FEED THE FUTURE

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

Semi-Annual Report
April 1, - September 30, 2015

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

II. Foreword

This report is organized under the structure of the approved workplan for project year two. Progress and accomplishments are related to objectives of the plan. Objectives that will be addressed in future years are not presented.

The Borlaug Institute, as the management entity (ME), has established subcontracts with its partners that are explicitly linked to the workplan. Partners report their progress in detail to the ME; the ME uses these reports as part of its performance assessment for partners in accordance with the Program Management Plan. These reports are then summarized in the semi-annual report submitted to USAID and are retained as reports on the subcontracts and under the Open Data initiative.

In year two, the Feed the Future ILSSI moved from predominantly a planning effort to initiating research and producing results. A table of contents, summary and references were added to help guide the reader through the report. The order of presentation coincides with the major work plan headings. Countries are listed in the same order under each major objective and the reporting organizations are also listed in a consistent order under each country.

III. Research Progress Summary

This cooperative agreement was formed to undertake research on small scale irrigation 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 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 households 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 in farmers' fields. Capacity building and training at multiple levels of scale are also substantive elements of the agreement. As the lead institution, Borlaug Institute for International Agriculture/Texas A&M University System (BI/TAMUS) is responsible for leadership, management and administration of the overall cooperative agreement. Partners to 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).

The first year of the agreement 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. Early research also began on field studies, household survey design and ex ante analyses of the consequences of small scale irrigation interventions using the Integrated Decision Support System (IDSS).

Research was initiated in Ethiopia, which served as the pilot country to develop integrated methodologies among partners, and was subsequently rolled out in Ghana and Tanzania. Collaborations with other USAID supported research, including other innovation laboratories were pursued; and joint activities are taking place in at least one Africa Rising site in each of the three countries. At the end of the second year, sub-awards were established with national partners in all three countries and field research continues.

Initial results of small scale irrigation interventions in farmers' fields were obtained in Ethiopia; protocols were then adjusted to reflect initial experiences, farmer training on use of interventions were conducted and engagement with stakeholders at the woreda and district levels has been maintained to allow for two-way research and feedback. Research sites and groups of farmers with interest in the project were established in Ghana and Tanzania followed by initiation of research. Equipment is in place in farmers' fields and specific protocols for implementation and data collection have been established. Lessons learned from the initial experiences in Ethiopia have been incorporated in the plans for comparable implementation in Tanzania and Ghana.

Baseline household surveys were completed and analyzed in Ethiopia; surveys in Tanzania have been completed and results are being analyzed; the survey instrument is being tested in Ghana for application in baseline surveys in the first quarter of project year three. The surveys explore gender- and nutrition-related factors along with economic consequences of the irrigation interventions. Surveys will be re-conducted late in the project and compared to baselines to assess the impact of irrigation, particularly in the dry season.

The application of the IDSS for ex-ante analyses of the consequences of small scale irrigation interventions was completed and reported for Ethiopia at the end of project year two. Similar studies for Tanzania and Ghana, initiated in project year two, will be completed in the first quarter of project year three. Data from multiple sources, including the ILSSI field studies and surveys, were used as input for the various baseline models that are part of IDSS. The impact of both field-tested interventions and other options are being assessed in relation to baseline models of the farming systems in watersheds surrounding the field research sites. Results obtained from Ethiopia compare the relative merits of multiple small-scale irrigation interventions and the importance of several elements of the related farming system in which the interventions are introduced. The IDSS provides estimates of the water availability for irrigation and assesses the upstream and downstream environmental consequences of the interventions. The system provides a stochastic estimate of the economic and nutritional consequences of these interventions.

Capacity building, training, and education activities are well underway. Farmers are receiving training on the use of small scale irrigation interventions and related farming practices and access to credit; local and district extension workers are actively collaborating on field studies. IDSS training workshops were sponsored by Bahir Dar University in Ethiopia and Sokoine University of Agriculture in Tanzania for approximately 70 and 50 students, faculty and private sector representatives. Graduate students are attending Texas A&M University and North Carolina A&T State University in graduate degree programs. Other students will attend Texas A&M for three months of training in the IDSS. Post-doctoral fellows are actively engaged in all parts of the ILSSI team for field work, survey implementation and analysis. Graduate students in national partner universities are actively participating in conducting field research and are using their experiences for their theses.

Leadership for ILSSI involves the Program Management Committee (PMC), led by Texas A&M with participation by the senior members of each participating partner. The committee has monthly Skype calls and held its annual face-to-face meeting in Morogoro, Tanzania, in July 2015. This assures ongoing consideration of strategy and timely consideration of opportunities and issues affecting the project. The USAID AOR is an ad-hoc member of this committee. The PMC met with ILSSI's External Advisory Committee (EAC) in Morogoro, July 2015. This committee is comprised of a representative from each country where research is being conducted, one from the private sector and one from the environmental community. The committee provided a summary report regarding year two progress following the July meeting.

ILSSI is actively pursuing external communications using the ILSSI website which has been substantially upgraded in year two. Seminars and briefings have been provided to the USAID Bureau for Food Security and for the USAID Missions in the three countries where research is being done. Engagement with private sector entities in these countries through sub-contracts has also ensued along with collaboration between national, regional, and local stakeholders and government entities. ILSSI has ongoing discussions with five other innovation laboratories for collaboration on related topics.

A. Research progress made during the reporting period by Component

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

IWMI has organized multi-year sub-contracts with national partners in all three countries: Ethiopia (Bahir Dar University, Arba Minch University (AMU), Send a Cow Ethiopia, and three local cooperatives); Ghana (University for Development Studies); and Tanzania (Sokoine University of Agriculture). In addition, ILRI has similar multi-year sub-contracts, as follows: Ethiopia (Amhara Regional Agriculture Research Institute, Southern Agricultural Research Institute); Ghana (CSIR Animal Research Institute); Tanzania (Sokoine University of Agriculture). Furthermore, NCA&T has multi-year sub-contracts, as follows: Ethiopia (Bahir Dar University); Ghana (International Development Enterprise); and Tanzania (Sokoine University of Agriculture). IFPRI had shorter-term contracts with Tanzania (Sokoine University of Agriculture) and Ethiopia (Association of Ethiopian Microfinance Institutions and Ethiopian Public Health Institute).

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

1.1. Small scale irrigation interventions, management, and practices

ILRI applied the Feed Assessment Tool (FEAST) in Ethiopia, Tanzania and Ghana including elements of Focus Group Discussions (FGDs) in all three countries (8, 9, 10, and 11). FEAST characterizes on-farm feed resources in the context of crop and livestock resources, ranks the importance of constraints perceived by farmers and identifies entry points for feed interventions. The growing demand for FEAST has increased demand for training and placed a considerable strain on ILRI's staff, to the detriment of other activities. Therefore the existing materials have been converted into a blended learning course with both online and offline modules, with a re-designed face-to-face component.

