interventions

- **Water source:** shallow wells, rooftop water-harvesting
- **Water-lifting devices:** motorized pumps
- **Irrigation management:** WFD, farmer practice
- **Crops:** vegetables (onion, tomato), fodder species (e.g., pigeon pea)
- **Credit access:** revolving fund

In year 3 the dry season irrigation technologies including pumps, drip kits and tanks and hoses were installed in all the research sites for onion, tomato and corchrus production. All measurement equipment has been installed and farmer field books distributed for continuous data collection. In addition wetting front detectors (WFDs) for irrigation scheduling were installed in January 2016, but farmers have faced difficulty in understanding how to use the WFDs. IWMI and UDS provided training on "packages" that combined agricultural water management technologies and practices with agronomy, as well as book-keeping and business planning; the combination of practices is expected to contribute to returns on investment for farmers and therefore increased and sustained adoption. Based on discussion between farmers and UDS/IWMI researchers, a key lesson for the next year is that planting will begin immediately after the harvest of rainy season crops to take advantage of residual moisture, particular as water harvested in tanks was inadequate for the dry season.

Motorized pump and shallow well

Also in Year 3, it was found that farmers planted late into the dry season, because of challenges with access to suitable land and other inputs. They continued to lack resources for fertilizer and in some interventions for fuel (for pumps). Extreme weather events (storms and flooding) and limited water availability in the dry season (shallow wells dry a few weeks into the dry season) also affected productivity. Late harvest contributed to lower prices for produce in some cases. Farmers also reported issues with some of the technologies, e.g. low quality of water hoses and low pressure from tanks.

Male and female farmers both prioritized motorized pumps because it reduces labor time and physical effort required. A few farmers stated that they found the UDS drip system (locally sourced and assembled) more robust and easier to use than the other system. Regardless of challenges experienced in the first full dry season under the project interventions, all the farmers committed to continuing with the project another year. Nearly all farmers (90%) said that their knowledge on irrigation has increased and that they will plan for earlier planting in the upcoming dry season; many aim to extend their plot size under irrigated farming. In one site where farmers took technologies on credit but did not experience extreme and damaging weather events, the farmers have begun making a set payments against the debt with each basket of produce sold. In another site, farmers said that they have hired labor in the area, such that the project has provided some wage labor locally.

In addition to direct engagement with farmers, the project continued to work closely with the local Ministry of Food and Agriculture (MoFA) officers. IWMI and UDS (national partner) also engaged at policy and planning level with the Savannah Accelerated Development Authority and met with the Ghana Irrigation Development Authority.

Data related to profitability across the technologies was collected from intervention sites, as well as data related to: knowledge and preference of agricultural water management interventions; constraints to dry season farming; farmers perceptions on farming as a business and record keeping; dry season vegetable production (agronomy & conservation); and marketing of produce. A first year of data was collected from market prices to analyze the trend of prices of dry season produce in four market centers in the Northern Region (Tamale and Gushegu) and the Upper East Region (Bolgatanga and Navrongo), as farmers often face periods of glut and low prices at certain points in the dry season.

Zanlerigu Project Site: Farmers using shallow wells

Technology	**Treatment Group**	**No. of farmers**	**Control Group**	**No. of farmers**
Type of irrigation system	1. Overhead irrigation with tank and hose + irrigation scheduling tool (4 farmers) 2. Overhead irrigation with tank and hose without irrigation scheduling tool (4 farmers)	4 4	1. Watering can + Irrigation scheduling tool (4 farmers) 2.Watering can without irrigation scheduling tool (4 farmers)	4 4
Total		**8**		**8**
Items free of charge	8 Water tanks (one for each farmer)		2 watering cans to each farmer (motivation)	

Items on loan or credit	2 water pumps on loan to each group of 4 farmers		-	
Selected crops	Onions		Onions	

Zanlerigu Home Gardens

Technology	**Treatment Group**	**No. of famers**	**Control Group**	**No. of farmers**
Type of irrigation system	1.UDS drip irrigation system (2 farmers) 2. Bucket-drip (iDE) irrigation (2 farmers)	2 2	Tank with water hose	1 -
Total		**4**		**1**
Items free of charge	Irrigation kits		2 watering cans and water hose (motivation)	
Items on loan	4 Water tanks		1 Water tank	
Selected crops	Local leafy vegetable: Cow pea or black-eyed pea		Local leafy vegetable: Cow pea or black-eyed pea	

Tanzania

Interventions

- **Water-lifting devices:** motorized pumps
- **Irrigation management:** farmer practice, drip and AWD (rice)
- **Crops:** vegetables and rice
- **Credit access:** revolving fund

In year 3 IWMI and national partner Sokoine University of Agriculture (SUA) began field interventions and collaborated to develop a context appropriate data template. Trainings were held for farmers on field interventions. Initial results from pocket gardens suggest some promise for profitability for the women farmers engaged in the project. Additional equipment for biophysical data collection was installed to ensure more consistent data collection at watershed level in the last two years of the project. IWMI increased the level of engagement with SUA toward ensuring the field interventions would be implemented as planned and required data collected; historical data has yet to be compiled. Given the high number of projects on related agricultural subjects being undertaken by SUA and development partners, graduate students were not available for data collection and this had

caused delays. As an alternative, the project has engaged and trained BSc level students for data collection in the field.

Preparation of beds for a drip furrow system

SUA conducted a preliminary economic study on the 5 pump groups in the 2 sites Mkindo and Rudewa on the profitability of motor pump irrigation for just one crop season during the dry season. Each pump group has 7 or 8 members and each pump group is assumed to irrigating 4 acres in total. The analysis showed that the preferred crops for irrigation including African eggplant, maize and tomato would be profitable per group with the African eggplant giving a profit of 1.7 million Tshs, maize about 340,000 Tshs, and tomato giving a profit of about 4.6 million Tshs. This kind of analysis will be done for each irrigation season for all the groups, and will also include revenue that will be generated from renting the motor pump among both members and non-members of the group as some of the groups have suggested doing.

SUA team purchased six motor pumps in December 2015 and distributed five pumps to two groups in Mkindo and three groups in Rudewa. Pumps were provided to farmers' groups on credit basis loans, and farmers are expected to pay back, thus contributing to the study on willingness and ability to pay loans for irrigation technology by farmers. SUA team trained farmers on data collection and record keeping. Notebooks for recording data and information were distributed to individual farmers and farmer groups. The following were the type of data that farmers were trained to collect: Irrigation water: Record start and finish time (duration of irrigation), date of irrigation, and crop type; Cost-benefit analysis: Production costs - Amount of fuel used, purchase price, labor, amount and price of inputs (seeds, fertilizer and herbicides), and dates. If farm rented (if any) and rent duration; Income: Crop sold, amount and price, crop type, date; Nutrition impact: Vegetables being sold within the village; Shared motor pumps: Records: Group members, borrowing, borrowing duration, renting, payments, crops grown by each member, field sizes, preferred schedules, minutes of meetings, records of the group bank account or other financial record; Loan payment: agreement between project and group on mode of payment, deposits records, challenges.

Transplanting in Mkindo Village

Also in year 3, tomato seedbeds for seedlings were prepared in mid-December 2015 and transplanting was expected to be done mid-January 2016. The seedlings were stolen just before transplanting. Another seedbed was prepared immediately. This time seedlings were affected by bacteria spot disease and only 6% of the seedlings survived. The seedlings were given to the youth group instead of starting the experiments. The youth group attempting irrigated tomato repeatedly suffered losses due to pests, so planted water melon that was harvested beginning of August 2016.

SUA is recording economic information on one youth group that grew tomatoes using the pump. The group is now selling vegetables and individual members have managed to grow eggplants they are now

harvesting and selling. Analysis will be done at the end of the season. IWMI provided four additional pressure based flowmeters in February 2016, which have since been installed by SUA.

SUA started a pocket garden project at Rudewa village under ILSSI, toward understanding nutrition and gender under the project. Training was conducted between February 15 – 19, 2016 to 10 women farmers, one ward agricultural extension agent and three field practical students from CANRE College. The training was conducted with a champion farmer, Ms. Walter, from Mwembe Village in Same District. SUA also plans another training in Mkindo Village.

Of the pocket gardens in Rudewa, three farmers have been selected to grow the same vegetable and seedling rate in a conventional plot for comparison purposes on irrigation amount, water use efficiency and productivity.

In Mkindo the project has been expanded and trainings were given from 30th of August till 2nd of September 2016. Similar experiments are carried out with 10 female farmers testing out the pocket gardens from which 3 farmers will additionally use conventional plots for comparison purposes.

Kitchen garden training at Mkindo village

To assist with project implementation in the field SUA recruited a research assistant in July 2016. SUA also works with village extension agents additionally, in Mkindo a new research assistant was hired (August 2016). SUA also works with village extension agents (one in Rudewa village and two in Mkindo village). While the project benefits from the consistent engagement from extension, and also increases likelihood of impact and diffusion of knowledge, IWMI is also working with SUA to reduce negative impact on the project of frequent turnover in SUA research assistant staff.

Emerging Results

Emerging results suggest cases of over-irrigation or under-irrigation in some SSI sites, calling for more effective irrigation scheduling techniques in SSI. Constraints to SSI development relate to investment and operational costs, labor requirements and lack of capacity in managing micro-irrigation systems. Some crops show potential for higher profitability, including local leafy greens that are not commonly irrigated. In addition, trend analysis suggests large fluctuations in dry season prices, and the need for farmers to plant and harvest early in the dry season to benefit from higher prices. Gender issues appear to affect labor roles in irrigation management and access to land and water thereby impacting on who takes a leading role in irrigated farming between men, women and youth.

V. Fodder Livestock Systems

Small scale irrigation is used in farmer's fields where several annual and perennial varieties of fodder are being evaluated in for on-farm use in livestock and for sale as cash crop with income enhancing family nutrition. Studies are moving towards a market chain approach with concurrent evaluation of sources of inputs and markets for fodder.

Ethiopia

This is the field of Desho grass is irrigated by the rope and washer system.

