Feed the Future Innovation Laboratory for Small Scale Irrigation (ILSSI)

Year Four (FY 2017) Annual Report

October 1, 2016 – September 30th, 2017

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I. Executive Summary

This annual report covers the fourth year of the Feed the Future Innovation Laboratory for Small Scale Irrigation (ILSSI) cooperative agreement (FY 17). Year one of the ILSSI project 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. In years two and three research was conducted on field studies, household surveys, and analyses of the consequences of small scale irrigation interventions using the IDSS. Stakeholder engagement and capacity development were actively pursued throughout the first four years and will continue to be a critical component in year five. The summary of achievements for year 4 can also be found in the Key Accomplishments Section below.

Mid-Term Report

The mid-term report was submitted to and approved by USAID in November 2016. It was organized to provide a comprehensive input to the ERC. This report was well received both by USAID leadership and the ERC.

Annex to Midterm Report

In April 2017, an annex to the midterm report was completed and approved. The annex report provided to USAID leadership and the ILSSI ERC additional and more detailed input regarding key project components and constraints. Building upon the midterm report, the annex report provided a comprehensive statement of progress and forward vision.

Semiannual report

The semiannual report covered activities in the first half of FY 17 in the established ILSSI format.

Exit Strategy

The midterm report and annex initiate the framework for an ILSSI exit strategy that will continue to evolve over the final year of phase I of the agreement. With or without a positive decision on non-competing renewal, the exit strategy will inform and guide either the completion or the renewal of ILSSI.

PMC and EAC Meetings

The PMC and EAC joint meetings held in Dar es Salaam and Bahir Dar were focused on strategic review of ILSSI accomplishments and, particularly, in framing the general plan for preparing for the ERC. The joint meetings also provided an opportunity to discuss the way forward for the remainder of ILSSI project (phase I). Annual stakeholder meetings in each country in year five were planned with EAC participation.

Strategic Planning Meeting TAMU

An extraordinary meeting of the PMC was held at Texas A&M in July 2017. During this three-day meeting, a solid consensus on the approach for integration of ILSSI components into an overall conceptual and reporting structure was established. Plans were also solidified for reports with authors and dates and the methodology to be used in supporting the USAID ERC during their travel to Ethiopia and Ghana.

Collaboration with SIIL and HNIL

Collaboration with the Sustainable Intensification (SIIL) and Human Nutrition Laboratories (HNIL) continues through year four and into the following year. The contract between ILSSI and SIIL (Kansas State University) is entitled Sustainably Intensified Production Systems Impact on Nutrition (SIPSIN); this highly integrated collaboration is enriching the ILSSI project by extending small scale irrigation to include a farming systems approach and by providing greater depth of inquiry into the effect of these systems on household nutrition. In a competitively awarded contract, the HNIL and other parts of SIIL along with partners in ILSSI, are conducting studies of the impact of sustainably intensified production systems on household nutrition.

Year Five Work Plan and Budget

The year five work plan is of particular importance in the completion of phase I of ILSSI and in ensuring comprehensive consideration of all ILSSI components for the transition to a potential phase II. Guidance from USAID forecasted FY 18 funds (project year five) would likely not be available until January 2018; however, carry over funds from year four were saved to provide for key operations in the first quarter of year five. The year five workplan assumes full funding with the remaining possible obligation to achieve the total forecasted budget. The ILSSI leadership team will remain in communication with USAID regarding any funding, and sequential programmatic, changes for year five.

USAID External Review

The USAID ERC spent two full days at Texas A&M in July at the onset of their review. During this time the ERC received extensive ILSSI presentations and information from each ILSSI component, as well as from an overall programmatic perspective. This two day meeting was critically important for the ERC team to understand, at the outset of their review, the complexity of the project and its interrelationships. The ILSSI PMC provided considerable logistical support to the ERC team during their deployment to Ethiopia and Tanzania and Ghana and maintained an active ongoing dialogue with the ERC team leader during the entire period of their review. The draft ERC report as been received and comments and suggestions provided to USAID as requested. Overall, the report is very positive and provides useful insights into stakeholder perceptions of ILSSI's performance and on recommendations.

Successfully Transitioning to Year Five

During year five, ILSSI plans to transition towards more active engagement with stakeholders in anticipation of continuing and further expanding these engagements as key parts of a potential phase II of ILSSI. External Advisory Committee (EAC) members will once again join ILSSI leadership in key stakeholder engagements in each country during year five. Additionally, national level stakeholder meetings are planned for March and June (2018) with the primary goal of completing communications initiated during the planning phase of the project.

The IDSS will continue to be utilized in the evaluation of field studies and of ex post studies of consequences of SSI interventions. Moreover, taking into consideration data and results analysis, the IDSS will be employed in the development of strategies to alleviate constraints identified by national stakeholders to the adoption and use of SSI and in scaling these results to watershed and national levels. Synthesis of results across the four project components commenced in year four and will increasingly be the ILSSI focus for the remainder of phase I (year five of the project).

Also during year five, the ILSSI team will consolidate research findings across the four ILSSI components into a comprehensive phase I report (see below for Final Report Preparation). The ILSSI final report will relate project results and findings to stakeholder communications at multiple levels of scale, thus leading to the adoption and use of SSI in farmers' fields, as well as in the application of analytic methods for planning and evaluation of national policies and strategies to enhance the livelihoods of farmers.

Final Report Preparation

The content and anticipated preparation schedule for the final report have been initiated with partners and will commence in the first quarter of year five. Completion of the report is scheduled for mid-July 2018 in anticipation of conclusion of the ILSSI agreement on August 12, 2018.

Schedule for Development of Final Report (2018)

August 12	End ILSSI Phase I
July 16	Final report and annual report to USAID
July 6	Final Partner Review and Inputs to ILSSI Final and annual Reports
June 29	Draft Final and Annual Report to Partners
June 22	Inputs from writers to ME – final and annual reports
May 31	Final guidance and call for papers to writers from ME
May 15	Review and update on status of background paper and final/annual reports
April 30	Semi-annual report to USAID
Feb 1	PMC meeting with international symposium – detailed plan and schedule for completion of ILSSI Phase I and Reports
Nov 15	Title, Scope, Authors for Related Capstone, Exit Strategy
Nov 8	Outline of Final Report and Related Papers
Oct 31	YR 5 Annual Report to USAID

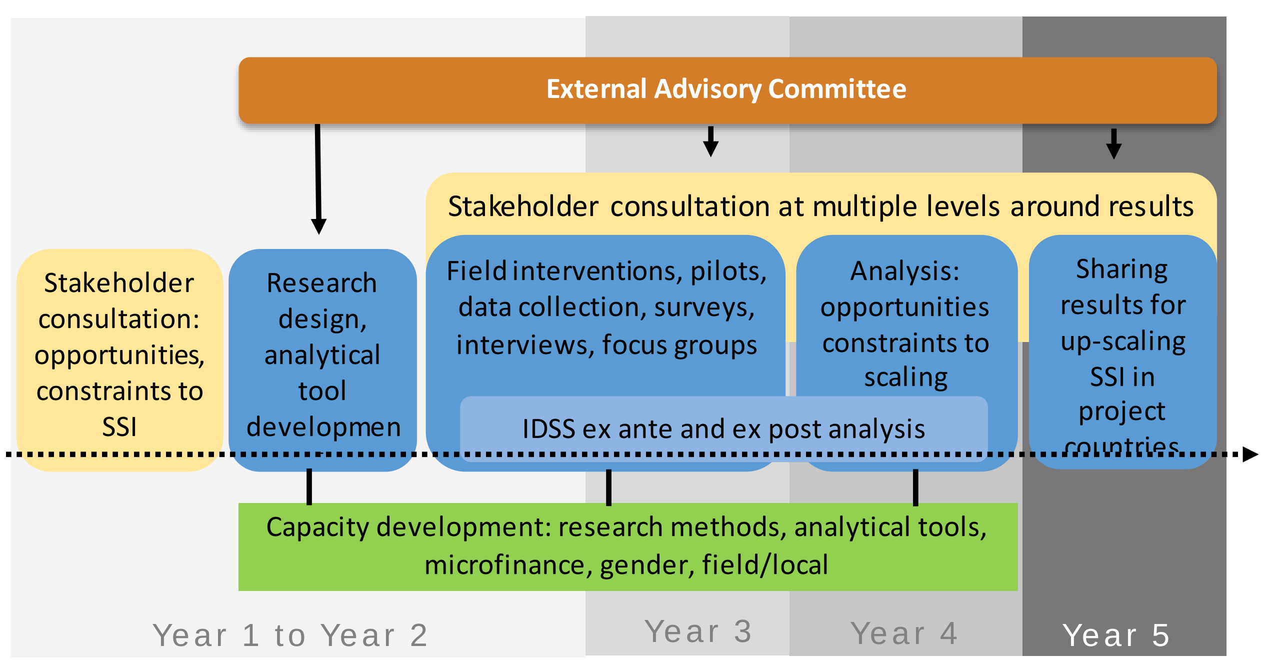
II. Research Program Overview, Structure, Activities and Highlights

The ILSSI project is led by the Borlaug Institute for International Agricultural at the Texas A&M University System (BI/TAMUS). Partners in this five year 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). National universities and other in country institutions, participating actively in field and household survey research, are sub-contractors to international center partners; these include Bahir Dar University in Ethiopia, Sokoine Agricultural University in Tanzania and the University of Development Studies in Ghana.