IFPRI: Survey protocols were adapted by IFPRI from Ethiopia for application in Tanzania and Ghana (6). A template for Focus Group Discussions (FGDs) was developed to be applied in all three countries, including each of the intervention communities and one control community. The FGDs seek to better understand factors related to technology adoption, as well as priority uses for water and labor requirements related to those water uses. Similar FGDs will be held in Tanzania in December 2015 (under IFPRI) and in Ghana in January 2016 (by IWMI) following the installation of all interventions. The questionnaire for the FGD focuses on the livelihood of the households, the roles and responsibilities within the household in relation to water use and technology adoption. Gender disaggregated data will be collected based on FGDs held with female and male farmers. The study will form the basis for a detailed follow up study on gender sensitive factors underlying adoption and dis-adoption of project technologies. IFPRI reports that fieldwork on the household level baseline survey and the sex disaggregated survey has been completed in Ethiopia and Tanzania. The baseline survey includes direct ILSSI beneficiaries, farmers with irrigation that are not part of ILSSI, as well as control farmers with no access to irrigation. IFPRI is currently cleaning and analyzing the data for Ethiopia and Tanzania to write research papers and has shared the data for Texas A&M University for use in the FARMISM model. Moreover, preparation for the survey in Ghana has been finalized. A contract has been signed with the University of Development Studies in Ghana to serve as the survey implementer. Enumerator training for the survey will begin on October 15, 2015, and the field work is expected to be finalized by the end of November, 2015.

IWMI: The FGDs were implemented by IWMI during September 2015 in Ethiopia (Dangila, Robit, and Lemo as ILSSI intervention sites) and Abagerima (control site). In addition, a protocol on credit and finance access and mechanisms was developed by IWMI as related to small scale irrigation that includes questionnaires for interviews and the focus group discussion (FGD) framework. Implementation of this protocol began in Ghana September 2015, and will be adapted to Ethiopia in the first quarter of project year three.

NCA&T reports that women farmers who volunteered to test commercial vegetable home gardens (CVHG, i.e. kitchen gardens) under drip irrigation and conservation agriculture technologies were chosen from the Feed the Future target areas in Ethiopia, Tanzania and Ghana. IWMI identified the villages and also recommended partners. Partners identified women who volunteered to conduct CVHG with drip irrigation and conservation agriculture.

1.2. Characterization of Site specific interventions planning and analysis

Ethiopia

IWMI: Available secondary data with regards to soil maps, land use and other relevant information have been collected in Ethiopia with the various district offices and made available to TAMAR. In Adami Tulu, Lemo and Angacha the baseline survey on water lifting technologies and credit access was finalized by TAMAR. In addition sites that form part of the Africa Rising and LIVES project are being characterized. BDU's baseline and event-based storm water samples have been collected since June 2015 and sediment quantity analyzed for Dangila and Robit. Groundwater levels have been monitored on a daily basis at both Dangila and Robit using open shallow wells and piezometer tubes, with locations shown in Figure 1. Note: Danghista is the village in the Dangila woreda/district.

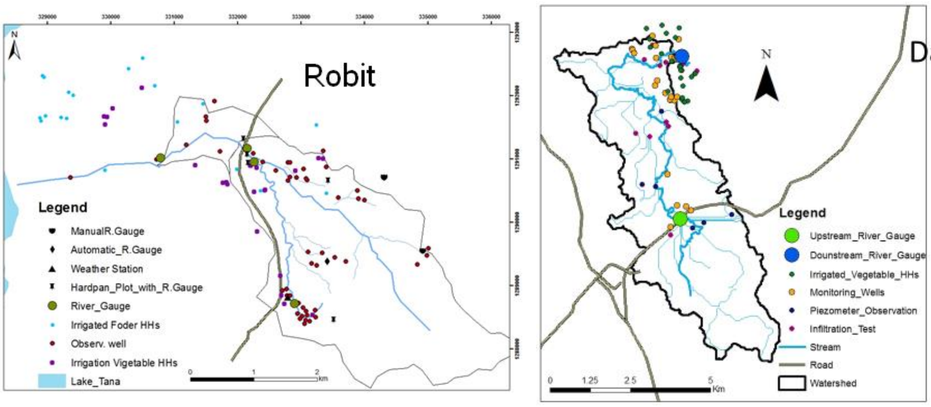

Figure 1: Overview of the monitoring locations and field experiments in Robit (left) and Dangishta (right)

The hard pan experiment was initiated in June 2015 as planned. Data on soil moisture change, runoff, and overall maize performance is being collected at regular intervals for the various treatment plots: zero tillage, traditional oxen tillage (20-30cm) and manual deep tillage (hard pan braking up to 60cm). TAMAR conducted water quality analysis of specific wells in Adami Tulu and tested it against standardized and sodicity specific parameters.

An overview of the intervention sites in Ethiopia is illustrated in Figure 2.

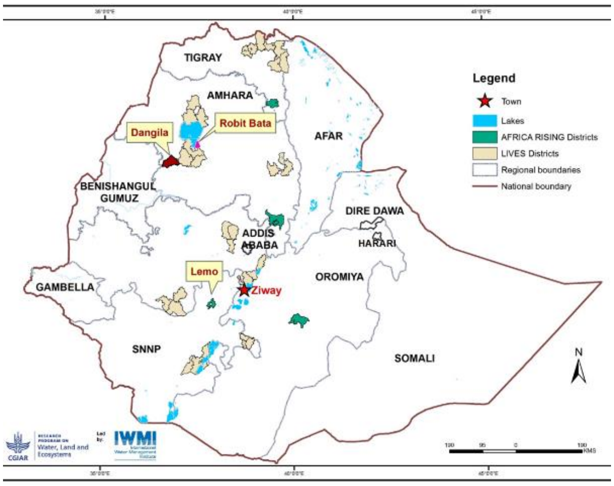

Figure 2: Overview of the selected ILSSI intervention sites in Ethiopia with respect to the LIVES and Africa Rising sites.