In Ethiopia, 24 and 26 new farmers' new farmers were selected in Angacha and Lemo woreda, respectively. In Angacha interventions centered on intercropping of forage grass options such as Napier and Desho with food-feed legumes such as pigeon pea and desmodium to: 1) increase overall biomass productivity per unit area, 2) increase overall biomass quality through protein richer legume biomass; and 3) improve soil fertility though nitrogen fixation. In Lemo interventions focused on intercropping of oats and vetches, as in the previous reporting period i.e. no new crop and/or forage combinations were tried, but new management options were investigated in that half of the participating farmers will use oat-vetch mixtures as multi cut forages. Previously oat-vetch mixes were cut only once which had several disadvantages. First biomass yield was limited. Second, all biomass was produced at once resulting in need of preservation. Third, the time window for using the biomass either as home produced feed or as a cash crop was short. |Multi cut management of oats and vetch increased biomass yield relative to one cut management by more than twofold. In Robit Bata Napier grass was planted by 12 new farmers on about a quarter of a ha. A total of 21 farmers (9 new and 12 farmer previously participating) intercropped Napier with Desmodium (7 farmer), Sesbania (7 farmer) and pigeon pea (9 farmer).

Forage biomass yield data were taken and samples were sent to the ILRI laboratory in Addis Ababa for livestock nutritional analysis. Forage biomass yield and fodder quality data were used to calculate meat and milk yields obtained from the different forage treatments. It became clear that benefits from planting forages under irrigation will depend are on the genetic potential of the livestock. For example preliminary modeling suggests that low yielding local dairy cattle will convert oats and vetch mixture harvested from 100 m^2 into substantially less milk than cattle capable of yielding 12 kg of milk daily.

	Total milk produced if cows give daily			
	3 kg/d	6 kg/d	9 kg/d	12 kg/d
Milk produced from 187 kg of oats-vetch mix harvested from 100 m^2 in dependency of dairy productivity	75	118	146	166

Farm gate price for milk is about 11 – 13 Birr per kg and above milk sales would amount to a cross milk sale income per ha of about 90 000 (3 kg/d) to 199 200 (12 kg/d). While these are rough and very simplified estimates at this point in time they strongly suggest that irrigated forages can be economically competitive and attractive relative to other crops. However at the same time our fodder markets surveys suggest that the oats-vetch harvest from 1 ha sold at the fodder market near project sites would be worth at least 110 000 Birr. Thus using oats-vetch mix as cash crop would be more rewarding than feeding it to low producing livestock on farm, even without considering the multiple implication of dairy husbandry on family and other labor requirements. These relationships are currently investigated in detail.

Ghana

In Ghana, following the rainfed production of 4 forage species *Sorghum almum*, *Brachiaria ruziziensis*, *Lablab purpureus* and *Cajanus cajan* by 12 farmers in Bihinayili, farmers pooled the fodder produced to fattening ten young rams for about 2 months with average initial weight of 14.11±3.50 kg. The fodder produced was offered ad libitum. Average final weight of the fattened rams was 15.64±2.82 kg. According to the farmers, *Cajanus cajan* and lablab (the legumes) were the most preferred by rams while *Sorghum almum* was preferred to Brachiaria. It took a day or two for the rams to get accustomed to Brachiaria. No data was collected on the sales price of the rams as the animals were not sold immediately after the feed trial. The weight gains in the rams on planted forages were not superior to weight gains observed on traditional grazing system probably because the trial was conducted before the dry season (feeds scarcity). Fattening with irrigated fodder during the dry season could be profitable. From farmers' visual appraisal, *Brachiaria* and *Sorghum* regenerated well after several cutting regime and during the dry season where there enough moistures. Post-harvest maintenance of fodder on fields was challenging because livestock tethered during cropping season were released for grazing after general harvest and destroyed planted fodder. Fencing using local materials was an option. Survey on market potential for irrigated fodder in Northern Ghana is underway.

Tanzania

In Tanzania, based on feed assessment studies (FEAST) potential feed and forages options in irrigated areas of Kilosa (Rudewa village), and Mvomero (Mkindo village) in Morogoro region and also in Babati district (Gichameda and Mawemairo villages) of Manyara region were assessed. These assessments were followed up with feedback meetings with farmers. While feed resources in form of natural pastures were abundant

in the wet season there were severe pasture shortages in the dry season. This is mainly due to due to insufficient feed conservation, storage, processing and utilization of livestock feeds. Consequently the following activities were conducted between October 2015 and March 2016 in four selected villages of Morogoro and Manyara regions by the project team. After lengthy discussion the project team and farms agreed on testing interventions on improved planted forages and enhanced use of crop residues. A total of 15 farmers were selected who volunteered their land for establishing irrigated fodder and kept improved dairy cattle. Planting of forages is currently ongoing.

Participatory Agronomic Forage Evaluation was conducted on eight farms under different irrigation systems in Mvomero, Kilosa and Babati districts. Irrigation using water pumps, flowing water and bucket irrigation was employed. Five Napier grass accessions, KK1; KK2; ILRI cvs 16835; 16837 and Ouma were planted. These varieties were supplied by the Kenya Agricultural Livestock Research Organization (KALRO) Muguga. The Buffel grass (*Cenchrus ciliaris*, Rhodes grass (*Chloris gayana*) were also planted.

Mr. and Mrs. Jonas standing in their forage plot in Mawemairo village

The legumes included *Lablap perpureum*, Glycine and Siratro and were all supplied by TALIRI Mabuki, Tanzania. Forage biomass and other agronomic characteristics were collected. Forages are also being screened for nutritional quality.

VI. Commercial Vegetable Home Gardens

Ethiopia

Surveying garden: mixed cropping (onion and maize) at Dangishita

In year 3, Thirteen women from both Robit Bahita (6 households) and Dangishita (7 households) areas were selected for two sets of management practices (drip irrigation with conservation agriculture and much tillage and vs. drip irrigation with no mulch and traditional tillage). Traditional system is defined as the current practice that female households currently use to manage vegetable production in the area. The project provided drip system tanker in the 1st year and seed input for the two years. Fertilizer application was the farmers' responsibility. Farmer's accessed water for the garden from the hand dug shallow wells. The water was lifted by a new lifter technology de veloped by Bahir Dar University in Dangishta except few farmers and Robit farmers use an old pulley system except one household. The first feedback from the farmers about the new pulley was very good but after using it for the whole irrigation period; they are telling us that the old pulley is better in terms of energy requirement and long durability of the bucket.

Garlic (in Dangishita) and Tomato (in Robit) were the two main vegetables cultivated during the first irrigation (October to February) period. From February 2016 to June 2016, women planted onions in the Dangishita and the Robit planted garlic. During the rainy period (June 2016 to October 2016), farmers planted grains (corn) and

vegetables (pepper) in both watersheds. Corn planted at Dangishta in one of the farmer plot during the rainy period. There is a clear difference on height of the corn between non-conservation plot (NCA) and conservation plot (CA).

Tanzania

In year 3, 15 female farmers participated in the project, with 70% of them expressing interest in expanding their plots to produce a variety of vegetables for diverse range of consumers. Field preparations, bed making, drip lateral setting and mulches incorporation were conducted during June of 2016 (this year) on both conservation agriculture and traditional tillage systems. Preparation of field required many activities including distribution of irrigation water to both treatment farms, rising of the bed level to avoid flooding, fencing of the plots to avoid the chicken attach/distractions, incorporation of the animal manure, maintenance of any leakages of the drip system, and replacement of any breakdown on the drip system.

Supervising farmers during beds preparations

Since August, farmers have begun to enjoy the yield and as of September some farmers have started to do nursery preparations for another round of crop cycle due to the fact that the previous crop are at the kill stage.

Ghana

The project was implemented in three different communities as a result of challenges encountered in the first two. Implementation in the first location (Nyangua) was halted after farmers became reluctant to adopt drip irrigation technology. Their fear was based on their experience with testing treadle pumps, which was not successful for them. The second location was flooded by unusual rainfall, so project activities had to be relocated even though the trial in the second location (Azum Sapelliga) was advanced and cucumber was harvested from the plots. The third location, Yemu, has access to year-round farmland and water, with plots not prone to waterlogging or flooding, and is located within 35 minutes of drive from iDE's office in Tamale, Northern Region, and Ghana.

Farmer weeding sweet potato plot

During the long dry season, women of Yemu community engage in cultivation of leafy vegetables for both domestic use and revenue generation. Production traditionally is over a shorter period of up to four months of the nine-month, long dry season. They are thus restricted in terms of the availability of fresh vegetables and their ability to bring in revenue over the entire long dry season. This results in little revenue compared to the amount of effort put in cultivation. Under this context, this project is timely and relieving for the community members, as it seeks to reduce drudgery for women. It also is offering women the opportunity to diversify their production to reduce risk through the cultivation of high-value vegetables.

To ensure commitment to achieving this impact, an initial community meeting with women and other stakeholders (elders) was held to explain the purpose of the research and also to discuss roles and responsibilities expected of each party. The outcome of this was a block of farms allocated to the female

farmers by community members to ensure they are close to each other and have the opportunity to support and learn from each other.

In the third project location of Yemu, fifteen plots of 100 m^2 each was put under cultivation. A 100 m^2 drip kit was laid out on each plot. Three crops identified by the female farmers were cultivated. A group of five farmers represented a treatment, resulting in three treatments total. The fields will be cultivated year round with three replications. Throughout this process, the iDE team will observe the farmers and collected activity-level data on a daily basis. Below is the list of farmers in Yemu location with crops under cultivation.

VII. Household Surveys

In year 3, fieldwork on the household level baseline survey and the gender disaggregated survey was completed in Ghana. The baseline survey included direct ILSSI beneficiaries (120 farmers), as well as additional farmers in nine villages of the Upper East region (800 farmers). The University of Development Studies in Ghana served as the survey implementer. Leveraging additional funding from the CGIAR Research Program on Water, Land, and Ecosystems (WLE), IFPRI managed to cooperate with iDE-Ghana in the Upper East region of Ghana to (i) increase the sample size of the baseline survey to 920, which is more than double the sample size in Ethiopia and Tanzania, and (ii) to do a randomized control trial to explore the impact of irrigation on agricultural productivity, nutrition, health and women's empowerment in Northern Ghana. In mid-December Dawit Mekonnen travelled a second time to Ghana to help ensure successful completion of data collection. IFPRI has finalized cleaning of the data collected from Ghana.

IFPRI has finalized the following early draft papers: "Irrigation's Potential to Address Food and Nutrition Security in Sub-Saharan Africa: Evidence from Ethiopia" was presented by Simone Passarelli at the annual IFPRI Research Day in Washington D.C. in March 2016. A second draft paper was presented in a session with Africa Rising and USDA Economic Research Service (ERS) at the 2016 Agricultural and Applied Economics Association (AAEA) Annual Meeting in Boston, MA, in July 2016 under the theme "Food and Nutrition Issues in Sub-Saharan Africa." Final draft papers include linkages between small-scale irrigation and nutrition and a draft paper linking small-scale irrigation with gender with a focus on Ethiopia and Tanzania. A third draft paper describes the analysis and results from gendered Focus Group Discussions.