ILSSI's leadership is comprised of the director, co-director, program manager, and the program management committee (PMC), which includes the leader from each of the partner institutions. The PMC maintains ongoing engagement via regular email communications and Skype meeting, as well through an annual meeting. The External Advisory Committee (EAC) is comprised of three country representatives (one each from Tanzania, Ghana, and Ethiopia) and a representative each from the private sector and the environmental community. While addressing the operational and ongoing year four project agenda, the PMC and EAC focused primary attention on (1) assessing and defining the integrated ILSSI product in terms of outcomes aimed at identified elements of the ILSSI stakeholder community and (2) developing strategic communications to USAID leadership and to the ILSSI External Review Committee (ERC) regarding the assessment of project progress.

This cooperative agreement supports research aimed at increasing food production, improving nutrition, accelerating economic development, and contributing to the protection of the environment. The overarching components of this cooperative agreement are: (1) the assessment of promising small scale irrigation (SSI) technologies and locations in the three target countries (Tanzania, Ghana, and Ethiopia) where irrigation is sustainably feasible; (2) stakeholder consultation at multiple levels of scale to define and evaluate the interventions 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 and cross cutting elements of the agreement.

Figure 1: Summary of the Major Elements of ILSSI Research, Capacity Building and Stakeholder Engagement, Including Year Five



The proportion of total funds for each partner correlates to the expectations for level of effort. The budgetary distribution for ILSSI is: BI/TAMUS (management entity and IDSS) 40%, IWMI 30%, IFPRI 15%, ILRI 10% and NCA&T 5%.

III. Key Accomplishments

A. USAID progress indicators

- Short-terming training was provided to 259 farmers, 61 government staff, 30 private sector actors and 115 members of civil society. Training ranged from practices and tools for on-farm water management and fodder production for farmers, to use of data collection and analysis using the IDSS (suite of models).
- ILSSI initiated research on 9 new technologies or management practices and in addition, undertook field testing of 8 new technologies. In addition, 15 new technologies were made ready for transfer.
- As part of ILSSI's commitment to enhancing research capacity in each country, 24 students received degree-related training and support, including research design, data collection, field research methods, publication preparation mentoring, and assistance to participate in national and global scientific conferences.
- A central part of ILSSI research was undertaking 28 water resources sustainability assessments. This included 6 transboundary basins and 13 basins within countries.
- ILSSI undertook 2 national-level consultations on key policy issues related to irrigation and irrigated value chains in Ethiopia, notably irrigated fodder.
- ILSSI produced 23 publications, 11 scientific conference presentations, 20 technical reports and 2 student theses, as international public goods during the reporting period.
- Unique data sets produced include: gender and nutrition at intra-household, on-farm water management, hydrological data (including shallow groundwater).

B. Major research results and activities

Cross cutting results

- Multiple benefits and on-farm/off-farm impacts of each technology need to be considered in programming beyond technical efficiency and income. SSI technology can benefit labor saving, improved yields, water productivity, profitability, and multiple purposes, with some overlap, but not in all cases.
- On-farm field trials showed that farmers tend to over- or under-water when new to irrigation, often in relation to perceived water availability. Easy to use irrigation scheduling tools improve water use. Government agencies in all project countries show interest; ILSSI is providing training on the tools.
- Small scale irrigated fodder production can be profitable as a cash crop (e.g., growing fodder markets), improving on-farm livestock (e.g., fattening), and stock productivity (e.g., milk); levels of profitability vary.
- Irrigation improves nutrition through an income pathway rather than a production pathway.

- Irrigating households produce approximately 3X the value of output in terms of US dollars than non-irrigating households. There is significantly higher food security among irrigators.
- Irrigation can empower women, but only with careful targeting and programming for each context. Empowerment scores, roles of women and men, contributors to women's disempowerment, distributions of benefits and costs – all such factors vary by country. Work burden is a major factor in all cases.
- Conservation agriculture (CA) methods have multiple benefits that support climate resilience. In addition to improved yield, irrigation water use significantly reduced, soil quality improved, and soil moisture content improved. The IDSS shows improved performance/yield under temperature stress.
- Decision makers, at national, program and project level, are beginning to use decision making tools in the IDSS. Other Innovation Labs and national government agencies are engaging with ILSSI to apply IDSS for planning.

Ethiopia

- There is high potential for SSI in Ethiopia. IDSS showed that SSI technologies could be used to develop irrigation in 0.8 million hectare, with 0.5 million for vegetable crop production and 0.3 million for pulse and root crops. The net income to farmers that adopt SSI would be around USD 250 million per year.
- Integrated use of shallow groundwater and surface runoff can support the irrigation water requirement and avoid negative environmental externalities, but not groundwater alone.
- Irrigation scheduling increases water productivity, improves yield and crop quality, and increases profitability and income, with reduced labor costs and fertilizer inputs. Nutrient loss also declines.
- Field studies and IDSS showed that nearly all water lifting technologies are economically feasible with high value crops and reasonable terms of credit. Labor is a major cost and constraint to sustainability.
- Access to credit increases SSI adoption under favorable terms. Adoption increases the closer a farmer is to a market and to a rural finance institution. Farmers prefer informal sources of credit at present.
- Ex ante assessments showed irrigated fodder is economically competitive with other crops; farmers in the ILSSI irrigated forage trials increased from 14 in 2014 to 357 in 2017), as did land allocations.
- Women and men farmers prefer solar pumps with groundwater for multiple purposes and saving labor.

Ghana

- Water quality and soil types are suitable for irrigation in the basins assessed by ILSSI.
- Irrigation scheduling tools increased water productivity and yields.
- SSI is profitable for motorpump water lifting and production of high value vegetables (e.g., onion and corchorus). Inter-planting onion with leafy greens such amaranth increases profitability. Labor is a major cost in irrigated production, but upfront costs of technologies and fuel constrain investment. Solar pumps offer a feasible technology.
- Prices at farm-gate and at local markets vary. ILSSI provided a schedule of prices for various crops to enable farmers to plant earlier to obtain better prices.
- Farmers added plots at the perimeter of the project sites and participating farmers increased plot numbers and sizes. Seed producers are producing seeds in the study area for ILSSI farmers.
- Based on identified issues and in response to stakeholder requests, ILSSI is currently assessing demand for irrigated fodder to identify potential markets and test production, links between SSI adoption and credit access, and the role of the private sector in the SSI supply chain.

Tanzania

- In on-farm field tests, yields improved under deficit irrigation for high value vegetable. ILSSI is supporting changes to the recommended crop water requirements so they are reduced.
- Motorpumps are financially feasible for high value vegetable production. *If* credit costs are reasonable and credit accessible, the payback period for motorpumps would be less than one year.
- As a homestead garden option to improve nutrition for households, pocket gardens use less water and labor than conventional gardens and women can control the small income from sales.
- At watershed level, the effects of irrigation technologies on hydrology are being monitored. Equipment is in place and data being collected to use in the IDSS to assessments on potential for scaling, and consider both postive impacts and negative externalities that require mitigation when SSI is scaled.
- Sokoine University is integrating irrigations tools shared by ILSSI into the model farms, for educating young scientists and also demonstrating to extension workers and other related stakeholders.

IV. Research Progress Report

This year four annual report is explicitly organized around the year four and five-year work plan objectives for ILSSI and the revised format for this report, as mandated in new USAID guidance.

Integration of Results: In year four and continuing into year five, the products and results of the research components are organized into an integrated framework that brings together the components in order to provide important insights on the potential use of small scale irrigation technology and related knowledge that will enhance the use of precious water resources and to support the livelihoods of smallholders in Tanzania, Ethiopia, and Ghana.

A. Field Research

IWMI

SUA undergraduate irrigation engineering students installing drip systems in Rudewa. Photo credit: SUA

In year four, IWMI continued to collect data across Ethiopia, Ghana, and Tanzania from the field irrigation interventions on water access (lifting and field distribution), water management (irrigation scheduling), and the cost-benefit of small scale irrigation. In Ethiopia, IWMI continued to assess methods to break up the hardpan toward sustainable groundwater recharge and water access for SSI. Recognizing the potential water scarcity as more production is irrigated, as well as competing water uses from other sectors, IWMI has aimed to test a number of new technologies at the field level. These new technologies can be applied to identify water stress and to indicate optimal amounts of irrigation at different production stages, all toward achieving sustainable intensification through SSI. The field trials have provided 2 to 3 seasons of data in Ethiopia, which has enabled the use of the IDSS to assess water resources at multiple scales, while jointly identifying potential advantages and constraints. The second season of data was collected in Ghana and Tanzania, which follows from the later programmatic start date in these two countries. IWMI's action research approach to the field interventions also provided an action research-based learning plan on field level issues for farmers, which complemented emerging results from the IDSS. As part of the field interventions, participating farmers in field trials continued training on the use of various technologies and practices related to irrigation scheduling and irrigated agronomy. IWMI's field activities were completed in partnerships with national tertiary institutions (Bahir Dar University in Ethiopia, University for Development Studies in Ghana, and Sokoine University of Agriculture in Tanzania). Data was collected by field assistants and graduate students at the partner universities, as part of capacity development under ILSSI.