ILRI: Using FEAST, the farming systems in Lemo and Angacha Districts were described. Major livestock production challenges, opportunities and possible potential interventions with special emphasis on livestock feed and related aspects for the improvement of livestock production and productivity were identified. Three sub-villages were purposively selected from the kebele based on the availability of irrigation practices. A total of 45 farmers (15 from each sub-village) were selected for focus group discussions. Female participation was encouraged. Farmers were selected based on wealth category (small, medium and large landholdings). Livestock production in the kebele was a type of semi-intensive system. Respondents in the three sub-villages mentioned a variety of purposes for keeping livestock, such as milk and meat production, source of cash (from sale of animals and their products), manure production, draught power (traction, threshing, and transport) and replacement stock. The average milk yield pear animal in Abiy, Gutoso and Mehal Kerekicho sub-villages was 2.1, 1.7 and 1.3 liters/day, respectively. Major livestock feed resources in the area were naturally occurring and collected fodders and crop residues. During the rainy season, naturally occurring and collected grasses were the most important feed resources in the study sub-villages. Availability of naturally occurring and collected fodders largely relies on rainfall and was adequately available only from June to October. Crop residues supplemented with enset leaves (*Ensete ventricosum*) were the main livestock feed sources during the dry season of the year. Feed was not in surplus at any time in the study sub-villages and November to June is a period of critical lack of feed resources.

From the Robit Bata kebele, three sub-villages (Deri Gedel, Jimma Midir and Terara Gichamintola) were selected for the focus group discussion. The three sub-villages were selected because they represented the ILSSI project area. In addition, the study sites are afflicted with hard rock pans and ground water is not easily accessible. A total of 45 farmers (15 from each sub-village) were selected for focus group discussion. Mixed crop-livestock production was the major production system in the three sub villages. The number of households in Deri Gedel, Jimma Midir and Terara Gichamintola were 400, 876 and 707, respectively. Livestock were considered as the backbone of crop agriculture. The type of livestock production system found in the three sub-villages was extensive where only during *Kiremt* cattle were kept around the homestead and fed using a cut and carry system. Major feed resources in the three study sub-villages in order of importance are crop residues, both naturally occurring and collected feeds and grazing. Even though crop residues represent the largest share of livestock feed, none of the farmers applied chemical or mechanical treatment methods to improve intake of crop residues or to reduce fodder.

NCA&T: In Ethiopia, fifteen volunteer, female farmers were identified in the Amhara region; eight in Robit Bata, and seven in Dangila. Drip irrigation system set-ups were provided to each of the farmers. Each volunteer has a well and at least 100 m^2 of land for growing vegetables beside their homes. Treatments are drip irrigation with conservation agriculture and drip irrigation without conservation agriculture. Water storage tanks, drip irrigation hardware, and a mechanical system to lift water using a pail to the storage tank are being tested. The women smallholders will pay for the tanks but not for the drip hardware. The payments will go to their group as capital to be lent to other women who will, in return, start to use drip. Inputs like seed and extension assistance is being provided by ILSSI. Labor from drip irrigation, without drip irrigation, and with and without conservation agriculture is being recorded in addition to yields. Onions were grown during the dry season. For Robit Bata, tomato was the first crop and was tested only in one plot due to unavailability of seedlings. For the one plot, the conservation agriculture system failed and only 70 kg was harvested in the tilled system. Because of lateness in seeding the onions, there was a crop failure in Robit Bata for all home gardens. In Dangila, three of seven home gardens had harvests. Yields in all three were higher under conservation agriculture (average 14 kg), compared with the tilled system (average of 7 kg).

Ghana

IWMI: Secondary information and data on hydrology and agronomy of the three watersheds are scarce and generally not available in published literature. Preliminary information and data have been collected from three key sources: the Ghana Meteorological Agency (GMET), online pages of the district offices of the Ministry of Food and Agriculture (MOFA) - now known as the District Agricultural Development Units (e.g., http://mofa.gov.gh/site/?page_id=1658) and published literature. Hydrological watersheds, based on 90 m resolution SRTM digital elevation model, have been delineated for the three project sites, namely, Zanlerigu (Nabdam district, Upper East Region), Dimbasinia (Kasena-Nankana East district, Upper East Region), and Bihinaayilli (Savelugu district, Northern Region). The sizes of these watersheds are Zanlerigu (17.4 km^2), Bihinaayili (19.5 km^2), and Dimbasinia (35.8 km^2). These watersheds were used as the areal extent for which hydrological and agronomic information and data were collected. Data on amount of rainfall harvested within the distributed tanks and its usage are being collected as well as other weather variables at the weather stations installed at Zanlerigu and near Dimbasinia. The consolidated weather data at Bihinaayili are being collected from Tamale Airport. Daily rainfall data are being collected at all the three sites.

An overview of the intervention sites in Ghana is presented in Figure 3.

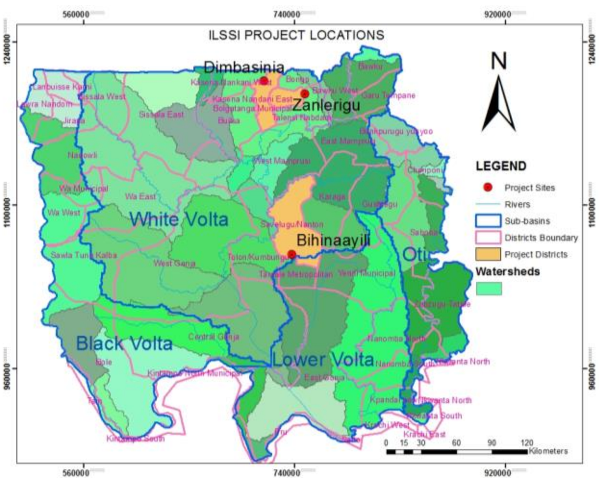

Figure 3: Overview of the selected intervention sites, Ghana.

ILRI: Existing and potential feed resources were evaluated in Northern and Upper East region of Ghana using FEAST. Two villages, Duko in Savelugu district of the Northern region and Zanlerigu in Nabdam district of the Upper East region were selected for the study. The study sites were characterized by mixed crop-livestock production systems. The major crops grown in both areas were maize, rice, millet, sorghum, groundnut, soybean yam and cowpea, which are all mainly grown during the raining season. Eighty percent of the farmers practiced mixed cropping where cereals and legumes are planted in the same field while others mono-crop on small plots. Four major livelihood activities contributed to household's income: crop farming, livestock rearing and businesses, labor and remittances. The main contributor to household income is crop farming and off farm labor in Duko and Zanlerigu, respectively. Sheep were the dominant livestock species in Duko, while draught cattle dominated in Zanlerigu. Grazing, from natural pasture and crop residues left on the field, contributed the largest proportion to livestock diets in terms of dry matter (DM), metabolizable energy (ME) and crude protein (CP) in Duko while collected crop residues contributed most in Zanlerigu. Disease was described by the farmers as the first constraint in Duko and shortage of water was identified by farmers as a major problem facing livestock in Zanlerigu. In both sites problems of livestock housing ranked second in order in importance. To mitigate these constraints farmers suggested an integrated approach to improve livestock production: collecting roof rain water for dry periods using small concrete reservoirs around the homestead to provide water for household use and to reduce pressure on the wells thereby making more water available for livestock. Irrigated fodder production using high yielding forages and planting of food-feed crops such as pigeon pea (*Cajanus cajan*) as edge rows in irrigated crop land was seen as an option. Interventions must also include proper animal healthcare.