VIII. Ex Ante Analysis of Small Scale Interventions in Ethiopia, Tanzania and Ghana

In December 2015 and January 2016, TAMAR completed ex ante analyses of the benefits, environmental effects, and economic viability of selected SSI interventions in Tanzania and Ghana, using the IDSS. In preparing the analyses, information about each site's natural resources, existing cropping systems, farm family characteristics, and market conditions for agricultural products were obtained from a number of international, national, and local sources (discussed in greater detail below). These data were then used as inputs to the IDSS, which consists of: the Soil and Water Assessment Tool (SWAT), a watershed-scale, hydrologic and water quality model; the Agricultural Policy/Environment eXtender (APEX), a farm-scale agricultural systems model; and the farm-scale economic and nutritional model (FARMSIM). Parameterization, calibration, and execution of SWAT, APEX, and FARMSIM were closely coordinated, with input and output data exchanged in an integrated fashion to assure comparability of production, environmental, and economic results. In September 2016, TAMAR completed ex ante analyses of proposed

SSI interventions at select LIVES sites in Ethiopia. A detailed discussion of TAMAR's ex ante analyses of sites in Ethiopia, Tanzania and Ghana follows.

Additionally, due to the ongoing success of the ILSSI project, a project was funded through SIPSIN to evaluate the sustainability of agriculture, improve nutrition, and improve agricultural production and farm-family economics. All of the information generated through the ILSSI project and additional field and survey results will be used to inform the SIPSIN project; likewise, going forward we will be able to leverage resources from the SIPSIN project to strengthen the ILSSI studies and to maximize the overall outcomes of both projects.

Ethiopia

TAMAR completed ex ante analyses of selected SSI interventions at ILSSI sites in Ethiopia in the final quarter of year two.

In 2015, ILSSI and LIVES entered into a memorandum of understanding in which ILSSI committed to complete ex ante analyses of five LIVES sites in Ethiopia. It was later determined that only three of these five sites (Dembiya, Mecha, and Meki) would be analyzed using IDSS, due to a lack of biophysical data. ILSSI will also provide LIVES with a complete report of its ex post analysis of Robit, which is one of the LIVES sites in the Lake Tana region (though it was not listed in or covered by the memorandum of understanding between the parties).

During the fourth quarter of year three, TAMAR completed its analysis of interventions at the Dembiya LIVES site, using the IDSS. Simulations indicated that Napier grass and fodder yields in Dembiya are limited by nitrogen and temperature stress, whereas alfalfa yield is limited by water stress and temperature stress. With improved fertilizer application, Napier grass and fodder yields could be optimized. The study also analyzed the farm-scale economic impacts of recommended fertilizer application on grain and vegetable crops, and irrigation of dry-season tomato and vetch crops using one of four alternative water-lifting technologies. Simulations showed that motor-pump irrigation of dry-season tomato and vetch crops generated the highest income and profits (despite high initial investment and capital costs), and that all of SSI scenarios outperformed the unirrigated baseline scenario. Notably, SSI and applied fertilizers did not improve nutrition levels, as the improvements in crop yields (with the exception of tomatoes) were relatively minor. TAMAR therefore proposed expanding the types of crops irrigated in the dry season to increase family nutrition and net cash income, but only if such crops can be irrigated without causing excessive soil erosion or reduction in environmental benefits. Further studies would focus on how the profits could increase if households shared a single pump for irrigation in the dry season, and on how diversifying the crops consumed (whether through the farming of additional crops or purchase) could impact nutrition.

IDSS analyses of the Mecha and Meki sites are slated for completion in year four.

Tanzania

During the first quarter of year three, TAMAR used the IDSS to complete ex ante analyses of SSI interventions proposed by ILSSI in three different districts in Tanzania: Mvomero and Kilosa districts, both in the Morogoro region; and Babati district in the Manyara region. In each of the three target sites, ILSSI

proposed implementing SSI, using diverted river water, to maximize cultivation of high-value vegetable and fodder crops in the dry season and productivity of the rice crop. A national report and reports on the results of the IDSS analyses of the Mvomero, Kilosa, and Babati sites are available.

Simulations indicated that there is ample water available for the proposed SSI interventions in Mvomero and Babati and that the proposed SSI interventions are sustainable and would not compromise the environmental health of their respective watersheds. In Kilosa, low flows were significantly affected by the withdrawal of irrigation water from rivers (though peak flows were not affected). This suggests that the proposed SSI interventions in Kilosa may not compromise the overall water balance significantly; however, ecosystems that depend on low flows may be affected, and some alternative, surface-water storage or groundwater extraction may be needed to supply human and livestock drinking water during periods of extreme low flows.

At all three of the target sites, suitable fields far from rivers receive less irrigation water than those close to rivers; accordingly, the proposed SSI interventions will require development of advanced surface water diversion and transfer technologies and/or wells to sufficiently irrigate fields located far from the rivers.

Simulations of flow, sediment, and crop yields at each of the sites showed that the application of additional fertilizer would increase crop yields substantially and, at the Mvomero and Babati sites, would also decrease the soil loss from erosion. The implementation of multiple cropping systems also affected simulated crop yields and sediment losses, though results varied from site to site. Simulations also showed SRI rice production would result in higher crop water productivity compared to traditional rain-fed rice. These results suggest that the SRI method of rice cultivation is preferable for the three ILSSI sites in Tanzania. Simulations also indicated the sensitivity of SRI rice yields to drying and wetting periods.

Economic analyses were conducted to estimate the effects of the proposed SSI interventions (in conjunction with the simulated, improved cropping systems) on farm family economics. Results of the economic analyses varied from site to site. In Mvomero, implementation of the SRI method of rice cultivation and multiple cropping of fertilized maize with irrigated vegetables only (not fodder) produced the highest net present value, net cash farm income, and ending cash reserves of the alternative scenarios simulated (including the baseline, non-irrigated scenarios). In Kilosa and Babati, cash income increased as the irrigated area increased. The most preferred scenario in terms of income generation was the one that allocated the largest area of irrigable cropland to vegetables, fodder and SRI rice.

Despite improvements in farm family economics resulting from the proposed SSI interventions, some nutritional deficiencies persisted under the improved cropping systems in each of the three sites. These results may be adjusted as new field data is received and informs ex post analyses of the study sites. TAMAR has proposed expanding the types of crops irrigated in the dry season to increase family nutrition and net cash farm income, but only if such crops can be irrigated without causing excessive soil erosion or reduction in environmental benefits. The relatively modest percentages of cropland in each of the three districts also limit the expansion of SSI and cultivation of additional crops at the target sites.

The IDSS analyses raised a number of issues to be resolved in future modeling and field research in Tanzania. These include the need to identify:

- the potential for shallow-groundwater irrigation in areas too distant from source for use of surface water;
- appropriate fertilizer amounts for more intensive cropping systems involving production of irrigated vegetable, fodder, and grain crops in the dry season; and
- appropriate management of fertilizer and harvest practices for irrigated fodder production.

The evaluation and comparison of alternative farming systems, including the types of crops grown, recommended management practices, and associated impacts on soil erosion and environmental benefits, are also subjects for proposed future simulation and field research in Tanzania.

Ghana

During the second quarter of year three, TAMAR used the IDSS to complete ex ante analyses of SSI interventions proposed by ILSSI at three different sites in the Republic of Ghana: the Bihinaayili watershed, located in the Savelugu-Nanton District in the Northern Region; the Dimbasinia (or Dambiasinia/Dimbasinia) watershed, located in the Kassena Nankana District in the Upper East Region; and the Zanlerigu watershed, located in the Nabdam District, also in the Upper East Region. At each of the three target sites, ILSSI proposed maximizing cultivation of high-value vegetable and fodder crops in the dry season by implementing SSI using irrigation water from either shallow groundwater or water-harvesting ponds, depending on the site. A national report and reports on the results of the IDSS analyses of the Bihinaayili, Dimbasinia, and Zanlerigu sites are available.

In the Bihinaayili watershed, water-harvesting ponds along the stream networks (used to collect and store overflow from the nearby Ligba dam) served as the proposed source of irrigation water. Simulations indicated that there would be ample water available in the watershed for the proposed SSI interventions; however, the proposed SSI interventions would reduce average monthly stream flow by 32.7%, reduce peak flows, and increase low flows. A decrease in peak flows (and a related reduction in sediment influxes) and an increase in low flows could have positive implications for upstream and downstream social and ecological systems; however, a decrease in average monthly stream flows could have negative impacts on downstream social-ecological systems. Moreover, the dugouts will be susceptible to siltation, and dredging sediment loads from the dugouts to the fields will be a challenging task. The exact upstream and downstream costs and benefits, both social and environmental, of the proposed SSI interventions in Bihinaayili, as well as potential methods of addressing sedimentation of dugouts, could be addressed in future research.

The proposed SSI interventions in the Dimbasinia and Zanlerigu watersheds relied on shallow groundwater as the source of irrigation water. There are large water resources potential in both watersheds; however, at both of these sites, the annual irrigation water requirements for cultivation of selected dry-season crops exceeded the average annual shallow groundwater recharge. Implementation of the proposed SSI interventions also caused modest reductions in the monthly stream flows in the two watersheds, and reductions in peak and low flows. Accordingly, in the Dimbasinia and Zanlerigu watersheds, TAMAR recommended combining irrigation from the shallow groundwater aquifers with irrigation from other water sources. For example, water-harvesting ponds such as those used in Bihinaayili could be used to store and capture surface runoff for SSI. TAMAR also recommended selecting water-efficient crops for dry-season cultivation in order to minimize reductions in stream flows. Analyses of potential dugout sites and

scale, likely costs and benefits of irrigating from dugouts, and recommendations as to specific water-efficient crops for cultivation, were beyond the scope of the study but could be addressed in future research.

Simulations of crop yields showed that the application of additional fertilizers would increase crop yields substantially at each of the three sites. The implementation of multiple-cropping systems also affected simulated crop yields at each of the three sites. At all three sites, multiple cropping of the rainy-season grain crops with fodder significantly increased simulated grain yields by increasing residual nitrogen, without adversely affecting fodder yields. At all three sites, multiple cropping of the rainy-season grain crops with tomato also increased simulated grain yields (although by lesser amounts), but significantly reduced tomato yields. In Bihinaayili, multiple cropping of soybean with dry-season crops did not significantly affect simulated yields of soybean or the dry-season crops. In Zanlerigu, high temperature stress was also a major factor limiting yields of certain crops. For example, the yield of pepper, planted as a rain-fed crop in the cooler season, was double that of irrigated, dry-season pepper. Planting temperature-sensitive crops (like pepper and oats) in the cooler season would therefore also optimize yields.