Farmer in Robit, Amhara Region.
Photo credit: Desalegne Tadesse, IWMI.

The IWMI field trials, supported by the IDSS analysis, demonstrate that farmer practices of both over- and under-irrigating across sites does not achieve maximum productivity or profit. In some areas, groundwater may be insufficient for full dry season irrigation, and is clearly inadequate for multiple irrigated cropping seasons. While this suggests the need for more investigation into suitable areas for irrigation using groundwater, it also indicates that effective irrigation scheduling techniques are needed for sustainable SSI. Irrigation scheduling tool utilization generally reduces the incidence of overwatering, which may be critical in areas that are prone to water scarcity. In limited cases the tools increased water use to achieve higher productivity and quality. Generally, IWMI research results indicate higher water productivity where irrigation scheduling is applied, thus resulting in improved yield and crop quality, reduced costs of labor and fertilizer inputs, and potential to improve household income through SSI.

Nearly all water lifting technologies can be economically feasible if crops are high value and credit for technologies and other inputs is obtained at a reasonable cost (Table 1 below). Some crop-technology combinations show potential for strong profit and household income increases. Technology payback period ranges between less than 6 months (i.e., one or two cropping seasons) and up to almost three years. One caveat to the profitability assessments relates to family labor, which traditionally has not been included in cost-benefit analysis. Research and field studies have shown that when family labor is measured and included in costs at local labor rates then profitability decreases (see, e.g., Dangila site in Table 1).

Table 1: Summary of economic feasibility of water lifting technologies for high value vegetables.

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

MP: Motorized pump
RWH: Rainwater harvested (rooftop)
IRR: Internal Rate of Return

++, + and – represent a high, medium and low effect; 0 is neutral.

While research suggests that access to finance will increase the likelihood of technology adoption, across the cases studied, the terms of payment (interest rates, repayment schedules, methods of debt collection) may reduce profitability or create strong disincentives to farmers to borrow for irrigation investments. Rates for borrowing vary widely by location and lender, and many farmers pay above official market rate for credit because they lack access to formal sources of credit and funding. Nearly all of the farmers surveyed and that participated in focus group discussions stated that semi-formal or informal sources of credit are preferred, rather than financial service providers, due to the perceived harsh repayment terms and methods of formal avenues.

Some crops show potential for higher profitability across technologies (such as local leafy greens that are not commonly irrigated) but might also have nutritional impact on dietary diversity in the market. 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 in order to benefit from higher prices. Labor is a major emerging factor for decision-making and SSI adoption across cases, as it affects cost and profitability, as well as labor constraints in rural households. Household gender and age structure likely influence willingness to apply for credit to invest in SSI, as well as willingness to adopt and sustain use of SSI technologies. Modalities for interventions with groups of farmers need to consider group size; group size dynamics need to be and will be investigated further in future research activities.

Table 2: Summary of the opportunities and challenges related to each of the water lifting technologies towards the control (example from Ethiopia ILSSI sites)

	Labor saving	Yield	Water productivity	Profit	Multi-purpose use
Control (bucket/watering can)	0	0	0	0	0
Rope'n'Washer pump	0	0	0	-/0	+
Solar driven motorized pump	++	+	0	++	++
Service provision: water suppliers & drip	+/-	++	++	+/-	-

++, + and – represent a high, medium and low effect; 0 is neutral.

In general, the emerging results suggest that multiple benefits and impacts need to be considered beyond technical efficiency and cash income (Table 2). For example, the introduction of manual water lifting technologies may increase household income and enable multiple water uses, but may not reduce labor input. In other cases, mechanized technologies, such as petrol pumps, may save labor and increase incomes, yet not reduce overall household labor or enable improved access to water for the household for multiple uses. For example, motorized pumps that are kept in the home for security or shared with other farmers must be moved to the field for each use, which can require household labor. Therefore, technology selection should be considered across a range of potential benefits for households, as well as local and national development goals.

Drip Irrigation on raised beds, Yemu Ghana

Further details regarding the research and emerging findings in each of the countries is available upon request.

ILRI

In year four, ILRI continued data collection from the field irrigation interventions for irrigated fodder across Ethiopia and to a lesser extent Tanzania and Ghana. In Ethiopia additional activities were implemented optimizing management of irrigated forages and testing multi-use of irrigated forages for fodder, food (grain legumes), soil improvement (N and organic matter enrichment), and water-use efficiency

Fodder Market in Ethiopia

(breaking of hardpans for improved groundwater recharge). In Tanzania and Ghana irrigated forage technologies were implemented later in the project, resulting in lesser adoption in these countries than in Ethiopia. In Tanzania and Ghana forage technologies are still in a farmer testing and piloting stage. It is clearly emerging that interest in irrigated forage technologies is greatest in Ethiopia, followed by Tanzania and finally Ghana. This ranking correlates positively with importance of livestock in the countries and inversely with farm sizes. In Tanzania fodder market value chain work was undertaken and in Ghana is currently taken up to more strategically explore and locate demand for fodder.

In Ethiopia strong evidence exists that small scale irrigation for fodder production takes hold. Table 3 shows the increase in number of farmers participating in ILSSI irrigated forage schemes. The number of participating farmers has grown from 14 in 2014 to 357 in 2017. Furthermore, initial land allocations of 100 m^2 per farmer have been extended in many farms to 1000 m^2 and above. The increase in numbers of farmers participating was both cause and effect of the engagement of influential regional and central players in agriculture and livestock research, extensions and policy formulation. Farmer field days and stakeholder meetings convinced these players of the interest in and opportunities of irrigated forages, which, in turn, resulted in further promotion. These findings are significant for Ethiopia and beyond. There are widespread perceptions among the development and research community that farmers with very small farm-holding (often of less than a ha) will not allocate arable land and water to fodder production. The Ethiopia experience proves this to be incorrect by indicating that irrigated fodder production can be a very attractive intervention for improving on farm livestock stock productivity and/or as an income opportunity from fodder as a cash crop.

Farmers participating in discussion on Irrigated Fodder

Table 3: Farmers adopting annual (oats - vetch mixes) and perennial (Napier, Desho) irrigated forage options in two projects sites in Ethiopia

Year	**Site**	**Forage Technology**	**Farmers/Year**	**Farmers/ Aggregated**
2014	Lemo	Annual	14	14
2015	Lemo	Annual	59	73
	Robit	Perennial	17	17
2016	Lemo	Annual	49	122
	Robit	Perennial	23	40
2017	Lemo	Annual	132	254

	Robit	Perennial	43	83
Total				357

Preliminary ex ante assessments based on forage yield, forage fodder quality and farm gate prices for animal produce (such as milk and meat) suggested that irrigated forage production will be economically competitive with food crop production and even with market oriented vegetable production.

In Ethiopia considerable efforts were expended during the reporting period to explore multi-use and multipurpose opportunities of forages. Grass and legume forages and food crops and legume forage/food feed crops were intercropped. The objectives were to increase and improve simultaneously and on the same area of land: 1) overall forage quantity and quality; 2) soil fertility through N enrichment; and 3) physical soil properties and water infiltration. The findings from intercropping Napier with a short (PP 1) and medium (MD) duration pigeon pea is presented in Table 4. ILRI research indicates that intercropping increased Napier yield and fodder quality traits.

Table 4: Effect of pigeon pea intercropping on Napier yield and fodder quality.

	Yield (t/ha/1st cut)	Crude protein (%)	IVOMD (%)
Napier sole	3.27	8.3	49.1
Napier + PP 1 (SD)	4.88	12.5	51.2
Napier + PP 2 (MD)	4.34	11.5	51.3

Along similar lines pigeon pea intercropping increased maize yields in a trial exploring effective ways to break hard pans.

NCA&T

Sweet potato Harvest, Nov 2016, Yemu Ghana

During year four of the ILSSI project managed by NCA&T, volunteer farmers at several experimental study sites in each of the three countries planted variety of vegetables under conventional tillage (CT) and conservation agriculture (CA), both under drip irrigation: Dangishita (garlic, tomato) and Robit (cabbage) in Ethiopia; Yemu (sweet potato, cucumber and green pepper) in Ghana; and Mkindo (African nightshade, amaranth and cabbage) in Tanzania. Harvesting of vegetables went well in all locations except for the case of tomato in Dangishita, which was damaged by unusual frost. In addition, Robit farmers were able to grow only the first dry cropping period (2nd season didn't work due to water shortage and higher priority to chat plant). Yemu faced challenge for efficient production due to lack of interest in farmers, engagement in various communal activities, and the culture of mono-cropping in the area. Similarly, second season of production in Mkindo did not do well due to pests and disease. Extension activities provided farmers with training on how to prepare and apply organic pesticide from locally available neem tree which is currently being used very effectively. Farmers and other stakeholder meetings were conducted locally by Bahir Dar University (BDU) in Ethiopia, Sokoine University of Agriculture (SUA) in Tanzania, and International Development Enterprises (iDE) in Ghana to train farmers and maximize the benefit from commercial vegetable home gardens (CVHGs). Two masters degree students are supported by the project for working in CVHGs study sites. Overall, the demonstration sites collected a good amount of data for statistical analyses and modeling, while at the same time demonstrating the positive impact of conservation agriculture such as drip irrigation for significant water, labor, and cost savings while also increasing vegetable yields.