NCA&T: In Ghana, 15 female volunteers were identified in Nyangua community, Northern Ghana, which is an Africa Rising site. This work is done together with the NGO iDE. Reyes presented the study to the women and gave a background on drip irrigation and conservation agriculture technologies. Most women home gardeners have shallow wells, similar to the situation in Ethiopia. Reyes and iDE Ghana Director (Kiger) met two times and finalized the treatments and the protocols. Contracts between iDE and NCA&T are very close to being completed. It is expected that by October/2015, iDE will start the CVHG study. A clear protocol on how data will be gathered and analyzed in commercial vegetable home garden experiments in the three countries will be established.

Tanzania

IWMI: Baseline biophysical data for field studies is being collected by the national partner, Sokoine University of Agriculture.

An overview of the intervention sites in Tanzania is illustrated in Figure 4.

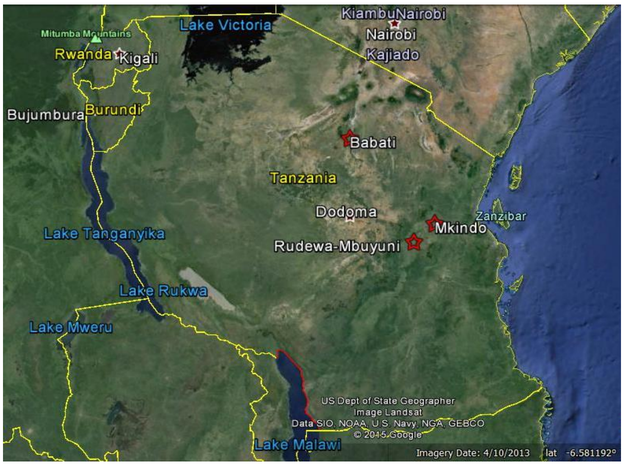

Figure 4: Overview of the selected intervention sites, Tanzania.

ILRI: FEAST was used to describe the production system in Babati district in the villages of Hallu, Matufa and Shaurimoyo. The results are currently being analyzed and synthesized. Preliminary findings suggest that availability and extent of communal grazing will largely determine the opportunities for planted and irrigated forages. However it is important to realize that farmers perceive a range of problems with different urgencies and feed shortage was ranked highest in only one site. Key issues identified were lack of improved dairy breeds, market access and market prices for live animals and livestock products and a shortage of livestock feeds particularly in the dry season.

NCA&T: Due to contract delays, CVHG experiments have not been fully installed in the gardens of the 20 participating women. Some plot demonstrations were started and several women had prepared the beds to compare conservation agriculture with tilled systems.

1.3. Targeting Framework

IWMI: Households were selected in both sites for Tanzania. In total 64 households were selected (about 30 households per site) within the Morogoro region. Corresponding GPS locations were collected by the national partner (SUA) and shared with the team.

ILRI: Various potential multipurpose forage options based on grasses (Napier, Desho (*Penisetum pedicullatum*), Rhodes grass (*Chloris gayana*), Panicum maximum, Oats, (*Avena sativa*) Wheat (*Triticum spp*) and legumes including Pigeon pea (*Cajanus cajan*), Vetch (*Vicia vilosa*), Dolichos (*Lablab pupureus*), Desmodium Greenleaf, Alfalfa (*Medicago sativa*), Cowpea (*Vigna unguiculata*), and Arachis pintpoi have been identified to: 1) increase livestock productivity and income from selling of forages, 2) improve soil fertility; and 3) break hardpans. Cropping of these forages as a single crop or intercropped is currently modeled to optimally match the forage option, sites and crop and livestock system.

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

2.1. Collation of data

IFPRI: The sub-national data for Ethiopia, Tanzania and Ghana have been compiled. These are district-level data (second administrative unit in a country) for 40 crops, mostly from 2005 to 2010. We have also compiled and processed spatial data (maps) for cropland and existing irrigation for these three countries. The cropland map for Ghana turned out to be challenging as the cropland maps from different sources (NASA, China 30 m global land cover product) differ significantly, and a hybrid map had to be created to deal with the uncertainty of the satellite images. Other input datasets for SPAM (Spatial Production Allocation Model) are ready and the first SPAM run is almost completed. The SPAM results will be delivered the TAMAR team by the end of October 2015.

Ethiopia

ILRI: In Angacha and Lemo 36 (31 male, 5 female) farmers willing to allocate at least 100 m^2 to irrigated crop production were selected to test Napier and Desho forages options. Row distance in Napier and Desho were 0.75m and 0.40m, respectively, while distances within rows were 0.50 m and 0.25 m for Napier and Desho, respectively. Data collected were watering rate per day, labor requirement, forage biomass yield, farmers' perceptions and potential market price of forage produced. Desho grass, which is more drought resistant than Napier, established quicker than Napier and showed promising biomass development after only three months, see also Figure 5.

Forage species	Planting date	Harvesting date	Height (cm)	Fresh wt/hectare (ton)	DM/hectare (ton)	Estimated cost /hectare (ETB in 3 month)
Desho	11/04/2015	15/07/2015	61.60±4.47	75.40±7.68	5.66±0.58	11320.00

Figure 5: Performance of irrigated Desho grass in Angacha (after three months since planting)

Feeding of Desho grass increased average milk yield by about 1 kg per day from 1.5 to 2.5 kg. Participating farmers declared willingness to double land allocation to Desho from 100 to 200 m^2.

In Robit Bata three Napier accessions (16764, 16793 and 16543) were planted on about 1500 m^2. 16 farmers (9 male, 7 female) participated down from the original 32 farmers that claimed interest to participate in the trials. High water requirement of Napier was noted where frequent forage cuts during dry season were expected. Feeding Napier to local cows does not appear attractive to farmers since the low milk level from these cows can be supported by available/traditional feed resources. Besides investing in cross-bred animals production of Napier for the fodder markets of Bahir Dar and Debre Tabor seems a promising option.