Plot-scale simulations of flow and sediment indicated that the proposed SSI interventions in Dimbasinia and Zanlerigu would not significantly affect runoff and sediment yields. In Bihinaayili, however, multiple cropping of sorghum (at both current and improved fertilization rates) with fodder and pepper increased sediment yields by between 20% and 26%.

Economic analyses were conducted to estimate the effects of the proposed SSI interventions (in conjunction with the simulated, improved cropping systems) on farm-family economics in communities in each of the three watersheds. In the Bihinaayili community, simulation results indicated that multiple cropping of dry-season crops with soybean was far more profitable than multiple-cropping of dry-season crops with maize. Similarly, in the Dimbasinia community, the scenarios that implemented multiple cropping of the dry-season crops with sorghum (rather than maize) were preferable. Multiple-cropping with maize and millet were found to be equally profitable in the Zanlerigu community.

The simulations also compared the costs and benefits of three alternative water-lifting technologies: pulley-and-bucket irrigation; diesel-pump (both rented and owned) irrigation; and solar-pump irrigation. At all three sites, the scenarios that implemented multiple cropping of the preferred rainy-season crop(s) with diesel- and solar-pump-irrigated dry-season crops produced by far the highest net present value, net cash farm income, and ending cash reserves of the scenarios simulated (including the non-irrigated and pulley-irrigated scenarios). Additionally, considering the lower maintenance and environmental costs of solar pumps, simulations at all three sites suggested that investments in solar water-lifting technologies would pay dividends in the long run.

Despite substantial improvements in farm family economics resulting from the proposed SSI interventions, at all three sites, the levels of certain nutrients remained at merely adequate levels, and a nutritional deficiency in iron persisted under the simulated, improved cropping system in Bihinaayili. These results may be adjusted as new field data is received and informs ex post analyses of the study sites. TAMAR has proposed expanding the types of irrigated, dry-season crops at all three sites to further increase family

nutrition and net cash income, but only if such crops could be irrigated without causing excessive soil erosion or reduction in environmental benefits.

As in Tanzania, TAMAR's analyses of the Ghana sites raised a number of issues to be resolved in future modeling and field research, including the need to identify:

- exact upstream and downstream costs and benefits (both social and environmental) of decreases in average stream flows and peak flows, as well as increases in low flows;
- potential methods of addressing sedimentation of water-harvesting ponds where utilized;
- the potential scale and locations, as well as the costs and benefits, of water-harvesting ponds or structures to supplement shallow-groundwater irrigation in Dimbasinia and Zanlerigu; and
- recommendations as to specific water-efficient crops for cultivation.

The evaluation and comparison of these and other issues, including the types of crops grown, recommended management practices, and associated impacts on soil erosion and environmental benefits, are subjects for proposed future simulation and field research.

IX. Identifying key constraints and opportunities to improve access to SSI

Analyses of constraints, gaps, mitigations. As noted in Section VIII above, the IDSS ex-ante analyses raised several issues (including knowledge gaps and constraints on irrigation at the study sites, to be resolved in future modeling and field research, and made suggestions as to possible ways of mitigating constraints on irrigation.

Ranked priority constraints in Ethiopia, Ghana, and Tanzania

Rank	Ethiopia	Ghana	Tanzania
1	Access to markets	Access to markets	Capacity development and irrigation expertise
2	Water availability and access	Water lifting technology access	Finance modalities and access to electricity, solar and wind
3	Access to appropriate SSI technology and knowledge	Climate change	Policy constraints and market access
4	Market access: Affordable and relevant inputs	Water availability and access	Climate change: water, temperature variability
5	Risks and vulnerabilities	Land issues	Competing water uses (with other sectors)
	Institutional issues	Diseases and Pests	Soil management and fertility
7		High labor cost for women	Cultural and social practices of stereotyping crops e.g. fodder vs rice perception
8		Access to knowledge and information services (capacity development)	Fodder technology is targeted to specific systems, either intensive or extensive system
9		Inadequate access to inputs and labor	Low genetic potential for livestock
10			Source of energy

Stakeholder meetings to prioritize constraints.

ILSSI, in collaboration with national experts and stakeholders, held a series of participatory stakeholder workshops in June and July 2016 to discuss the issues raised in the IDSS ex ante analyses. These workshops provided an opportunity for stakeholders' input based on their knowledge and experiences, and their institutional interests and priorities. Ultimately, the workshops produced a consensus-based, consolidated list of prioritized constraints specific to each country. The above table presents a consolidated list of these priority constraints for each country, listed in the order ranked by the workshop participants. Comprehensive reports on the stakeholder meetings in Ethiopia, Tanzania, and Ghana, detailing the workshop objectives, participants, proceedings, and conclusions, are available, as well as an integrated report.

The IDSS team has begun analyzing this prioritized list of constraints for Ethiopia, with the goal of producing context-specific proposals for mitigation of these constraints in year four.

IDSS constraints and mitigation analyses. In anticipation of the stakeholder workshops discussed above, the IDSS team also completed a gaps and constraints analysis of SSI systems in the Robit watershed in Ethiopia, with the goal of producing context-specific proposals for mitigation in year four. The table below summarizes proposed strategies for mitigating constraints on SSI interventions in the watershed, as detailed in the report. IDSS analyses of constraints and mitigations in Tanzania and Ghana will be initiated in year four.

Constraints	Possible Mitigating Strategies
Lack of adequate irrigation water at the field scale	Use water-harvesting structures to store locally-generated surface runoff
Adverse environmental effects at the watershed scale resulting from reductions in stream/peak flows	Combine shallow groundwater and harvested surface runoff
Low soil fertility, ineffective management practices	Apply fertilizers and irrigation at optimal rates
High soil erosion rates	Implement terracing; identify and implement alternative cropping systems to reduce erosion; use water harvesting structures to minimize runoff
High irrigation labor costs	Use family labor and less labor-intensive irrigation methods (e.g., drip irrigation)
Lack of experience with operation and troubleshooting of water-lifting technologies	Provide proper training for new users
Policy limitations (e.g., high import taxes on solar)	Advocate changes in policies

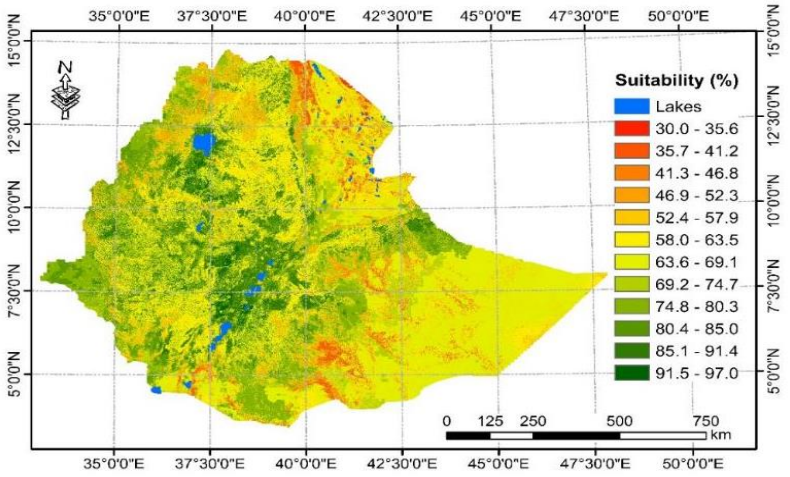
Possible mitigating strategies for priority constraints on SSI interventions in Robit

Key opportunities for small scale irrigation expansion

In year three, the ILSSI team began developing a model for upscaling of SSI. ILSSI's upscaling analyses will evaluate the potential for expanding SSI in the project countries, as well as the impacts of large-scale implementation of SSI on biophysical factors (e.g., crop yields), environmental sustainability, and economic

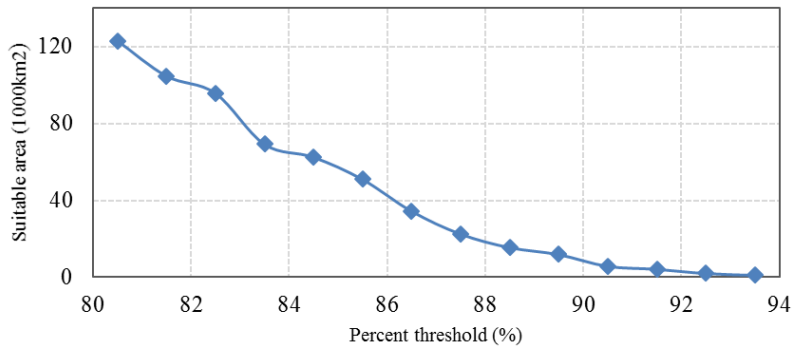
and family welfare in the project countries. A summary report on the methodology and progress of these analyses is available, and a more detailed report is near completion.

In Ethiopia, upscaling analysis is underway and slated for completion in year four of the ILSSI project. Data collection is almost complete, and the pre-suitability analysis for Ethiopia has been completed. Preliminary results of the pre-suitability analysis were presented at the 2016 International SWAT Conference in China as a poster. Slope and rainfall deficit were found to be the most important factors in assessing suitability for irrigation, followed by population density and soil characteristics. In the preliminary suitability map, below, values range from 30% to 97%, where 30% indicates the least suitable land and 97% the most suitable land.



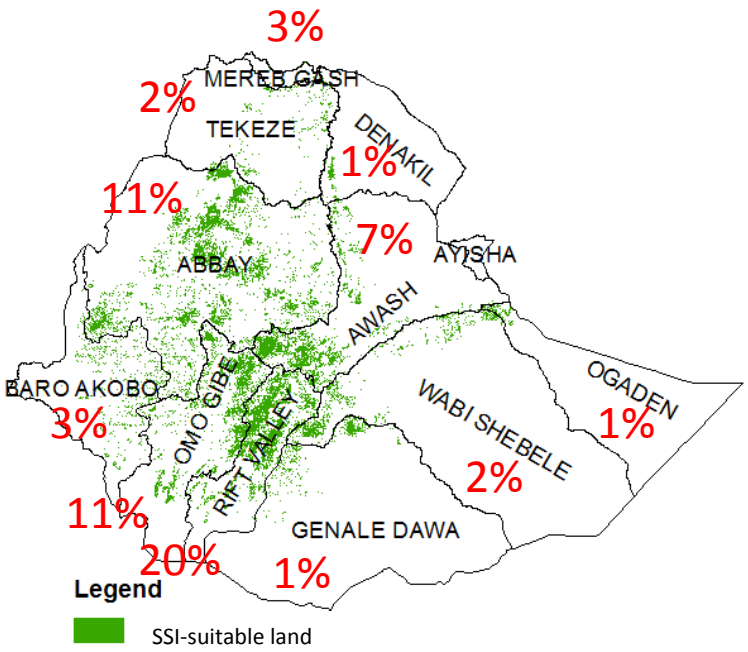
Preliminary suitable land for SSI

A constraint map with a value of zero and one was used to exclude unsuitable areas and to optimize with a user-defined threshold number. The chart below indicates the area of suitable land for a variable threshold number.