Groups of female farmers from Yemu after an information session meeting with iDE

Cabbage under conventional Tillage Practices

A one tailed, paired t-test was carried out to compare vegetable yields and irrigation water uses from CT and CA plots. Vegetable yields were found significantly higher under CA compared CT; garlic, cabbage, sweet potato, cucumber yields were increased by 46%, 9%, 57% and 85% respectively. On other hand, irrigation water uses were significantly reduced under CA compared to CT; irrigation water used was lowered by 18% and 44% for cabbage and garlic respectively. No tillage practice improved soil quality as reflected from the growing vegetable yields. iDE claimed to observe improved soil quality under CA in terms of increased water-holding capacity, nutrient availability, fertilizer use efficiency and productivity. Likewise, BDU observed higher soil moisture content and reduced crop coefficient under CA plots.

The APEX model was evaluated at all study sites for its capability in simulating field hydrology and vegetable yields. Modeled water balance and vegetable yields were evaluated using various performance measures including NSE (Nash-Sutcliffe efficiency), PBIA (Percent bias), RMSE (Root Mean Squared Error), RSR (observation standard deviation ratio), and R^2 (Coefficient of determination). The model, after the successful calibration, was applied to examine the impacts of conservation agriculture on hydrology and vegetable growth. Water loss was found to decrease significantly (Dangishita and Robit sites in particular): evapotranspiration (ET) and surface runoff (Q) decreased by about 55~84% and 52~92% respectively. On other hand, water savings was increased tremendously under CA, as depicted from increased percolation (one and half to seven times more compared to CT). Likewise, crop parameters from the model result indicated improvement under

CA in terms of leaf area coverage and temperature stress conditions, resulting in increased vegetable yields. Current plans of work for year five will continue field experiments and data collection strategies until Feb of 2018. Statistical analysis and modeling for the newly collected crops will be followed. Extended modeling exercise will be conducted to examine the impacts of upscaling of CVHGs to a larger scale.

B. Household Surveys

In year four, IFPRI, along with national partners, implemented the endline household surveys in Ethiopia and Tanzania and initiated preparation of the endline survey in Ghana. The following provides a brief summarization:

Intra-household distribution over rights following technology adoption.

Irrigation-Nutrition linkages: The research on irrigation-nutrition linkages and the pathways through which irrigation influences nutrition shows that access to irrigation significantly improves both household income and the diversity of crops that farmers produce. Increasing household income, in turn, leads to higher dietary diversity, while increases in production diversity do not contribute to increases in dietary diversity. Thus, irrigation in the study areas is likely to influence nutritional outcomes through an income pathway rather than through a direct production pathway. This is consistent with other literature on this topic, which has shown that when production diversity is already high, the association between production diversity and dietary diversity is insignificant or even turns negative, likely due to foregone income benefits from specialization. The paper summarizing these results is currently under review at *Food Security*.

Irrigation significantly improves both household income and the diversity of crops that farmers produce

Additionally, IFPRI published a practitioner-directed piece titled "Beyond the Drinking Glass: Expanding Our Understanding of Water-Nutrition Linkages" in *Field Exchange* (February 2017, Issue 54) focusing on the major potential pathways through which irrigation can influence nutritional status.

Irrigation-Gender linkages: IFPRI's quantitative Irrigation-Gender linkages research work in year four using the first round of household surveys in Ethiopia, Ghana, and Tanzania shows several preliminary findings with concrete policy implications. First, the results show that the relationship

Anthropometric training as part of the survey training at Sokoine University.

between women's empowerment and irrigation is not straightforward. Results are inconsistent across the three countries with irrigators in Tanzania and Ghana associated with higher empowerment scores and irrigators in Ethiopia associated with lower empowerment scores. Second, men's and women's roles in irrigated agriculture are different across the three countries: women in Ghana and Tanzania have more input into irrigation decisions than women in Ethiopia. Third, the contributors to women's disempowerment vary, although work burden (lack of leisure time) and lack of group participation are common in all the three countries. Credit access was a bigger constraint in Ghana and Tanzania for women's empowerment, while speaking in public is a bigger problem in Ethiopia. Fourth, the research indicates that irrigation may lead to a different distribution of benefits (and costs) among different household members, requiring for in-depth intra-household analysis. Fifth, without conscious effort to integrate gender (for instance, on needs, preferences, and constraints), irrigation interventions may exacerbate existing gender inequalities. Sixth, outcomes (i.e. nutrition, health and women's empowerment) are likely to be different when women have control over decisions to adopt and use irrigation. This research work by Bryan et al (2017) was presented at IFPRI's Annual Research Day is being finalized for journal submission.

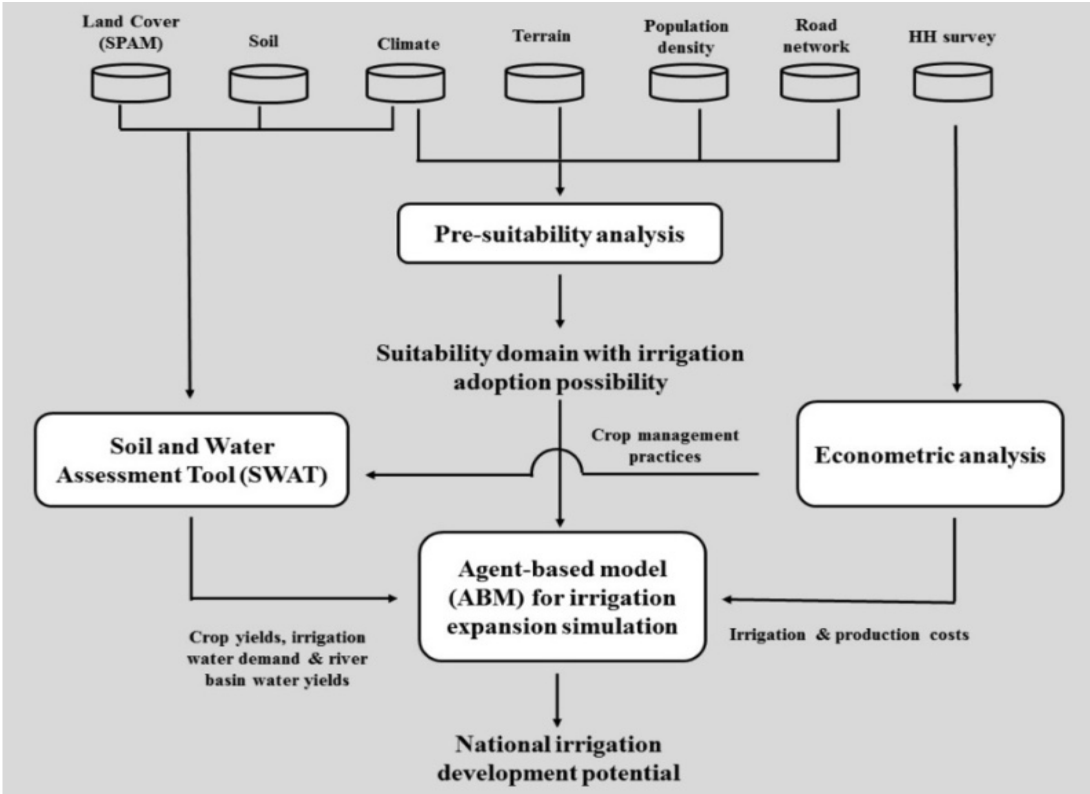
ILSSI Farmer using solar powered pumping to irriaate.

IFPRI's qualitative irrigation-gender linkages work, in collaboration with IWMI, led to a new conceptual framework for examining the intrahousehold distribution of benefits from technology adoption, focusing on small-scale irrigation technologies. Drawing on qualitative data from Ethiopia, Ghana, and Tanzania collected under ILSSI, the framework contributes to the conceptual and empirical exploration of jointness in control over technology by men and women. This is done by identifying a series of decisions following technology adoption, and how these decisions affect how the technology is used, by whom, to whose benefit, and with what costs. Given the focus on technology adoption as a strategy for agricultural development and women's empowerment, understanding the intrahousehold distribution of costs and benefits and the jointness of control over a technology can help guide technology promotion in a way that advances programming objectives, rather than simply interpreting technology adoption as an end in and of itself.

C. IDSS

The Integrated Decision Support System (IDSS) is a suite of proven, interactive and spatially explicit agroecosystem models: The Soil and Water Assessment Tool (SWAT); the Agricultural Policy/Environment eXtender (APEX); and the Farm Scale Nutrition and Economic Simulation Model (FARMSIM). Together, these models predict short and long-term changes in production of crops for people and livestock, farm economies and environmental services produced by changing land uses agricultural technologies, and policies, climate, and water resource management.