Ghana

ILRI: As a result of inadequate seed and for purposes of evaluation, three forage grasses were cultivated with one forage legume: *Chloris gayana* (Rhode grass), *Brachiaria ruziziensis* (Congo grass) and *Sorghum almum* (forage sorghum) and *Lablab purpureus* (the forage legume). A total of 100 m^2 size plot was mapped out and divided into two sections, 50 m^2 each for grass and legume. *Cajanus cajan* was planted as hedges on pilot farmers' plots.

At Zanlerigu in the Nabdam District, treatments for each of six farmers (18 farmers in total), consist of:

- Chloris gayana and Lablab purpureus
- Brachiaria ruziziensis and Lablab purpureus
- Sorghum almum and Lablab purpureus.

At Bihinayili in the Savelugu District, the same treatments were used for each of four farmers (12 farmers in total).

Due to late onset of rainfall at both districts, planting of the rainfed fodder seeds began in the second week of July (at Bihinayili) and third week of July (at Zanlerigu). Soil sampling and analysis were done in both districts (Nabdam and Savelugu). The summary of the planting parameters for the forage species are presented in Table 1. The fodder production was rainfed. Full emergence of all forages species was observed except *Chloris gayana*, i.e. generally *Chloris gayana* did not survive in Savelugu District whereas it germinated and survived in Nabdam District.

Table 1: Forage species and planting parameters

Forage grasses	Planting Methods	Plant spacing	Quantity per farmers	Number of farmers
Chloris gayana (Rhode grass)	Drilling	60cm apart	100g/50 m^2	10
Brachiaria ruziziensis (Congo grass)	Drilling	60cm apart	100g/50 m^2	10
Sorghum almum (Forage sorghum)	Drilling	60cm apart	100g/50 m^2	10
Forage legume				
Lablab purpureus (Lablab)	Dibbling	50 x 50 cm	175g/50 m^2	30
Hedge row				
Cajanus cajan (Pigeon pea)	Dibbling	50m apart	250/100 m^2	30

Additional observations on the planted fodder species in the two project sites:

- Insect pests were a problem for forage legumes at Savelugu District. There is a need for insecticide application at early life of forage legumes.
- Fertilizer application is required for any meaningful herbage yield to feed livestock in both districts.
- *Chloris gayana* germinated but was not well established in both districts. A substitute fodder species would be required for both rainfed and irrigated fodder in the two districts.

- Some farmers at Bihinayili suggested fodder plot sizes can be doubled as some farmers are willing to offer more land for fodder production.
- Due to late rains and late planting which resulted in low biomass of planted fodder species, feeding trials will not be feasible since there may not be any meaningful regeneration periods for fodder to feed livestock. Bihinayili farmers are of the opinion that plot sizes are too small to make any impact on livestock feeding trials. Where possible two or more farmers can offer larger plots at one location instead of scattered plots.
- Farmers at Zanlerigu suggested that we should not wait for full onset of rains to sow fodder seeds.

IWMI: Other data collection instruments for the Ghana region included the installation of an automated weather station in the Zanlerigu project site. The weather station is functional and is on site. Data collection from the weather station commenced on 1 August 2015 and is remotely accessed by IWMI. For Dimbasinia community, IWMI has installed a weather station at nearby community Nyangua, which falls within the same catchment and will share monthly data with UDS. For Bihinaayili community, arrangements have been made to access weather data from the Tamale Airport weather station. Analysis of secondary hydro-meteorological data for the three watersheds has commenced. The climate data have been cleaned and quality controlled (QC) using the QC tool in RClimdex. Water availability for crop production has been determined in each basin, based on a simple water balance approach that uses rainfall and evapotranspiration as the main inputs. Data on cropping patterns and basic agronomic characteristics (including traditional irrigation practices) have been collected for all the three sites. Water samples have been collected at watershed scale from wells and reservoirs to assess the water quality for domestic use and irrigation activities. Water collected from rainwater harvesting will be tested in October.

IFPRI: The Ethiopian Household Survey data were used to break down irrigated and rain-fed crop areas because these numbers are more credible than those from other sources. The breakdown of irrigated and rain-fed crop areas has been completed for Ethiopia. Similar datasets for Ghana have been processed. The cropping system for Tanzania was broken down using information from expert opinion and data from a partial agricultural survey.

2.2. IDSS Model

Ex-ante analyses of selected small-scale interventions using the IDSS were completed in September 2015 and national and regional reports are available (1).

TAMAR and IFPRI held a meeting at TAMU on the modeling approach on October 31, 2014. The discussion specifically focused on the deliverables and modelling/data task allocation and collaboration between the two teams. There are five major models in this project: SWAT, APEX, SPAM, DREAM and FARMSIM. The goal is to integrate these models into a TAMUS's Integrated Decision Support System (IDSS). Full integration of these models would take considerable time and could not be completed during the course of this project. Rather, we will develop an initial prototype which roughly links these models together. An overall modelling framework that details the linkages and scales was agreed upon during this meeting. The division of labor between the IFPRI and TAMAR teams was also finalized: IFPRI will be responsible for SPAM and DREAM modeling, while the TAMAR team will be in charge of SWAT, APEX and FARMSIM. A follow-up meeting between the IFPRI and TAMAR modeling teams will take place in November 2015.

During the reporting period, ILSSI used the IDSS to evaluate the benefits, environmental effects and economic viability of selected small-scale irrigation interventions in the selected sites. 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 EXtender (APEX), a farm-scale agricultural systems model; and the farm-scale economic and nutritional model (FARMSIM).

The baseline farming-system scenarios simulated with FARMSIM, SWAT and APEX for the selected sites were typical farming systems currently used by farmers in each respective region. Baseline scenarios consist of the most commonly cultivated grains, which vary by site and are grown as monocrops during the main rainy season. Baseline scenarios also encapsulate these crops using tillage practices common to each site and current and site-specific fertilizer application rates. Alternative scenarios simulated with FARMSIM and APEX for each site included the addition of one or more irrigated, dry-season crops in all irrigable cropland areas; that is, on irrigation-appropriate soils with slopes of less than 8%. In addition, APEX was used to simulate seven different irrigation application levels for irrigated onion crops, and SWAT was used to simulate irrigation and various fertilizer application rates. FARMSIM was used to simulate the effects on farm-scale economics of using five alternative water-lifting technologies.

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. A description of the methodology of this study follows.