Irrigation-suitable land area at different suitability levels (60,000 km^2 is suitable for a threshold level of 85% and 96,000 km^2 is suitable for a threshold level of 82%)

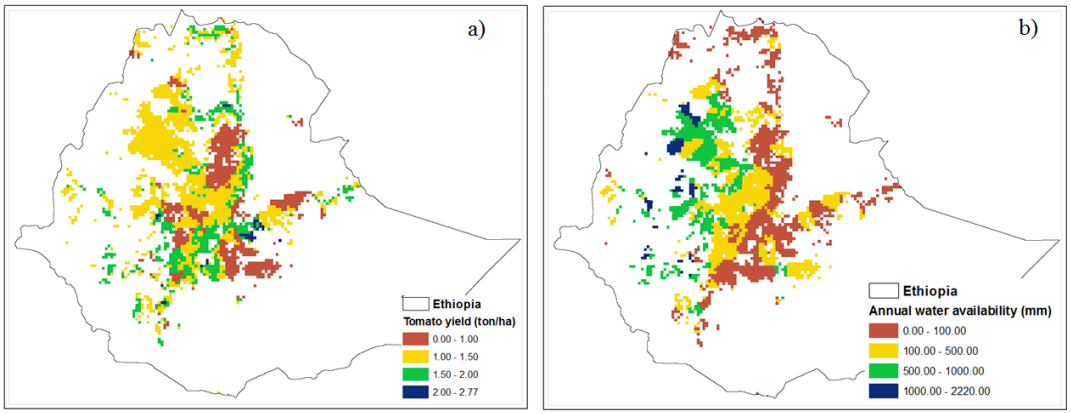
Pixels with a suitability value of greater than 85% were identified as suitable areas; accordingly, nearly 5.3% of the landmass, or approximately 60,025 km^2, was deemed suitable for irrigation. The optimized irrigation suitability map, shown below, shows the location and percentage of irrigable land in each of the major river basins. The Abbay (Blue Nile) basin has the largest area of suitable land (21,186 km^2), while the Rift Valley basin has the highest percentage of suitable land (20%).



Suitable irrigable land map, after excluding constraints and applying suitability threshold

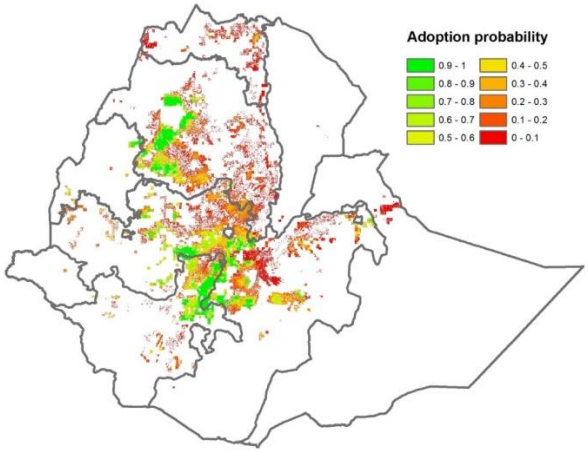
A paper summarizing the completed analysis, entitled "Assessing Potential Land Suitability for Surface Irrigation using Groundwater in Ethiopia," will be presented at the upcoming AGU conference. The team is also preparing a scientific journal article on groundwater irrigation potential in Ethiopia.

SWAT modeling is underway in Ethiopia, and spatially disaggregated estimates of water availability, irrigation water consumption, and irrigated crop yields are being provided to the ABM for the irrigation expansion simulation. In Ethiopia, SWAT is simulating a variety of potential irrigated, dry-season crops, including tomato, onion, pepper, cabbage, and potato. Preliminary findings, shown in the map below, show that tomato yield can range from less than 1 ton/ha to 2.8 ton/ha (fig. 7(a)), and that the available water resources (including surface runoff and ground water) across agricultural fields can range from less than 100 mm to over 2000 mm.



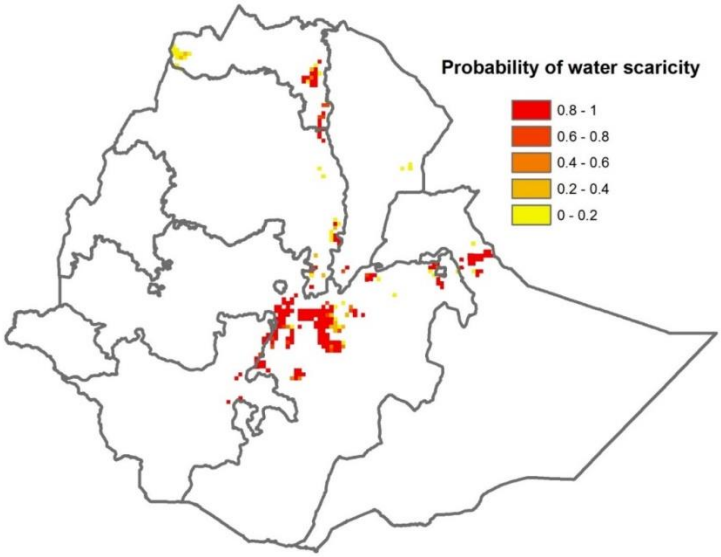
Spatial tomato production across agricultural lands; and (b) available water resources, including surface runoff generation and groundwater recharge

In Ethiopia, we are using the ABM to simulate and analyze a variety of candidate crops, including vegetable crops (tomatoes, onions, cabbages, peppers and vegetables-other) and pulse and root crops (chickpeas, lentils, and potatoes). Preliminary results, below, indicate that SSI development potential in Ethiopia is about 800,000 ha, mainly in Oromia, Amhara and SNNP. Simulations show that, while adoption of SSI could be widespread, SSI adoption is most likely to be successful in select areas as the Central Rift Valley and areas near Lake Tana. We recommend that future endeavors promoting SSI adoption target these areas.



Adoption probability of SSI in Ethiopia

ABM simulations also identified river basins that are prone to water scarcity, shown in the map below. In these regions, we recommend that appropriate institutional arrangements be made in conjunction with SSI investment activities, to reduce negative environmental and socioeconomic consequences of SSI development.



Risk of water scarcity associated with SSI expansion

The upscaling analysis in Ethiopia is slated for completion in year four of the ILSSI project. Data collection efforts are underway for upscaling analyses in Tanzania and Ghana, which will begin in year four.

Irrigation potential of the groundwater in Ethiopia

The TAMAR team has also been working on mapping the areas of irrigation-suitable land in Ethiopia; the input data preparation for the multi-criteria evaluation model has been completed. Potential land in Ethiopia suitable for irrigation using groundwater was identified using GIS-based Multi-Criteria Evaluation (MCE) techniques. The land suitability was determined by developing and assigning weight to the key factors that affect the irrigation potential of the land from groundwater using a 1-km grid. The factors used were identified from literature and with consultation with experts in the region. Factors considered included physical land features (land use, soil and slope), climate characteristics (rainfall and evapotranspiration), and market access (proximity to roads and access to market). Factors were weighted using a pair-wise comparison matrix, reclassified, and overlaid to identify the suitable areas for groundwater irrigation. Groundwater data from the British Geological Survey were used to estimate potential groundwater availability and analyze the irrigation potential for dominant crops. The irrigation potential of groundwater was based on the ratio of groundwater availability to the total crop water requirement (CWR) of the dominant crop.

The study indicated approximately 6.0 million ha of land is suitable for surface irrigation in Ethiopia. A larger portion of the suitable land is located in the Abbay, Rift Valley, Omo Ghibe, and Awash River basins. The study also indicated that the Abbay, Baro Akobo, Omo Ghibe, and Rift Valley basins have a shallow groundwater access within 20 m from the surface. The comparison between available groundwater and total crop water requirement indicated that the basins are not self-sufficient to irrigate all the suitable lands; instead, they will irrigate a smaller portion of the suitable land (< 20%).

Preliminary results of the study were presented at the 2016 International SWAT Conference in China as a poster, available for review. The study will be presented in the upcoming AGU conference entitled "Assessing Potential Land Suitability for Surface Irrigation using Groundwater in Ethiopia." A scientific

journal article is in preparation for submission to a peer-reviewed journal. IWMI provided TAMU with extensive appraisal and suggested new data for use in their first model runs for Ethiopia sites. IWMI presented the findings of the irrigation suitability analysis to the Ethiopian Agricultural Transformation Agency.

X. Capacity Development and Stakeholder Engagement and Dialogue

TAMAR

TAMAR is supporting three postdoctoral fellows and one M.S. student at TAMAR laboratories, all of whom are male and are African nationals. See the annex entitled "Long-Term Training" for additional details regarding those students currently enrolled in a degree program funded in full or part by USAID.

TAMAR is also supporting multiple students at project partners and cooperating national institutions in Ethiopia, Tanzania, and Ghana in the use of the IDSS and its component models (SWAT, APEX, and FARMSIM), as follows:

In Ethiopia, TAMAR is supporting two male students at Bahir Dar University (BDU) in use of APEX. TAMAR is also supervising two Ph.D. students at Addis Ababa University (AAU). Gebrekidan Worku Tefera, a Ph.D. student from AAU's College of Development Studies, is preparing a Ph.D. thesis on "Watershed Management Scenarios under Changing Climate in Jemma Sub Basin, Blue Nile Basin" using the SWAT model. Temesgen Gashaw, a Ph.D. at AAU's Center for Environmental Science, is preparing a thesis on "Valuation of land use/land cover change effects on stream flow patterns in the Upper Blue Nile Basin, Northwestern Ethiopia." Additionally, TAMAR has discussed the use and integration of FARMSIM in thesis research with three male students from Ethiopia. One is currently pursuing his PhD in Germany (Getachew Legese Feye), while the two others are awaiting admission into PhD programs in the fall of 2016 (Berihun Tefera and Kaleb Shiferaw). Discussions will continue with these students in the coming year after they finalize their research proposals.

In Tanzania, TAMAR is supporting: three male students in the use of APEX, two of which are faculty at Sokoine Agricultural University (SUA); one faculty member and one Ph.D. student (both male) at the University of Dar es Salaam (UDES) in the use of SWAT; and two male Ph.D. students at SUA in the use of SWAT.