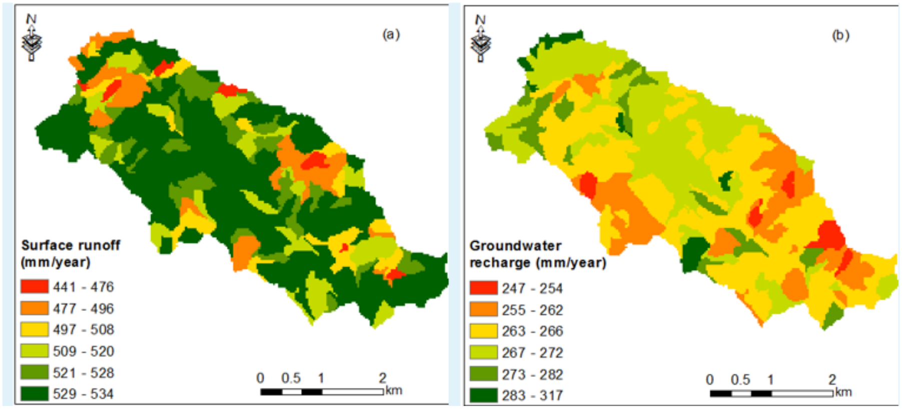
Figure 2: Methodological framework for assessment of national SSI development potential



IDSS models were used to study ex-post and gap and constraint analysis of the impacts of small scale irrigation at the farm level. The IDSS and Agent Based Modeling (ABM) were used to study the scaling of SSI to the entire country in Ethiopia.

The water resource potential of the Robit, Dangishta and Lemo sites in Ethiopia were assessed. Long term daily rainfall data was analyzed to characterize the metrological drought using Standard Precipitation Index (SPI). The SPI analysis indicated high rainfall variability with a significant rainfall amount occurring during the dry season, but the dry season rainfall amount was not found enough to support vegetable and fodder production. Moreover, the shallow groundwater recharge alone was not sufficient to support the optimal crop water requirement for tomato and onion production in the Robit and Dangishta watersheds since there are other competing demands such as household and livestock use. The field-scale analysis also indicated that soil evaporation attributed a significant proportion of evapotranspiration (i.e. 60% of the evapotranspiration for onion and 40% for tomato). Use of mulching or other soil and water conservation interventions could improve crop water use efficiency by reduce soil water loss and also enhance shallow groundwater recharge. Therefore, integrated use of shallow groundwater and surface runoff may support irrigation water requirement and also avoid negative environmental externalities.

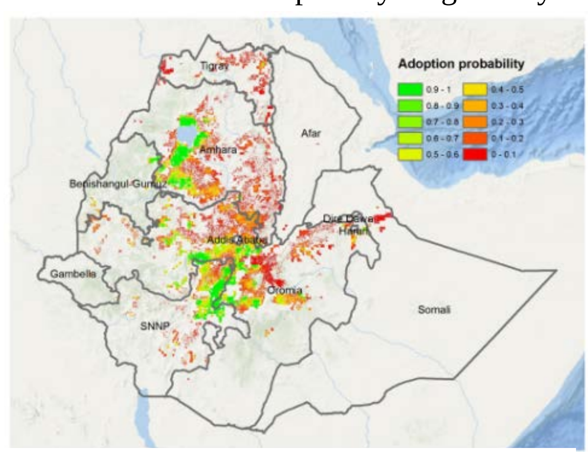
Figure 3: Water resource potential of Robit watershed; (a) annual average surface runoff (mm/year) and (b) annual average groundwater recharge.



Gaps and constraints analysis of fodder production was accomplished using 30 randomly selected farmers in two different ecological zones in Ethiopia. Half of the farmers grow Napier or Elephant grass (Pennisetum purpureum Schumach) in Robit watershed. The other half of the farmers grow mixed oats and vetch in Lemo watershed. The field data indicated a strong relationship between yield and amount of water applied. The simulation indicated nitrogen and phosphorus as the major yield limiting factors followed by water and temperature stress for Napier. In Lemo, oats yield was limited by nitrogen while vetch yield was limited by temperature.

The assessment of profitability and nutrition from the use of SSI technologies to grow vegetables and fodder during the dry season show a positive economic and nutrition outcome. However, in a few cases the cost of production indicated losses or reduction in profit and nutrition. Although there was deficiency in calcium intake, the increase in fodder production for sale and animal feeding was an important factor in milk production increase and consumption at the household level, as well as subsequent nutrition improvement.

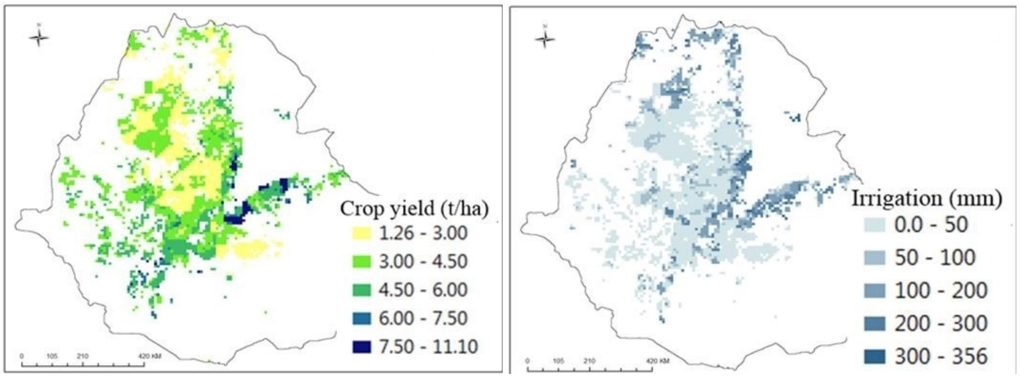
Investment in irrigation tools such as pumps led to an increase in irrigated areas, crop production and thereby better cash profit. Similar results were observed with the application of fertilizers in optimally irrigated systems. The use of drip irrigation technique produced higher yields and profit than in furrow-irrigated systems. Nutrition analysis showed that households that generated profit from vegetables and fodder sales had great potential to buy supplemental food items (e.g. animal products) to complement the nutrition and assure food security at the household level.



Adoption probability or transferability of small-scale irrigation technologies across Ethiopia

Biophysical modeling and ABM were used to assess national development potential of small-scale irrigation. Such analysis were also used to map adoption probability or transferability of small-scale irrigation technologies across the country. The IDSS was used to simulate 9 major rain fed crops and 6 dry season irrigated crops including fodder. The simulated dry season irrigated crops were cabbage, onion, pepper, tomato, lentils and fodder crop (vetch). ILSSI findings showed that that substantial amount of vegetable yield can be produced using irrigation during the dry season. For example, under favorable agroclimatic conditions, the pepper yield could range from 1.26 t/ha-11.10 t/ha across the agricultural fields. The irrigation water requirement could range between 31 mm and 685 mm, which is available in most parts of the country. However, the shallow groundwater and surface runoff should be used in an integrated manner for environmental sustainability.

Figure 4: Pepper Yields under irrigation (left) Irrigation water requirement for Pepper (Right)



Adoption of small-scale irrigation technologies could occur over a large spatial area in the Ethiopian highlands with the highest potential being in the Rift Valley of Ethiopia, and around Lake Tana. The total potential area for small-scale irrigation development in Ethiopia is estimated to be 0.8 million hectares, of which 0.5 million hectares can be used for vegetable crop production and 0.3 million hectares can be used for pulse and root crop production. The net income generated from the irrigation development to farmers who adopt the small-scale irrigation technologies will be around $250 million USD/yr. However, this estimate may vary based on the choice of the small-scale irrigation technologies and associated adoption cost. It is important to be cautious when implementing SSI since it may result in water scarcity. For example, this study found that SSI adoption may pose higher risk of water scarcity in the Rift Valley basin.

V. ILSSI External Collaboration

Continuing in year four, ILSSI has maintained successful external collaborative efforts with USAID and other funded projects.

FtF Innovation Laboratory Collaboration

ILSSI partners and the FtF Nutrition Innovation Laboratory, along with Bahir Dar University in Ethiopia were awarded a contract by the FtF Sustainable Intensification Innovation Laboratory (SIIL) to study the impact of sustainably intensified production systems on household nutrition. As part of this collaboration, ILSSI is also working with the SIIL Appropriately Scale Mechanization Consortium (ASMC)—a pilot study with the FtF Horticulture Innovation Laboratory to apply the IDSS to the analysis of results of farm level studies in Uganda is continuing with expected first application of the IDSS to field data in August 2017.

IFPRI also played an active part in this collaboration. Specifically, IFPRI implemented the baseline SIPSIN survey together with the ILSSI endline survey in Ethiopia. Combining the two datasets will enrich the efforts of both ILSSI and SIPS-IN; for ILSSI, more detailed nutrition data are now available for a subset of ILSSI households, as well as actual measurements of malaria and anemia. Of note, in the first round, not a single case of malaria was detected in the dry (irrigation) season in the SIPSIN study area. Moreover, IFPRI also collaborated with the Appropriately Scale Mechanization Consortium (ASMC) by incorporating a module on tools into the ILSSI endline survey.