2.3. Model input data

Model input data used in SWAT and APEX simulations for each site included:

- The 30-m resolution Digital Elevation Model (DEM) from SRTM Enhanced Shuttle Land Elevation Data. These data were improved to 10-m resolution by re-projection with cubic convolution and using stream network burning to define streams, delineate the watershed, define slopes, and discretize subarea parameters. Slope classes were defined within the watershed based on their suitability for irrigation.
- For SWAT analyses, an existing land use map published by the Ethiopian Ministry of Water and Energy was used for two of the study sites (Adami Tulu and Lemo). For Robit and Dangila APEX simulations, a LANDSAT-8 image from the USGS Global Visualization Viewer, processed with ERDAS IMAGINE 2014, MULTISPEC, and ArcGIS 10.1 was used. This image was classified using cluster analysis, and major land-use classes were identified.
- The soils map shape file published by the Ethiopian Ministry of Water and Energy, classifying the soil type(s) in each watershed area. Soil parameters used by SWAT and APEX were estimated with the SWAT soil parameter generating tool.
- Weather data were obtained primarily from nearby weather stations and published by the Ethiopian National Meteorological Services Agency. These data included rainfall, temperature (min/max), relative humidity, sunshine hours (solar radiation), and wind speed. Quality control of the data was performed to eliminate erroneous values that were beyond historical extreme records. Missing values were estimated using the WXGN weather predictor. For each site, SWAT and APEX used the same weather dataset.

Subbasin Delineation. For analysis of each site, SWAT divided each watershed into subbasins (referred to as subareas in APEX) with areas ranging from one to ten hectares. The watershed discretization generated for SWAT was used to calibrate APEX to gauge streamflows and sediment yields. The subbasins/subareas were defined with assistance from IWMI staff. For each site, subbasin/subarea shape and size were identical for the two models, to guarantee that SWAT and APEX streamflow volumes and sediment yields would be comparable.

One subarea within each watershed was selected as a case study for simulation with APEX. Each such subarea overlapped with the sample of households that were used for the farm-level economic and nutritional analysis (FARMSIM) for each site.

Crop Management. Generally, crop management in Ethiopia varies from farmer to farmer and from year to year, depending on when the rainy season begins. Baseline crop management schedules and fertilization practices (type and rate) for each site were based on farmer interviews (IFPRI surveys) and expert opinion. Government recommended fertilization rates were also implemented as scenarios to see the impact of improved fertilization rates on crop production. For SWAT simulations, irrigation was implemented in all areas designated for agricultural land use and with slopes of less than 8% (as recommended by FAO).

Initial plans to simulate dry-season tomato production in Robit and Adami Tulu, and dry-season apple and avocado production in Lemo, were changed based on input from local experts. Alternative farming systems involving the dry-season cultivation of onions (and, in the case of Lemo, onions and fodder) were simulated instead, because of the perishability and associated costs of tomatoes, apples and avocados.

Stream Flow and Sediment Calibration. Due to the lack of measured data at the outlets of our study sites, for each site, SWAT was calibrated to actual stream flow data gathered from the nearest river gauging station, and parameters were transferred to the study sites. APEX field-scale runoff values were calibrated to match

SWAT predictions using the automatic calibration tool APEX CUTE, ensuring that the water balance and sediment loss estimates of the two models were similar.

Crop Yield Calibration. For each site, estimates of historical mean yields of cereal crops were obtained from the 2005 Spatial Production Allocation Model (SPAM) dataset for an area including that site. Yield estimates for dry-season onion used in model calibration were acquired from the publications by the Ethiopian Central Statistical Agency. For Lemo and Adami, crop yields and fertilization rates were used from the IFPRI survey database.

Economic Analyses. FARMSIM was used to provide economic analyses of several promising small-scale irrigation interventions identified by SWAT and APEX simulations, including the addition of an irrigated, dry-season, second crop or crops (which varied according to site) and recommended fertilization rates.

FARMSIM also was used to analyze the costs and benefits of various water-lifting devices to extract shallow groundwater. Even where there is sufficient groundwater potential to irrigate dry-season crops without compromising the environmental health of a watershed, the dry-season production of high-value crops can be limited by the labor requirements and/or costs of irrigation. Accordingly, FARMSIM evaluated the costs and benefits of five different water-lifting technologies for irrigating dry-season crops: 1) pulley and bucket (Figure 6); 2) hand-operated rope-and-washer pump (Figure 7); 3) animal-powered rope-and-washer pump (Figure 8); 4) gasoline motor-powered rope-and-washer pump (Figure 9); and 5) solar-powered rope-and-washer pump (Figure 10). Though not widely used in Ethiopia, rope-and-washer pumps powered by animals, gasoline motor and solar technology are utilized in other parts of Africa, as pictured below, and were determined to be potentially viable options for irrigation in the selected watersheds.

Figure 6: Pulley-and-bucket system

Figure 7: Hand-operated rope-and-washer pump

Figure 8:Rope-and-washer pump operated by horse

Figure 9: Gasoline-motor-powered rope-and-washer pump

Figure 10: Solar-powered rope-and-washer pump

For the sake of brevity, hereinafter, hand-operated rope-and-washer pumps, animal-powered rope-and-washer pumps, gasoline motor-powered rope-and-washer pumps, and solar-powered rope-and-washer pumps will be referred to as hand-operated pumps, animal-powered pumps, motor pumps and solar pumps, respectively.

Labor requirements of traditional water-lifting technologies (pulley-and-bucket irrigation and hand-operated pumps) can put very large time and energy demands on farm families. Animal-powered pumps reduce human labor with fairly low initial and maintenance costs, since most farms already own and maintain large animals like a horse or bullock. Motor and solar pumps require significantly less human labor but have higher initial and (in the case of motor pumps) maintenance costs. The most economically advantageous technologies varied from site to site depending on water requirements of the dry-season crops and other site-specific land, soil, weather, and management practices.

Based on the total amount of water required to irrigate a crop for the entire dry season, and the total amount of water per hectare delivered by each water-lifting technology (based on pumping rate and irrigation hours), we computed the fraction of water supply provided by each technology. Taking into account the total irrigable land available for a given crop (e.g. onion) and its water requirements, we used the amount of water that could be supplied by each technology to compute the fraction of cropland that could be irrigated with minimal water stress for each water-lifting technology.

The FARMSIM model was run 500 times for each of the scenarios—the baseline scenario and alternative small scale irrigation interventions—to sample variation in crop yields due to weather and other stochastic variables. To determine which of the scenarios would be most beneficial to farm families, three types of economic indicators were calculated: Net Present Value (NPV), Net Cash Farm Income (NCFI), and Ending Cash Reserves (EC).

TAMAR continued supporting IDSS users through moderation of an IDSS Google user group and response to user queries. TAMAR is also supporting students and faculty in Ethiopia, Tanzania, and Ghana (see activity 4.1.3. for details). TAMAR conducted an IDSS training workshop in Morogoro, Tanzania, in July 2015, as discussed in detail below. TAMAR has provided the SIMETAR software program to six cooperating scientists, in addition to all FARMSIM short course participants.