In Ghana, TAMAR is supporting one female Ph.D. student, Fati Aziz, in the use of SWAT in her Ph.D. thesis. Ms. Aziz was a guest scientist at College Station from June-November, 2015. TAMAR is also supporting Dinko Hanaan Dinko, who is pursuing his M.Phil. in the Department of Geography and Resource Development Department at the University of Ghana. Mr. Dinko's thesis is on "Climate change/variability and water security in the Sudan Savannah zone of Ghana."

TAMAR also trained a female Vietnamese Ph.D. student from NCAT in EPIC (a predecessor of SWAT and APEX); and another male Ethiopian student from NCAT on APEX.

Visiting students from BDU and SUA

Additionally, from June 1 – September 30, 2016, TAMAR hosted three male students from BDU and two male students from SUA, and provided them with day-to-day support on the use of various component IDSS models in research activities in

their respective countries. TAMAR also provided these five individuals with short-term training in the IDSS. A report on the visit and the short-term training workshops is available.

IWMI

The list of graduate students whose field work is supported under ILSSI is found in Annex 1.

An updated list of graduate students whose field work is supported under ILSSI is found in Annex 1.

Student theses completed:

1) 2016 Bahir Dar University, Abdu Yimer –Rainfall-Runoff processes in the upper Blue Nile Basin. The case study of Dangishta watershed - Bahir Dar University
2) 2016 Bahir Dar University, Misba Hussen - Improving Subsurface Recharge By Breaking Hardpans Through Mechanical Means - Bahir Dar University
3) 2015 Bahir Dar University, Tesfaye Ewnetie - Assessing the performance of manual water lifting technologies and irrigation scheduling based on measured soil moisture and farmers practice on irrigated tomato production, and comparing soil moisture monitoring and estimation methods: the case of Western Amhara sub- region
4) 2015 Bahir Dar University, Melaku Tesema - Evaluating Simple Irrigation Technologies to Improve Crop and Water Productivity of Onion in Dangishta Watershed
5) 2015 Bahir Dar University, Hannibal Mulugeta - Production, water use and crop coefficient development for Napier grass under small scale irrigation: the case of Robit Kebele
6) 2015 Arba Minch University, Desalegn Tegegne – Assessment of Water Demand, water and crop productivity of selected fodder varieties under small holder irrigated farming practices using wetting front detector
7) 2015 Bahir Dar University, Teshager Assefa Sisha-Analysis of Technical Efficiency of Small Scale Irrigation Technologies: The case of Robit and Dangeshita
8) 2015 Bahir-Dar University, Mihret Dessie-Cost-Benefit Analysis of smallholder irrigation technologies: The case of Robit and Dangeshita
9) 2015 Arba Minch University, Meneyahel Zegeye Tesefaye – Farmers willingness to pay and choice of smallholder water lifting technologies: evidence from Adami Tulu, Lemo, Dangila and Bahir Dar Zuria woredas, Ethiopia

Student theses on-going:

1) Muluye Gedfew –Comparing the effect of soil moisture and climate based irrigation scheduling strategies on tomato production and partial nutrient balances: Case study in Robit watershed - Bahir Dar University
2) Talake Asnekew – Optimizing irrigation scheduling to improve onion production in Danghista, Ethiopia - Bahir Dar University
3) Addisu Wondimnew – Assessment of pesticide residue contamination and transportation in soil and water - Bahir Dar University (under SIPS from July onwards)
4) Haptamu Mesche - Hydrological and agronomic impacts of Berken and deep tillage systems through hardpan disruption, Upper Blue Nile, Ethiopia – Bahir Dar University
5) Belainew Belete-Impact of Small Scale Irrigation Technology on Farm Household Welfare: Micro Econometrics Approach-Bahir Dar University

Tariku Yadeta Fufa- The impact of small scale irrigation on farm production and productivity- Arba minch University

IFPRI

In December of 2015, IFPRI trained a team of researchers from Sokoine University to conduct focus group discussions to collect qualitative data for ILSSI on gender-based differences in access to irrigation technologies. IFPRI also met with key government stakeholders in Tanzania to start planning for gender-irrigation technical capacity building activities that took place in the first half of 2016.

On December 4, 2015, Claudia Ringler managed, with IWMI, a session on Agricultural Water Management at the Washington DC Dupont Summit Event, which included a presentation on Irrigation, Gender and Nutrition linkages based on ILSSI research (presentation by Simone Passarelli): Agricultural Water Management Confluences of Policies, Institutions, and Technologies. A blog piece was produced based on the event (The Goldilocks Dilemma of Balancing Irrigation Technologies, Policies and Institutions. The Goldilocks Dilemma of irrigation)

In March 2016, IFPRI in partnership with IWMI and the Ministry of Agriculture and Natural Resources led a Gender and Irrigation Technical Workshop on the ILRI campus that convened nearly 50 stakeholders from government, NGOs, research, and donor communities in Ethiopia. The workshop included 20 speakers from different sectors and interactive discussions on approaches to effectively integrate and address gender in irrigation interventions and research. A checklist for integrating gender into irrigation projects was developed and is being refined through the workshop series. Ethiopia participants expressed interest in using the checklist to inform a new process of gender mainstreaming guidelines in the Ministry of Agriculture.

Sophie Theis and Elizabeth Bryan traveled to Ethiopia and facilitated the workshop. A news article was produced for the ILSSI blog: ILSSI Technical Workshops in Ethiopia, Tanzania, and Ghana to Address Gender issues in Small Scale Irrigation

Workshops in Ghana and Tanzania are being organized in April 2016 in partnership with IWMI and the Ghana Irrigation Development Authority in Ghana (April 13-14) and with Sokoine University of Agriculture and the Ministry of Agriculture, Livestock, and Fisheries in Tanzania (April 20-21).

XI. Prepare and Conduct Short Courses on Use of the IDSS

TAMAR

In year three, TAMAR conducted workshops in Ghana, Ethiopia, and Tanzania for the purpose of training participants in the IDSS and its three component models (SWAT, APEX, and FARMSIM). Reports on the workshop proceedings and participants in Ghana, Ethiopia, and Tanzania, as well as a comprehensive report, are available.

The Accra, Ghana workshop was sponsored by the Council for Scientific and Industrial Research/Water Research Institute, and was held on February 1-5, 2016. A total of 50 participants attended the Accra workshop. 30 participants were trained in SWAT by Yihun Dile; 11 participants were trained in APEX by Abeyou Worqlul; and 9 participants were trained in FARMSIM by Jean-Claude Bizimana. Of the 50

participants, 10 were women, with 5 attending the SWAT workshop, 2 attending the APEX workshop, and 3 attending the FARMSIM workshop.

The Addis Ababa, Ethiopia workshop was held on February 8-12, 2016; in addition, an advanced SWAT workshop and separate FARMSIM clinic were conducted in Addis Ababa on February 15-17, 2016, and a SWAT clinic was held on February 18-19, 2016. The Addis Ababa workshops and clinics were to be sponsored by Jimma University; however, due to security concerns in the Oromia region, the events were relocated to the Addis Ababa offices of ILRI. IWMI helped in arranging workshop facilities and accommodations for the trainers. A total of 65 participants (including 7 women) attended the IDSS workshops in Addis Ababa. A total of 48 participants (6 of whom were women) were trained in introductory SWAT by Yihun Dile; 8 participants (all men) were trained in APEX by Abeyou Worqlul; and 9 participants (including 1 woman) were trained in FARMSIM by Jean-Claude Bizimana. A total of 30 people (of which 2 were women) attended the Advanced SWAT workshop in Addis Ababa, led by Yihun Dile. A total of 14 participants (all men) attended the SWAT clinic, led by Yihun Dile; and 3 participants (all men) attended the FARMSIM clinic, led by Jean-Claude Bizimana.

The Arusha, Tanzania workshop was sponsored by the Nelson Mandela African Institute for Science and Technology, and was held on June 6-10, 2016 at NM-AIST. A total of 46 participants attended the Arusha workshop. 24 participants were trained in SWAT by Yihun Dile; 14 participants were trained in APEX by Abeyou Worqlul; and 8 participants were trained in FARMSIM by Jean-Claude Bizimana. Of the 46 participants, 13 were women, with 7 attending the SWAT workshop, 4 attending the APEX workshop, and 2 attending the FARMSIM workshop.

A Temple, Texas workshop was held at the Blackland Research Center from September 7-9, 2016. A total of three visiting scientists from Ethiopia (all male) and two visiting scientists from Tanzania (both male) attended the Temple workshop. 2 participants were trained in SWAT by Yihun Dile; 1 participant was trained in APEX by Abeyou Worqlul; and 2 participants were trained in FARMSIM by Jean-Claude Bizimana.

ILRI

Ethiopia: In Robit Bata training was delivered for both the new comers and the previous year irrigated fodder participant farmers. The training was prepared for two days. On the first day, training was prepared for new participant farmers including woreda and kebele agriculture experts while on the second day, training was for both new and previous year participant farmers. The first day of training focused largely on forage, particularly Napier grass development which is provided by Misganaw Walle which lasted more than 2 hours. The second day of training consisted of three components, i.e., intercropping (by Misganaw Walle), water requirement (by Melaku Tessema guest trainer from IWMI - BBU) and improved dairy cow management and breeding (by Tewdrose Bimirew).

Kudimi kebele was selected for experience sharing purpose. This kebele is located at Merawi district which is 60 km away from Robit Bata and is selected since there are farmers who have good experience on irrigated fodder development. Prior to experience sharing, role model farmers (Ato Tena Kebede) were selected in terms of Napier development, legume intercropping and dairy cow husbandry practice. About 11 new participant farmers, 5 kebele agricultural experts and 4 agricultural experts from woreda agriculture office were shared experience from Ato Tena Kebede on forage (Napier grass development and

feeding, Rhodes grass production and feeding, Sesebania production and utilization, intercropping of Desmodium and utilization), improved dairy cow management like construction of crash and feeding trough, and feed storage construction that can protect the feed from sunlight, rainfall and termite. Participants understand the following two main points from the experience sharing: 1) the importance of land allocation for Napier grass, and 2) the value of integrated forage development and intercropping of legume forages.