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.

USAID Mission Engagement

ILSSI leadership meets with USAID Mission staff during each country visit in order to further understand USAID local needs and to report on how ILSSI products are proving to be beneficial on the ground and finding traction in the host country. Engagements with the Tanzania and Ethiopia Missions were made in mid-May 2017. Ethiopia Mission staff visited field research sites in Bahir Dar and provided positive and useful reactions and responses. Follow up briefings were then held in Addis Ababa.

Ethiopia Mission staff visited field research sites in Bahir Dar and provided positive and useful reactions and responses

External Advisory Committee

The External Advisory Committee (EAC) met jointly with the PMC in Dar es Salaam in May 2017 and followed this meeting with a visit to field sites in northern Ethiopia and a meeting with USAID Mission staff in Addis Ababa. The EAC offered strong encouragement to proceed with stakeholder engagement, particularly with the IDSS. Country representatives pledged to participate in stakeholder engagements in year five in order to facilitate successful technology transfer.

Stakeholder Engagement

The major emphases for the remainder of year four and year five will be integrating and organizing the results of phase I and using this to engage multi levels of stakeholders in Tanzania, Ghana, and Ethiopia in order to ensure that any concerns regarding the remainder of phase I have been adequately addressed and that there is full awareness of results in the context of their possible application on the ground. An internal workshop was held at Texas A&M in June 2017 to finalize the format and approach for presenting the ILSSI product as an integrated package that shows how the components come together to provide a unique

NCA&T Demonstrating Conservation Agriculture Practices to stakeholders at the village level perspective on small scale irrigation technologies and know-how.

Field research will be mostly completed in the remainder of year 4 and the final endline household surveys will be completed in years four and five. The ex- post and constraints analyses for all three countries will be completed in year five. Application of new national level natural resources assessments will be continued with government agencies, such as the Agricultural Transformation Agency (ATA) in Ethiopia, in support of their policy and planning endeavors.

ILSSI provided all necessary support to the USAID External Review, which was completed in October of 2017. The full ILSSI team visited the USAID Bureau of Food Security in Washington in July 2017 to brief senior staff and administrators on the current results of the cooperative agreement. ILSSI continues to actively engage the USAID Missions in all three countries to assure their awareness of the product and to explore ways in which both the innovations and the analytic methods can be made useful to the Missions and on the ground. Plans are being made to host an international symposium in Washington, DC in January 2018. The ILSSI mid-term report (November 2016 – http://ilssi.tamu.edu) addresses the exit strategy. Prepared as one input to the review and decision process for renewal, mid-term report presents the conceptual framework and vision for a possible continuation of the agreement.

VI. Human and Institutional Capacity Development

A. Short Term Training on IDSS

During this reporting period, week-long IDSS and Advanced Soil and Water Assessment Tool (SWAT) training workshops were held at the University of Dar es Salaam (Tanzania), Addis Ababa University (Ethiopia), and Kwame Nkrumah University of Science and Technology (KNUST)(Ghana). These workshops were sponsored and partially funded by national universities or/or national water management related organizations, depending on the location of the workshop. A total of 196 participants (142 men and 54 women) were involved for the short term trainings.

Table 5: Number of participants: for the IDSS training

	University of Dar es Salaam			Addis Ababa University			KNUST		
Model trained	M	F	Total	M	F	Total	M	F	Total
SWAT	17	10	27	3	1	4	19	11	30
APEX	9	3	12	6	6	12	13	8	21
FarmSIM	8	1	9				9	4	13
Advanced SWAT	19	6	25	39	4	43			
Grand Total	**53**	**20**	**73**	**48**	**11**	**59**	**41**	**23**	**64**

The workshops included a variety of sessions on the advanced use and application of IDSS models. ILSSI scientists currently serve as mentors to university students who have participated in the workshops, as well as members of graduate committees in national universities for students whose thesis project involves use of ILSSI model components. Field research in all three countries involves employment of graduate students whose participation provides motivated collaboration in ILSSI's project as well as materials which are being used for their theses.

Texas A&M Research Scientist Demonstrating the SWAT model at an IDSS Workshop in Tanzania

At the local farm and village levels, training on the use of SSI interventions is ongoing and is a key component of successful technology transition.

The Ethiopian ATA has requested a special workshop on the IDSS to train their staff to effectively use the system on the ground. Further details on numbers of students trained is available upon request.

Five international students from Bahir Dar University in Ethiopia and Sokoine Agricultural University in Tanzania completed 90-day training courses in the use of the IDSS in residence at Texas A&M at the beginning of this reporting period. These students have returned to their parent universities and are actively engaged in research using the IDSS. Several publications have been written and are being published on the students' IDSS-related research. These publications are under review and are not yet publically available.

B. Institutional Capacity Development

The IDSS team is currently engaged with and supports the Ethiopian Agricultural Transformation agency in developing and evaluating national strategies. Discussions are now are now under way to provide training and continuing collaboration in the application of the IDSS to national planning and evaluation of agricultural transformation strategies. Products of the household surveys are being used in ATA by the gender group as hard data on use of and issues associated with irrigation technology by women farmers.

Bahir Dar University is in the process of institutionalizing the IDSS in their curriculum. Their plan is to make Bahir Dar University as a center of excellence providing IDSS capacity building to the East African region, and applying the IDSS paradigm in their research activities at the university.

The Development Bank of Ethiopia (DBE) previously known as Agricultural and Industrial Development Bank of Ethiopia provides loans to the major development activities in Ethiopia, which includes agricultural, industrial and to other business sectors. DBE supports multiple projects across Ethiopia investing in agriculture sector. They are currently preparing an official letter to demand a capacity building training on the IDSS. In the upcoming ATA tailored training few DBE participants will be invited to attend the training.

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

C. Long Term Training

Long term degree granting education programs are being pursued at Texas A&M University, North Carolina A&T University. In addition, ILSSI is supporting the graduate education of students in partner national universities, most of whom are doing their thesis work and using the IDSS on data related to the project which they are involved in collecting and monitoring.

All students (both foreign and U.S. based) who are *currently* enrolled in a degree program funded in full or part by USAID

Name of Student	Gender	University of Study	Degree [1]	Major	Graduation Date	Home Country	Home Institution [2]
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 University	M.S.	Agricultural Education	August 2016	USA	N.C. A&T
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	Ph.D.	Water resources	June 2018	Ethiopia	Bahir Dar

		University		Engineering			University
Misba Abdela	M	Bahir Dar University	M.S.	Water resources Engineering	June 2016	Ethiopia	Bahir Dar University
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.				
Sintayehu Alemayehu	M	TAMU	M.S.	Env. Sci.	Dec. 2017		

VII. ILSSI Success Stories

The following success stories provide a glimpse into the active and positive engagement of the ILSSI project:

In Robit (Amhara region, Ethiopia) one youth farmer gave up chat production and began producing vegetables; this shift suggests adequate profit to incentivize farmers to produce vegetables rather than chat. Additionally, a group of youth farmers engaged with ILSSI secured land to start irrigated production of vegetables in the dry season.

Also in Robit, in one season a female farmer profited approximately $100 US dollars from tomato and pepper production, enabling her to pay back debt on other productive investments. This particular farmer also stated that her family has increased vegetable consumption from their produce.

Most of the farmers in Zanlerigu (Upper East region, Ghana) decided to increase the number of plots under irrigation. One farmer, in particular, is looking at increasing from 10 plots to 100 plots in this season alone. The area under irrigation has increased, and the fencing around plots has been expanded by farmers. Given the increase in area irrigated, at least two onion seed farmers are now producing seed within the fenced area, which is also under irrigation. These farmers are selling the seed directly to the farmers in the ILSSI plots and within the irrigated area.

In Tanzania, Sokoine University is developing a model farm designed to showcase working agricultural production systems and suitable irrigation technologies (e.g. drip, sprinkler) including best water management practices. Upon learning about the wetting front detectors and other related soil moisture measuring and irrigation scheduling tools under ILSSI, SUA has made the decision to integrate these tools into the model farm, for educating young scientists and also demonstrating to extension workers and other related stakeholders.

The introduction and popularity of irrigated fodder at selected sites was an unanticipated success. The experiments with irrigated forage were described by an ILRI key informant as "*almost an afterthought*" and have proven popular with farmers. Together with Africa RISING, ILRI promoted various forage plants, such as desho and Napier grass, to grow either for use by farmers for their own livestock, or for sale. The number of farmers using irrigated forage increased from 22 to 67 over the course of the project, and key informants interviewed by the ET reported that returns on irrigated forage have proven to be attractive enough for farmers that they have expanded their land under fodder cultivation.

In Ghana, ILSSI project participants reported that the new irrigation technologies they were using (including diesel pumps, rainwater collection) and methods (optimizing water use through WFD and TDR, spacing seeds further apart) were delivering clear benefits to them. These participants also noted that non-project farmers from the community were interested in joining the project. In Bihanaayili, participants reported that they had drawn up a list of 60 farmers, which they had submitted to the ILSSI focal point at UDS.