2.4. Field test results for identified technologies and practices

Ethiopia

All technologies have been installed and farmers have had at least one season to try the various technologies. Data are currently being collected and collated on the costs/returns to farmers related to the irrigation technologies and choice of cropping.

IWMI: A first season of onion (Dangila), tomato (Robit and Bochesa), Desho (Angacha), oats and vetch (Upper Gana) and Napier grass (Robit and Angacha) were monitored between February and July 2015. The monitoring included weekly and irrigation specific soil moisture measurements, crop development (length of growing periods, planting density, plant height, leaf area index and harvest indicators), irrigation timing and quantity and amount of labor specific to each of the agricultural activities performed during the irrigation season. For the fodder trials additional plant samples were taken for nutrient (NPK) analysis. Engineering and agronomy students from national partner universities used specific data collection templates for their research, whereas the socio-economic students mainly relied on the farmer field books and the baseline survey conducted by IFPRI.

- In Upper Gana (Lemo)[1] fifteen rope and washers and three solar pumps were installed for the irrigation of avocado and oats and vetch. In addition 12 wetting front detectors were installed to assist farmers in irrigating avocado and fodder (Figure 11). The field books developed under ILSSI for the recording of agronomic, irrigation and livestock related practices were distributed to all the farmers with instructions on how to fill them out.

Figure 11: Installation of the solar pump in Upper Ghana together with Practica (left) and installation of wetting front detectors for avocado by the TAMAR students (right).

- At the end of the first season farmer feedback was collected in the various sites with respect to the irrigation technologies. Farmers' preferences were found to be site specific.
- Robit: The R&W was not found to be acceptable to farmers due to various reasons. Farmers were given the opportunity to return the technology to the multi-purpose cooperative in exchange for a different technology of preference. Hybrid tomato was grown in the previous season, and due to its yielding properties and good fruit quality, farmers sold it at a higher price than other tomato varieties.
- Dangila: Farmers preferred the rope and washer over pulley. Farmers were given the opportunity to return the technology to the multi-purpose cooperative in exchange for a different technology of preference. A local onion variety was grown in the last season, and it was low yielding with low economic returns.
- Upper Gana: Farmers had mixed opinions with regard to rope & washers: shallow wells and good functioning of the R&W yielded a positive evaluation, whereas deeper wells and poorer R &W quality led to a less favorable evaluation. In Upper Gana farmers will be given another season to test out the technologies as both avocado and fodder did not lead to an economic benefit in the first season as avocado are one year old seedlings and fodder was only used for home consumption. Despite that, farmers all decided to allocate land for the irrigation of high value horticulture crops in Upper Gana.
- Adami Tulu. Adami Tulu (Bochesa). In collaboration with Send A Cow/SEDA, five motorized pumps (each shared by five farmers reaching total of 25 farmers) and six Rope & Washer pumps were distributed for farming irrigated highbred tomato. The credit scheme for the technologies is managed by the partner institution (SEDA). The farmers will no longer be trained to create a savings group due to a number of challenges in savings group creation. All beneficiary households have signed credit agreements. At a June 2015 field trip, farmers with the R&W technology expressed challenges operating their technology due to installation issues by a local provider and due to a lack of maintenance. The local partner SEDA agreed to fix all R&W technologies by October 15th. Motor pumps acquired through ILSSI were used to grow additional crops to those agreed upon with ILSSI and expressed satisfaction with the results. In short, farmers preferred motorized pumps to rope & washer, although motorized pumps are more expensive in terms of investment and operation costs. The field books developed under ILSSI for the recording of agronomic, irrigation, production cost and returns and livestock related practices was translated into local language (Oromifa) and distributed to all farmers with instruction on how to fill them out. At the end of first season field visit

[1] Rope & washer and solar pumps are introduced via the FtF Africa Rising project in Lemo, a communal ILSSI-Africa Rising site and evaluated in collaboration with ILSSI.

were made to get farmers' feedback on the interventions and their production activity. Some of the target farmers' activities differed from expectations, though some model farmers2 properly used the technologies to maximize their incomes. Hybrid tomato had mixed results. In some cases, it was high yielding, but there were also occurrences of disease and pests. The tomato was marketable in the area; however, some farmers noted that tomato was not as successful as other crops. Soluble salt concentrations of water in some wells were high, and might have affected tomato development and yields for these farmers. In response to the mixed result and potential dis-adoption, a field day was organized for all target households in order to draw from the best performing households so that all farmers could learn from the successes and failures. Similarly, data collection using the field books had some gaps and will be amended in the future by modifying the data collection tool. The quality of water from the various water sources and its effects on crops and soils is going to be investigated further in the next season and necessary precautions will be taken.

- Irrigated fodder. Regarding the irrigated fodder interventions in Robit, Upper Gana and Angacha, farmers saw the impact of forage on their dairy cows and oxen, but did not perceive it as an economic benefit in itself. This led to less favorable conditions to enter into a rope and washer credit agreement in Upper Gana. In Robit and Angacha, farmers are planning to increase the area of land allocated to fodder production (last season's allocation was on average 100 m^2) in the coming season such that impacts of fodder on the dairy cows and oxen are measurable, and if they have some surplus fodder, they can sell it and gain some income from it.
- Solar pumps were installed in the joint site with Africa RISING in early September after a delay with importation processes. The manufacturer provided training at local level for farmers and local development officers on installation, operation and management. Training materials were prepared and provided to local stakeholders. The evaluation protocol for solar pumps is in place for the upcoming season.


Figure 12: Measurement of soil moisture at 10, 20, 30, 40, 60 and 100 cm using the soil moisture profiler (left) and monitoring of weed management practices in an oats and vetch field (right).

ILRI: A preliminary cost benefit analysis for irrigated forages is presented here based upon findings from work in Lemo with oats-vetch forage mixes fed to small ruminants (Figure 12). This preliminary analysis was conducted at farm level evaluating three different farmer categories, in relation to irrigation options: 1) Irrigated Forage option, 2) Non-Forage Irrigation option (current dominant use of irrigation); and 3) the current Dominant Rainfed Production option. Table 2 provides details of mean estimated costs.

Table 2: Average Costs (Ethiopian Birr)

Type of costs	**Irrigating Fodder**		**Non-Forage Irrigating**		**Pure Rainfed**	
	Mean (n=12)	**Std. Dev.**	**Mean (n=15)**	**Std. Dev.**	**Mean (n=15)**	**Std. Dev.**
Irrigation machine costs	1298.75	1613.04	456.67	709.38	0.00	0.00

[2] It should be noted that model farmers often have more assets and capital, and also have access to more inputs and information.