Ghana: In Ghana farmers were trained on irrigated fodder at Bihinayili in Savelugu district on 28 February 2016. The objective of the irrigated fodder production in Northern Ghana is to demonstrate potential of irrigated fodder in the area. Training of partners, namely Animal Research Institute (ARI), agricultural extension officers and farmers, was conducted on 28th of February 2016 at Bihinayili in the Savelugu district based on guidance provided from earlier training by ILRI. The objective of the training was to introduce the participants to small scale irrigation of fodder crops and to train the agricultural extension officers in fodder planting techniques and data collection. The training focused on layout of plots, planting methods and seed rates. Twelve farmers were involved in the training and were selected for dry season fodder production. Eight of the farmers agreed to participate in the irrigated fodder production. These farmers are also involved in IWMI's small scale dry season vegetable production using overhead water storage tank for irrigation.

Tanzania: Conducted training to farmers on the importance of establishing irrigated forage in alleviating feed shortages, forage production, management, harvesting, conservation and or storage, processing and utilization. The training was conducted by the subject matter specialist from TALIRI, ILRI and the extension service. A total of 57 were trained ahead of implementing the intervention.

IWMI

Training and capacity development in Robit:

- Frequent follow up trainings for farmers in the field of agriculture and water management, as BDU had observed a significant capacity gap within the first dry season of year 3. (As listed in table below)
- Farmers were (again) trained this season on nursery preparation and tomato seedling management by an agronomist (Habtamu, from ARARI).
- Field visit: Farmers, students, woreda focal persons and project coordinators went on a field visit to learn from another ILSSI site (Dangishta watershed).
- Training held in Adami Tulu on water management (WFD) for all farmers.

Trainings and capacity development in Dangeshita:

1. New farmers were trained on the project and expectations.
2. Training on WFD for the new ILSSI farmers
3. All farmers trained on about nursery preparation, transplantation and irrigation (Addisu and Melaku), maintenance and installation of Rope & washer (Melaku and Girma, ILSSI farmer from previous year)
4. Field visit: Farmers, students, woreda focal persons and project coordinators went on a field visit to learn from another ILSSI site (Robit watershed).

Trainings: Farmers, local government subject matter specialists, private sector

Date	Purpose of training	Number of trainees	Location/Site
14/10/2015	Project objective awareness (new farmers), crop selection and refreshment training	29	BDU
25/10/2015	Training to farmers about nursery preparation and tomato seedling management by an agronomist	19	Robit Bata
29/11/2015	Field and learning visit - Dangishta watershed	32	Dangishita
8/10/2015	Project information (new farmers)	9	Dangishita
4/10/2015	Nursery preparation, transplantation and irrigation (old and new farmers)	29	Dangishita
20/10/2015	Maintenance and installation of Rope & Washer	19	Dangishita
07/02/2015	Field and learning visit	31	Robit
	MoFA staff (3) and students were trained on biophysical and socioeconomic data collection	5	Upper East Region, Ghana
	Trained on fabrication of UDS drip kits	2 (private plumbers)	Upper East Region, Ghana
23 Dec 2015	Use and maintenance of water pumping machines.		
12 January 2016	Assembling and disassembling of iDE and UDS drip kits		
	Techniques in land preparations-raising of beds, measuring plot sizes, land		

	levelling for installation of drip kits		
	Testing and maintenance of the drip kits system		
	WFD use		
	General agronomic practices- water and soil management		

XII. Institutional capacity development

TAMAR

National partner institutions such as BDU, UDES, and SUA are actively engaged in the project. TAMAR is supporting students and faculty at these institutions in their research; see Section IX for a detailed description.

During year three, IDSS workshops were conducted in Ghana, Ethiopia, Tanzania, and Texas, as discussed in detail in Section X, above. This training involved capacity building for both students and faculty at the host and other universities, as well as government agencies.

TAMAR has also provided certain models to cooperating scientists, short course participants, and partner institutions, as detailed in Section XIII.

NCA&T

Both SUA and BDU's capacities in commercial vegetable home garden production systems under CA and drip irrigation is being built up. Students, staff and faculty are being built up through interactions with N.C. A&T team. Team also translated in Swahili learning materials for conservation agriculture vegetable production. Dr. Idassi and Mr. Festo finished Swahili translation of first sheet titled: "Hatua 14 za kulima mbogambogakwa njia ya kilimo hifadhi (Conservation Agriculture) na umwagiliaji wa matone (drip irrigation) ya maji." The fact sheet was a translation of the 14 steps to growing vegetables with conservation agriculture and drip irrigation from blog at: 14 steps to growing vegetables with conservation agriculture and drip irrigation. It will be used at the summer vegetable training workshop targeting commercial vegetable home gardeners in Mkindo Village, Morogoro. Efforts will be made also, to train participants on how to establish a strong drainage system around their gardens for flood protection.

These commercial vegetable home garden systems are also being evaluated using the APEX model.

XIII. Technology Transfer and Scaling Partnerships

TAMAR has provided IDSS software (SWAT, APEX, and FARMSIM/SIMETAR) to: several cooperating scientists at each cooperating ILSSI institution; participants in the IDSS workshops (detailed in Section X); and graduate students and staff at national partner institutions (such as Bahir Dar University, University of Dar es Salaam, Sokoine University of Agriculture, and Nelson Mandela- African Institute for Science and

Technology) who are actively engaging in the project and whom TAMAR is supporting in their research (detailed in Section IX). See Section VIII, above, for a description of the IDSS and its component models.

In all sites in Ethiopia, where activities started earlier than in Tanzania and Ghana, numbers of participating farmers and land allocation to early forage options of Napier, Desho and Oats and Vetch have increased.

XIV. Issues and Concerns

As the project has moved to the generation of substantial new data from all components, the matter of ensuring overall integration of product into a coherent and integrated analysis is both exciting and challenging. Quality of data from field studies continues to be an ultimate limitation on the application of the IDSS. Reality checks on the IDSS product with stakeholders are also important to ensuring the quality and utility of the final product. Working with farmers in their fields has the ongoing challenge of consistency of data acquisition as adjustments to markets, weather and experiences and adjustments to individual social/cultural issues occur. Availability and affordability of useful interventions and access to credit are ongoing challenges.

The ILSSI team is challenged going into year four with the task of completing all field studies on the ground and organizing data and observations into a coherent set of country level reports along with an overarching report on lessons learned for application across/between countries.

Baseline household surveys will be augmented with the second round where the question will be on evaluating the outcomes of small scale irrigation on households in terms of economics and nutrition as well as gender related factors affecting adoption of SSI in smallholder households.

The IDSS methodology has been substantially extended in the first three years and in years four and five it will be challenged to evaluate solutions to constraints and to deliver outcome assessments at national levels of scale.

ILSSI is challenged to bring the component parts of the study into a coherent synthesis of the total result in a form that is usable and useful to stakeholders at multiple levels of scale. In years four and five, ILSSI will be focused on a set of relevant outcome statements that clearly state the outcomes and the projected impacts of the project.

XV. Future Work

IFPRI

The key activity in the next reporting period will be to complete end line surveys for Ethiopia and Tanzania. A series of draft papers will be finalized and submitted for publication.

Upscaling analysis will be advanced in other countries.

TAMAR

TAMAR will continue to provide technical support, data, and advice for IDSS users in CGIAR partner and cooperating national institutions.

Ex post analyses in Ethiopia, Tanzania, and Ghana will be completed in year 4.

Scaling of results to the national level will be completed in Ethiopia in year 4, and similar analyses will be initiated in Tanzania and Ghana. Collaboration with IFPRI on scaling to the national level will be actively pursued.

The irrigation suitability analysis tool will be evaluated and finalized.

Application of the IDSS to Africa RISING and LIVES and other partnerships will be completed in year 4. Support to ongoing Mission studies and collaboration with other FtF innovation laboratories (such as the Horticulture lab) will be continued.

TAMAR will conduct IDSS training workshops, including introductory and advanced five-day workshops, in all three countries, with approximately 60 trainees in each basic workshop. Participants will include both university students and others from government and private sector.

TAMAR will continue to actively mentor researchers using the IDSS or any of its component models. Graduate student involvement and three-month trainings of selected teams of national university staff/students at Texas A&M will be continued into year 4.

TAMAR will continue to expand and revise the ILSSI website, prepare background publications for the USAID External Review Committee, and publish student theses and post doc reports as journal articles. Publications in referred journals will be submitted.

IWMI

General: IWMI will continue the field studies in all three countries to compare motorized and manual water lifting technologies in conjunction with various field application methods and irrigation scheduling tools. In addition, IWMI will continue the research on micro-finance opportunities and constraints for small-scale irrigation technologies. Data collected by IWMI and national partners will be used to analyze profitability across three irrigation seasons in Ethiopia, and two irrigations seasons in Ghana and Tanzania. Multi-year price variation for irrigated crops will also be analyzed for Ghana. Watershed and groundwater recharge data and analysis will also continue in Ethiopia.

Capacity development and outreach

As part of the field interventions, ILSSI and national partners will continue to conduct field level capacity development and trainings on irrigated fodder and related tools, agricultural water management and scheduling, and agronomy for irrigated cropping. Graduate students will continue to be supported and mentored in research methods, data collection and analysis for interventions in all three countries. Additional IDSS trainings are planned for all project countries (add dates if planned).

ILSSI also plans to deepen outreach with select national decision-making and planning institutions in each country, building on established linkages already made in the first three years. In addition, stakeholder consultations would be developed around mitigating constraints to uptake of SSI and catalyzing best bet opportunities for upscaling. More attention will be given to identifying and engaging with private sector actors with interests in technologies and finance.