Thirty two ILSSI farmers were interviewed as part of a focus group and reported that their crop yields had increased following use of the new technologies or practices, in some cases significantly (e.g., double), enabling them to improve their living standards and or/income. In Ethiopia, the project found there was higher than expected demand for irrigated fodder. After using dry-season irrigation, farmers reported yields were twice what they were without irrigation. Irrigated fodder is more nutritious, yielding stock with higher milk and meat yield.

VIII. Issues or Concerns Encountered During the Reporting Period

Research in farmers' fields facilitates adoption of results but, unfortunately, has the disadvantage of lack of experimental control over management adjustments that may be made during cropping seasons, as well as with new plantings that help to assure productivity and profitability. Thus, the quality of data from field studies can present an issue in modeling the results and effectively expanding said results to larger scales. To compensate with the modeling, ILSSI acquires data from multiple national and local sources, including programs sponsored by USAID in the surrounding area. The non-quantitative observational results of field studies provide one key source of "expert opinion" that is being used to drive the IDSS models.

ILSSI's international partners have offices with scientific and support staff in Ethiopia and Ghana but lack this level of in-country representation in Tanzania. This has made monitoring and evaluation and mentoring to national partners in that country more challenging. Consequently, the quality and quantity of product and the timing of delivery from field studies in Tanzania is lower. Issues with scope of effort and delivery of data are also an issue in Ghana, but to a lesser degree. The household surveys and the application of the IDSS in ex ante and ex post studies are generally on schedule and producing the expected product in all three countries.

All CGIAR centers are undergoing very substantial budget reductions, which have resulted in loss of key staff to the ILSSI project and a high demand on remaining staff to take responsibility for more tasks and to participate in fund raising. For ILSSI, this is manifest in both IWMI and ILRI where key leadership at the project level continues to change. Key scientific personnel are also moving to new locations. Despite budgetary and personal constraints, IWMI, IFPRI, and ILRI management remain committed to successful performance in ILSSI.

These, and other factors, contribute to a systematic issue in lack of timely acquisition of data from field studies for delivery to the IDSS component of the project. Data collected by national partners often requires substantial "cleaning" to remove inconsistencies and errors. In some cases, initial contracts with national partners have not been successful and created delays in acquisition of data. Progress is best in Ethiopia; the main issues lie with the field data from the other two countries. Major emphasis will be placed on improved engagement with national partners in the remainder of year four and year five.

Three of the four major ILSSI components are performing on schedule with delivery of results as initially anticipated. The mid-term report shows a high level of productivity with good results over the preponderance of the project. It is expected that a comprehensive final product will be achieved at the end of year five.

IX. Anticipated Engagement for Year Five

A. IWMI

In the final year of the project, IWMI will complete the field studies and field level data collection, as well as field-based analysis. This includes a final season of irrigation interventions in two sites each in Ghana and Tanzania, and completing and collecting data on a final season for the hardpan experiment in Ethiopia. In addition, IWMI will undertake and finalize microfinance research in Ghana and Ethiopia, while conducting joint analysis with IFPRI on the subject in Tanzania and Ghana based on the endline surveys.

Capacity development efforts in the final year will emphasize supporting and mentoring the students engaged in fieldwork to ensure theses completion. Also, IWMI will close out the project and share results following the finalization of interventions in the dry season in each country. Farmer forums and farmer learning exchanges will be carried out with farmers and local authorities (e.g. extension and/or agriculture department) at the subnational level that have participated in the ILSSI project. In addition, IWMI plans to interview farmers to gather information on what farmers learned, particularly toward understanding how knowledge and practices about SSI spread beyond the initial intervention plots. Field and local level engagement activities will be done in collaboration with ILRI and NCA&T to ensure synergies and comprehensive knowledge sharing. Capacity development materials related to the key technologies will also be completed and shared more broadly to support scaling efforts.

Simultaneously, while research is being finalized and efforts in capacity development progress, IWMI will continue to contribute to achieving impact in the project though outreach and engagement at multiple levels. At the field level, IWMI will work with national partners to conduct 'exit' meetings with farmers and local stakeholders in all sites to discuss and document lessons learned and implications for scaling. At the national level, IWMI will work with cooperative partners and national partners to convene key stakeholder workshops to share research results. IWMI will also collaborate with cooperative partners, national partners and the EAC to identify opportunities to contribute to existing networks, platforms, and events regionally and globally to share

ILSSI project results in line with the impact pathways and stakeholder mapping already developed. For example, in Ghana, IWMI will lead a special session on small scale irrigation at a national conference in Tamale at UDS in October 2017 in order to share results from ILSSI and Africa RISING; IWMI is also exploring opportunities to present to the Ag Sector Working Group, as a platform for scaling results across donors and implementers. These are considered key activities to ensure continued impact following the end of phase one of ILSSI. Finally, with the feedback from these consultations, IWMI will lead the development of a series of knowledge products for each country, cutting across all project components that synthesize research-based evidence based on the information needs of stakeholders identified in earlier consultations.

B. ILRI

ILRI's planned activities for year five of the project include:

Ethiopia

1. Continuation of data collection on irrigated fodder in the project sites in Ethiopia.
2. Evaluation of forage biomass yield and quality to be used as input into ex ante assessments.
3. Capacity development and stakeholders' engagement dialogue on irrigated fodder production.
4. Develop comprehensive brief on irrigated forages for ATA to influence Ministry's development and investment plans.
5. Support upscaling of irrigated forage technologies.

Ghana

6. Continuation of data collection on irrigated fodder in the project sites in Ghana.
7. Evaluation of the nutritional value of the tested fodder species and feed samples from the survey on market potential of irrigated fodder.
8. Completion of the survey on the market potential for irrigated fodder, data entry and analysis, and report of the survey.
9. Capacity development and stakeholders' engagement dialogue on irrigated fodder production.

Tanzania

10. Continuation of data collection on irrigated fodder in the project sites in Ethiopia.
11. Evaluation of forage biomass yield and quality to be used as input into ex ante assessments.
12. Capacity development and stakeholders' engagement dialogue on irrigated fodder production.
13. Synthesis of the survey on the market potential for irrigated fodder.

Results and findings from each of these activities will be included in year five project reports.

C. IFPRI

At the beginning of year five, IFPRI will implement the endline household survey in Ghana. IFPRI will also finalize a series of research papers on irrigation-nutrition and irrigation-gender linkages. An additional paper will focus on determinants of and constraints to adoption of small-scale irrigation with a focus on entry points for policy engagements. IFPRI will also work with TAMUS to finalize the upscaling analyses for Ghana and Tanzania in year five.

IFPRI will also increase outreach with end-users of the research in year five, including the coordination of an ILSSI AGRILINKS seminar on gender-irrigation linkages, which will primarily focus on implementers of USAID technical assistance projects, participation in a small-scale irrigation conference at the World Bank in January 2018, which primarily focuses on multilaterals and African policymakers, support to the final ILSSI conference in early 2018 with a broad focus, including USAID staff, Feed the Future Innovation labs and African policymakers, as well as participation in other relevant events, such as Stockholm World Water Week, Africa Water Week and the World Water Forum. IFPRI or national partners will also participate in the final in-country outreach events of ILSSI in year five.

D. NCA&T

Field data monitoring is on progress and will be continued until February 2018. BDU, iDE and SUA will continue to assist farmers and monitor data collections. Statistical analysis and modeling for the newly collected data will take place upon successful completion of data collection. Focus will be given to upscale experimental and modeling results from commercial vegetable home gardens. This will help to evaluate the large- scale adoption of CVHGs under conservation agriculture.

E. IDSS

Ex post studies and constraints analyses for each country will be completed in year five. Data from field and survey research will be incorporated in the final report for the IDSS.

The IDSS analysis and the multi-criteria GIS suitability analysis of Small Irrigation Intervention in Ghana and Tanzania are already started and scheduled to be completed in quarter 2 of year five and will be included in future reports. Like Ethiopia, this further analysis will help to assess national development of potential of small-scale irrigation and map adoption probability or transferability of small-scale irrigation technologies across these two countries. Drafts of these studies will be available for the AOR in December 2017.

ILSSI agreed to establish a Memorandum of Understanding (MoU) with ATA and the Ministry of Agriculture and Natural Resources (MoANR) to facilitate the use and adoption of the IDSS in order to better inform decisions on the impacts of agricultural transformation agendas on biophysical and socio-economic factors. ATA and MoANR staff requested further, continued training in the use of the IDSS so that they are adequately equipped to use the suite of models themselves, singly or collaboratively, to inform current and future decisions related to small scale irrigation technologies. ILSSI will provide customized training/education on the application of the IDSS to the specialized areas of application/interest to the ATA, MoANR, and their partners.

The Development Bank of Ethiopia (DBE) also requested to receive IDSS capacity building training to improve its staff skills in the agriculture sector. DBE is also interested to get the outcomes of ILSSI (e.g. spatial irrigation suitability maps) to prioritize investment areas across the country.

Bahir Dar University is interested in institutionalizing IDSS at the Blue Nile Water Institute. Bahir Dar University plans to serve as a center of excellence in providing IDSS capacity building to the East African region, and also applying the IDSS paradigm in its research activities. The BDU president requested ILSSI support until the BDU program is self sufficient.

F. Innovation Transfer and Scaling Partnerships

In the context of the continuum from input to output to outcomes to impact (Figure 5), ILSSI will utilize the IDSS in an analytic capacity to model both outcomes and impact from the outputs of field research. This provides an ability to estimate the results of technology transfer that have not been previously available to USAID. ILSSI is using this capability to forecast the production, environmental and economic consequences of SSI innovations in advance of the actual adoption and use of the results. The IDSS also provides the ability to scale results from field studies and household surveys to larger scales up to national levels, thereby providing stakeholders and decision makers at these levels with a new capacity to assess the consequences of ILSSI results to larger scales. Stakeholder engagement in the development of related infrastructure at local levels is being scaled up and out as an important part of the scaling effort. The national level models for assessing natural resource and economic impact of new technology also provide national stakeholders with a very important planning methodology. ILSSI plans to continue its active engagement with national stakeholders for the remainder of year four and into year five; these collaborations will foster efforts to enable local/in-country stakeholders to utilize the IDSS applications based on their specific needs and to provide capacity development workshops on the successful transfer of these methods to practice for their respective staffs. A recent summary of small scale irrigation technologies which have been evaluated by ILSSI is available in a tabular format that projects the estimated time at which specific capacities will be ready for adoption.

Figure 5: ILSSI Technology Transfer Continuum

X. ILSSI Data Management Plan/USAID Requirements

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

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

Texas Data Repository

ILSSI has partnered with the Texas Data Repository (TDR), an online platform for Texas A&M University researchers to publish and archive datasets and data products.

The TDR is built on Dataverse, an open source software developed by Harvard University. The TDR is hosted by the Texas Digital Library, a consortium of Texas academic libraries focused on long term access and preservation of digital content. The TDR is committed to preserving and providing ongoing access to research data for at least 10 years after submission.

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

Dataverses

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

The ILSSI Dataverse is organized by country and region. It contains sub data verses named after countries, these country dataverses contain sub dataverses named after regions, and they may also hold datasets that apply to the country level

Each regional sub dataverse includes datasets relevant to that region. Each dataset may be based on a different model and analysis conducted in a region. More information on the on the structure of the ILSSI Dataverse can be found Here. ILSSI has begun working with the researchers at Texas A&M to upload the IDSS dataset to the Dataverse; this process is scheduled to be completed by September 30th, 2017. Subsequently a link to the Texas A&M Data sets will be uploaded to the USAID Digital Data Library (DDL) by October 30, 2017.

Field level Data Storage

In addition to the data created and stored at within the TAMU Dataverse, it is also recognized that the data storage requirements for our field level partners are like those required by USAID. As such, the data generated by our partners is being stored in Dataverses and other web spaces unique to each institution and datasets. For example, IFPRI stores data on a Dataverse hosted by Harvard University, while IWMI stores data on an internal water portal with the data being linked back to Texas A&M. Links to these data sets will be included and uploaded to Digital Data Library. In addition, ILSSI will also explore the option of linking these data sets to the ILSSI data to have a central location for all ILSSI Data.

XI. Environmental Monitoring and Mitigation Plan (EMMP)

ILSSI's current EMMP describes monitoring, advice and other activities intended to evaluate and mitigate any possible consequences of the project as it is conducted in farmer's fields at very local levels. While USAID (ILSSI) does not procure or distribute agrichemicals as part of the project's protocol, farmers do purchase and use these chemicals, often on the advice of their extension agents. ILSSI notes these uses and provides advice where indicated. Areas of concern are reported to appropriate government officials for engagement with farmers. In August 2017 ILSSI conducted a meeting with multiple agencies of government regarding results of water sampling for agrichemicals. Follow on actions were identified and are to be implemented after the next round of sampling in September 2017.

The ILSSI team applies the IDSS to model and assess the impact of SSI interventions involved in field studies at larger levels of scale – watershed and beyond. The IDSS predicts available land and water resources appropriate for sustainable small-scale irrigation. For both ex ante and ex poste studies, the IDSS estimates the environmental consequences at the watershed level of the various SSI interventions used in field studies and the range of variables, such as fertilizer, used in these interventions. While the environmental consequences of actual field studies are negligible due to the small size of research plots, the IDSS allows these results to be evaluated at a relevant level of scale.

It is assumed that the available land area suitable for sustainable and profitable small-scale irrigation – as predicted by the IDSS initially – is irrigated using the interventions conducted at the field studies. The SWAT (Soil and Water Assessment Tool) model is used to estimate the environmental impact of these interventions at the watershed level. This includes such variables as the downstream effects of upstream use of ground and surface water, the estimated agrochemicals that may be attached with runoff or sediment from fields, the draw-down of aquifers and river flow such as baseflow and high flow. Where available water is less than optimum for best irrigation results, the IDSS estimates the amount of available water so that best use can be made of the limited supply using best available irrigation technology such as drip irrigation.

One example of the IDSS was the ex-ante analysis of the Robit watershed in Ethiopia showed only 6% less water than what would be available with the introduction of small scale irrigation at the most downstream point of the watershed studied. Similarly, in Ghana, a study site indicated the ground water is available in limited form, thus only 67% of the watershed land area were suitable for irrigation.

The ILSSI team is currently exploring the feasibility of applying SWAT to the assessment of the effect of the indicators in our current EMMP (which only addresses the field plot level) in order to more accurately estimate the environmental consequences at the watershed level. It is anticipated that the environmental effects at the watershed level to also be negligible (the SWAT will document this result), which could be very relevant to the ILSSI project and EMMP. In addition to showing that the environmental consequences of ILSSI interventions are minimal, the application of SWAT also demonstrates a capacity of the IDSS.

These additional analyses represent a demonstration of the utility of the IDSS for a more meaningful assessment of environmental implications in research in SSI, as well as much broader interventions than SSI.

A. Year 5 EMMP Plan

The ILSSI project has monitored field interventions to ensure that the project does not cause adverse effects on the environment or present risks to populations in the project area. To that end, the ILSSI project developed an environmental monitoring and mitigation plan (EMMP) under USAID guidance which outlined a set of indicators appropriate to each intervention site and created a template for monitoring. The project sought to ensure that ILSSI does not promote pesticide intensive crops or the field application of pesticides in the project's field interventions. ILSSI has not been involved in committing resources to demonstrating activities in interventions that pose risks. To help ensure implementation, ILSSI team provides continuous training of national partners on the EMMP, such that the sub-contracted national partners also follow the guidelines and support monitoring; they sign a document stating they understand and agree to uphold the EMMP.

Interventions are reviewed each year with farmers and research scientists, and the EMMP is also revised as needed, based on any new issues that have emerged. While the project does not collect data for each indicator in the EMMP, it monitors key components and also raises awareness of farmers and local partners on those indicators.

The ILSSI team has implemented the EMMP monitoring as planned and has not identified any instances in which the project interventions caused adverse effects to the environment or local population. Though the ILSSI project anticipates closing field interventions in late 2017/early 2018, the team plans to continue EMMP monitoring for the short remaining duration of phase I where field implementation is taking place. At the end of the project, the team plans to summarize the results of the EMMP in the final report.

Table 6. EMMP for each country with context relevant indicators for field implementation period.

Indicators	Ethiopia	Ghana	Tanzania	Remark	Findings
Water – safety (fecal contamination)	Yes	Yes	No	In both Ghana and Ethiopia the water sources uses for irrigation are also used for domestic use	No contamination has been caused by the field interventions. Fecal coliforms were found in one surface water body tested in Ghana in the watershed, but not in the project interventions sites.
Erosion/sedimentation	Yes	No	Yes	Sediment concentration in streams is monitored	
Agro-chemicals	Yes	Yes	Yes	Fertilizer application under irrigation is monitored	No adverse impact has been observed
Sustainable irrigation (water quantity)	Yes	Yes	Yes	Soil moisture is monitored throughout the irrigation season to estimate potential leaching.	No leaching has been observed in the farmers' plots. Farmers are being trained in irrigation scheduling to improve water use efficiency. IDSS and field analysis suggests that optimizing water use could enhance fertilizer use

					and in some sites potentially reduce the quantity needed against current use.
Water quality	Yes: N,P,K	Yes: pH, EC, N, P, K	Yes (EC, N, P, K)	Manual water sampling of water resources used in irrigation	Water quality for irrigation varies by site but no observed cases where water is not suitable for irrigation.
Soil quality	Yes	Yes	Yes	Soil samples before and after the experimental implementation are taken of the top soil and analyzed on standard soil physical and chemical properties to assess potential depletion of soil fertility due to irrigation	Soil type/properties vary by site but no observed cases where soil is not suitable for irrigation.

Table 7. EMMP for each country: Additional context relevant indicators post- field implementation.

Indicators	Ethiopia	Ghana	Tanzania	Remarks	Results
Malaria	Yes	No	No	Post-intervention testing for malaria in endline survey through SIPSIN.	N/A
Water borne diseases	Yes	No	No	Post-intervention survey for malaria in endline survey through SIPSIN	N/A
Water balance					N/A

XII. List of Publications

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