Annex I. IWMI - List of graduate students for current fiscal year

Name	M/F	Univ	Dept	Degree	Research topic	Site	Data to collect	Expected graduation date	IWMI supervisor
Belainew Belete	M	BDU	Economics	M.S.	impact of small scale irrigation technology on farm household welfare	All sites in Ethiopia	Socio-economics survey	October, 2016	Dr. Gebrehaweria Gebregziabher
Talakie Asnake	F	BDU	Hydrology	M.S.	Optimizing irrigation scheduling to improve onion production	Dangishta	Baseline surveys, soil physio-chemical properties, soil moisture, discharge rates of lifting technologies, periodic onion performance including plant height and ground cover, irrigation amounts and intervals, onion yield	Jun-17	Dr. Petra Schmitter/ Dr. Prossie Nakawuka
Muluye Gedife	M	BDU	Hydrology	M.S.	Effect of Irrigation scheduling on partial nutrient balances for tomato	Robit	Baseline surveys, soil physio-chemical properties, soil moisture, discharge rates of lifting technologies, periodic onion performance including plant height and ground cover, irrigation amounts and	October, 2016	Dr. Petra Schmitter/ Dr. Prossie Nakawuka

							intervals, onion yield		
Adisu Wondimu	M	BDU	Environmental Engineering	M.S.	Assessment of Pesticide residual contamination of soil and water resources: Case of Robit Bata	Robit	data on pesticide residual from soil, ground water and surface water	Jan-17	Dr. Petra Schmitter
Debebe Lijalem	M	BDU*	School of Civil and Water Resources Engineering	Ph.D.	Optimizing use of groundwater for irrigation in the dry season in the Robit-Bata watershed located in the Lake Tana basin	Robit	Climatic data, groundwater fluctuations, well yield, soil physical properties, streamflow, sediment concentration, sediment physio-chemical properties, DEM, land use/land cover map, soil map	June 2017	Dr. Petra Schmitter/ Dr. Prossie Nakawuka
Misba Abdela	M	BDU	School of Civil and Water Resources Engineering	M.S.	Improving subsurface recharge by breaking hardpan through deep tillage	Robit	Baseline survey, soil physio-chemical properties, soil penetration resistance, soil infiltration rates, rainfall data, groundwater fluctuations, soil moisture, plot runoff,	July, 2016	Dr. Prossie Nakawuka/ Dr. Petra Schmitter

							sediment concentration from treatment plots, sediment physio-chemical properties, periodic crop performance, crop yield		
Abdu Yimer	M	BDU	School of Civil and Water Resources Engineering	M.S.	Rainfall-Runoff process in the Upper Blue Nile basin: the case study of Dangishta watershed	Dangishta	Climatic data, stream flow, sediment concentration, sediment physio-chemical properties, soil infiltrability, groundwater fluctuations, soil moisture, soil physio-chemical properties, DEM, land use/land cover map, and soil map	July, 2016	Dr. Prossie Nakawuka/ Dr. Petra Schmitter
Kassaw Beshaw	M	AMU	Department of Water Resources and Irrigation Engineering	Ph.D.	TBD***	Upper-Gana and Bochesa	Climatic data, stream flow, soil physio-chemical properties, water (from wells and river) chemical properties, sediment concentration, sediment physio-chemical properties, DEMs, soil maps, land use/land cover maps, groundwater fluctuations, well yield	June 2018	Dr. Petra Schmitter/ Dr. Prossie Nakawuka

Demelash Wendemench	M	AMU	Department of Water Resources and Irrigation Engineering	Ph.D.	TBD	Upper-Gana and Bochesa	Soil physio-chemical properties, soil moisture, water chemical properties, lifting technologies' discharge rates, well yield, irrigation amounts and intervals, crop periodic performances, crop yield	June 2018	Dr. Petra Schmitter/ Dr. Prossie Nakawuka
Tariku Yadeta Fufa	M	AMU	Economics	M.S.	The impact of small scale irrigation on farm production and productivity	All sites in Ethiopia	Socio-economics survey	October, 2016	Dr. Gebrehaweria Gebregziabher
Ghana									
Raymond Tetteh	M	UDS	Agric. Mechanisation and Irrigation Technology	MPhil		Bihinaayilli, Zanlerigu and Dimbasinia	Improved irrigation practices among smallholder dry season vegetable farmers in Northern Ghana. Identify and assess the types of improved irrigation practices available; analyze water use productivity; analyze and predict the sustainability of improved practices and impacts on the ecosystem using APEX	December, 2017	Dr. Davie Kadyampakeni

Annex II. – Long Term Training

[1]

Name of Innovation Lab: Feed the Future Innovation Lab on Small Scale Irrigation in Ethiopia, Tanzania and Ghana

Name of Student	Gender	University of Study	Degree[2]	Major	Graduation Date	Home Country	Home Institution[3]
Tewodros Assefa	M	NCA&T State University	Ph.D.	Energy and Environmental Systems	December 31, 2017	Ethiopia	Bahir Dar University
Tsehay Azeref Wondmeneh	M	Bahir Dar University	M.S.	Agronomy	June 2017	Ethiopia	Bahir Dar University
Hailie Alebachew	F	Bahir Dar University	M.S.	Horticulture	June 2017	Ethiopia	Bahir Dar University
Mariana McKim	F	NCA&T State	M.S.	Agricultural Education	August 2016	USA	N.C. A&T

[1] Include all students (both foreign and U.S. based) who are *currently* enrolled in a degree program funded in full or part by USAID regardless of when they started their program. Include those studying in the U.S., their home country or a third country.

[2] B.S., M.S., Ph.D., other (specify)

[3] Fill out for foreign students only. Specify if the student is from a NARS, an educational institution, the private sector, etc.

		University					
Sintayehu Alemayehu Teshome	M	Texas A&M College of Agriculture and Life Sciences	M.S.	Ecosystem Science and Management (Range Mgmt)	June 2017	Ethiopia	TAMAR
Belainew Belete	M	Bahir Dar University	M.S.	Economics	October 2016	Ethiopia	Bahir Dar University
Talakie Asnake	F	Bahir Dar University	M.S.	Water resources Engineering	June 2016	Ethiopia	Bahir Dar University
Muluye Gedife	M	Bahir Dar University	M.S.	Water resources Engineering	December 2016	Ethiopia	Bahir Dar University
Adisu Wondimu	M	Bahir Dar University	M.S.	Chemical Engineering	June 2017	Ethiopia	Bahir Dar University
Debebe Lijalem	M	Bahir Dar University	Ph.D.	Water resources Engineering	June 2018	Ethiopia	Bahir Dar University
Misba Abdela	M	Bahir Dar University	M.S.	Water resources	June 2016	Ethiopia	Bahir Dar Universit

				Engineering			y
Abdu Yimer	M	Bahir Dar University	M.S.	Water resources Engineering	June 2016	Ethiopia	Bahir Dar University
Kassaw Beshaw	M	Arba Minch University	Ph.D.	Water resources Engineering	June 2019	Ethiopia	Arba Minch University
Demelash Wendemench	M	Arba Minch University	Ph.D.	Water resources Engineering	June 2019	Ethiopia	Arba Minch University
Tariku Yadeta Fufa	M	Arba Minch University	M.S.	Economics	December 2016	Ethiopia	Arba Minch University
Raymond Tetteh	M	UDS	M.S.				

Annex III. Publications

IWMI

Tewodros T. Assefa, Manoj K. Jha, Seifu A Tilahun, Ephrem Yetbarek, Anwar A Adem and Abeyou Wale. 2015. Identification of Erosion Hotspot Area using GIS and MCE Technique for Koga Watershed in the Upper Blue Nile Basin, Ethiopia. *American Journal of Environmental Sciences. Volume 11, Issue 4. Pages 245-255*

Tewodros Assefa, Manoj Jha, Sushama Pradhan. 2015. Modeling Onsite Wastewater Treatment Systems (OWTS) for Nutrient Fate and Transport for Lick Creek Watershed. *SWAT 2015. International soil & water assessment tool conference. October 14-16, Purdue University, West Lafayette, IN, USA*.

Tewodros T. Assefa, Seifu A Tilahun, Demesew A Mihret, Essayas K Ayana, Michael Mahri, Petra Schmitter, Manoj K. Jha, Simon Langan. 2015. Reservoir sedimentation and hotspot areas in Koga Watershed of the Upper Blue Nile Basin, Ethiopia. TropiLakes 2015. Tropical Lakes in changing environment: water, land, biology, climate and humans.

Adugnaw Tadesse, Mamaru A.Moges, Debebe Lijalem, ,Dessalegn C. Dagnew, Tewoderos Taffese, Mulugeta A.Belete, Seifu A. Tilahun, and Tammo S. Steenhuis. Assessment of nitrate concentration in drinking water sources in rural areas of Ethiopia. 2015. ICAST-2015 Conference, Volume 3, Bahir Dar, Ethiopia.

Assefa, Tewodros; Jha, Manoj; Reyes, Manuel; Srinivasan, Raghavan; Worklul, Abeyou. 2015. Evaluation of Land Suitability for Irrigation and Potential of Water Sources Using GIS and MCE Technique for Lake Tana Basin. *Submitted to ASABE international meeting, Dec 2015*

Reyes, M.R., Enku, T., and Azeref, T. 2016. Success story of an Ethiopian Commercial Vegetable Home Gardener (submitted hopefully chosen to be included in the FtF newsletter April 2016.

TAMAR

In year three, TAMAR published a paper highlighting the IDSS integrated models in the Agriculture Water Management journal, based on the results of site studies in Ethiopia. TAMAR also published a paper that introduces an open access tool used to run the SWAT model. Additionally, the result of the irrigation area suitability mapping was presented as a poster at the 2016 SWAT conference at Beijing Normal University, China. The referencing details for the two papers and poster are as follows:

Clark, N., J. C. Bizimana, Y. Dile, A. Worqlul, J. Osorio, B. Herbst, J. W. Richardson, R. Srinivasan, T. J. Gerik, J. Williams, C. A. Jones, and J. Jeong. 2016. Evaluation of New Farming Technologies in Ethiopia using the Integrated Decision Support System (IDSS). *Agric. Water Manage.* (2016), doi.org/10.1016/j.agwat.2016.07.023

Dile, Y., P. Daggupati, C. George, R. Srinivasan, and J. Arnold. 2015. QSWAT: Introducing a New Open Source GIS User Interface for the SWAT Model. *Environ. Model. Softw*. 85, doi.org/10.1016/j.envsoft.2016.08.004

Worqlul, A., J. Jeong, J. Osorio, T. Gerik, R. Srinivasan, and N. Clark. 2016. Assessing Irrigation Potential and Land Suitability in Ethiopia. Poster presentation at SWAT Beijing conference 2016, Beijing Normal University, China.

Annex IV. Knowledge Products

IWMI

Compiled a zero draft of the paper reviewing trends, constraints and opportunities of small scale irrigation in four East African countries: Ethiopia, Kenya, Tanzania and Uganda.

Draft report on the microfinance trainings and lessons learned across multiple sites in Ethiopia.

Mini workshop with students at BDU in February, at which 10 presentations based on ILSSI research were shared across students of ILSSI and LIVES.

Poster was presented at the 'Sustainable Agricultural Water Management Theme Meeting' in Addis Ababa, Ethiopia from 26 to 29 January 2016.

IWMI prepared a flyer on ILSSI activities in Ghana. This has been shared with the USAID mission in Ghana, the Savanna Accelerated Development Authority and the Ghana Irrigation Development Authority, among other development partners.

In March, a research report has been drafted for biophysical characterization of watersheds in Ghana, Ethiopia and Tanzania.

ILSSI was presented on the EAIR 50th year Anniversary and shared posters with Africa Rising and LIVES on solar pumps and wetting front detectors.

Poster presented in Leuven Belgium: "The importance of Ethiopian soils in irrigation and overall watershed management" in the Africa in Soil conference (4 December 2015).