Total seed costs	3438.83	2070.32	4028.13	3614.63	2707.13	1551.40
Total oxen costs	3091.67	2240.72	4227.53	2995.03	2226.00	1795.43
Total pesticides costs	362.92	464.66	158.87	159.86	156.53	170.54
Total herbicides costs	11.25	18.36	2.73	10.31	0.00	0.00
Total other costs	300.00	1039.23	256.67	773.87	100.00	313.96
Total fertilizer costs	6232.50	4132.90	7918.63	5060.63	4179.97	2390.85
TC crop labor	**15132.98**	**9619.72**	**11424.72**	**6904.07**	**7647.78**	**5829.19**
TC livestock labor	**29916.25**	**55348.17**	**14993.33**	**16253.42**	**12141.78**	**8583.45**
TC other on livestock	1665.08	1897.80	1380.80	2148.96	347.13	417.08

Clearly labor costs are the most important costs that likely will determine the overall profitability of the interventions. The high labor costs for irrigated forage households ultimately resulted in an overall disappointing benefit-cost ratio, see Table 3, where households practicing rainfed agriculture fared best.

Table 3: Benefit-Cost Ratios

Farmer category	**Mean Benefit-Cost Ratio (BCR)**
Irrigated forage systems - Farmers participating in irrigated forage trials, i.e.	0.60
Non-project irrigation systems - Farmers using irrigation but not participating in irrigated fodder trials (i.e. current dominant use of irrigation)	0.86
Pure rainfed systems - Farmers not using irrigation i.e.	0.95

However it is important to point out that some of the costs and benefits are not easy to value, and are therefore assumed to cut across all farmers/farmer categories and include:

- Cost of grazing as a form of feed for animals meant for fattening in the irrigated forage option: cost of grazing labor and rented grazing land will be included in the analysis, in cases where a farmer incurred these costs.
- Value of water used for irrigation: the assumption here is that the water used for irrigation produces crops, which are in turn, valued. Consequently, the focus is on the value of crops produced from irrigation rather than the water used for irrigation.

In addition, the analysis presented here represents only one year of performance for the project. The assumption in estimating the BCRs is that the investment life of the irrigation equipment and wells would last for ten years. Consequently, data on the successive years of the project is necessary to have a complete analysis of the cost and benefits of irrigated fodder options by farmers during the whole project life.

Ghana

IWMI: Biophysical baseline surveys have been conducted on all the three sites and biophysical historical data compiled for all districts. Measurement instruments including weather station and piezometers have been installed. The irrigation intervention technologies and measurement equipment have been purchased and/or constructed. This includes tanks (16 tanks each of 1000 litres and 16 tanks each of 300 liters), watering cans, motorized pumps, irrigation drip systems and 65 wetting front detectors. Fifteen rain gauges were also installed, five at each site (GPS coordinates of rain gauges: Dimbasinia: 10.93645^o N 1.06155o W, 10.93809^o N 1.06088^o W, 10.93956^o N 1.06006^o W, 10.93769^o N 1.05969^o W, 10.93876^o N 1.06238^o W, Bihnayili: 9.60695^o N 0.86160^o W, 9.60620^o N 0.86574^o W, 9.60637^o N 0.86701^{o}W, 9.60555o N 0.86608^o W, 9.59861o N 0.85880^o W; Zanlerigu: 10.80274^o N 0.72280^o W; 10.80442^o N 0.72181^o W; 10.80534^o N 0.72301^o W).

Installation and training of farmers was underway in September and October by national partner University for Development studies in Bihinaayili, Zanlerigu and Dimbasinia sites in preparation for the dry season.

- Zanlerigu. The rainwater harvesting component of the project has been initiated during the current rainy season. Roof ridges were constructed and rain water harvesting equipment installed. Five storage tanks (about 3000 L volume) were distributed and set up with the initial five households for this protocol. The drip systems were constructed in September. The rainwater will be used for supplementary irrigation using drip kits for the irrigation of leafy vegetables beginning in the upcoming dry season. Tanks, hoses, water cans and motorized pumps have been procured for use during the dry season irrigation of onion at farm gardens. One-half of the eight farmers will use wetting front detectors while the other half will use conventional farmer practices.
- Bihinaayili. Tanks, water cans, hoses and motorized pumps have been ordered for use during the dry season irrigation of onion at farm gardens. A total of eight farmers will participate in this activity at this site. One-half of the farmers will use wetting front detectors while the other half will use farmer practice.
- Dimbasinia. Tanks, motorized pumps and water cans have been ordered and will be used to grow pepper during the dry season. A total of 24 households will participate in dry season pepper production. One-half of the farmers will use wetting front detectors while the other half will use farmer practice.

Tanzania

IWMI: The inception workshop was held in May 2015 with various stakeholders and Sokoine University. The research design, selection criteria and roles of partners were further defined. Workplans were developed for SUA. The partners also visited sites for selection of villages and households, and local stakeholders and leaders were consulted.

- Site selection was restricted to Mkindo and Rudewa Mbuyuni villages found in Mvomero and Kilosa districts, Morogoro region in Tanzania respectively. In both sites the main interventions are motorized pumps as the water lifting technology and system of rice intensification.
- Background data from other related projects and Ministry data have been collated; most of these are biophysical data.
- Characterization of current irrigation practices (water sources, conveyance methods and crops grown) in the sites have been collated using both researcher observation and a baseline survey based on FGDs.
- In Mkindo 17 households were selected for motorized pumps and 16 households for SRI while in Rudewa 16 and 17 households were selected, respectively. In Rudewa village, a group of eight youths was also identified to be given a motor pump to manage a piece of land collectively with vegetables and also rent out the pump to be able to collect more revenue.
- Additionally FGD's with specific emphasis on gender and nutrition were undertaken to inform the finalization of irrigation and kitchen garden interventions.
- Monitoring equipment (weather station and river gauges) have been bought and are currently being installed at the sites. Soil sampling is being planned.

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

3.1. Field test results

Ethiopia

IWMI: The results from the first dry season irrigation experiments are being evaluated by IWMI with Bahir Dar University (BDU) and TAMU students. Preliminary results show that there are site specific constraints influencing technology preference and suitability. Further socio-economic analysis is planned to understand if these constraints are related to social or economic factors of the household or to technical and/or water factors. One preliminary observation across sites is the need for improved conveyance that can reduce labor requirements and potentially increase adoption. A mechanism for conveyance and distribution of water to/in the field directly is currently not available for the rope and washer farmers and may be a factor in tendency for dis-adoption. The FGDs and follow-up, detailed semi-structured interviews will aid towards a better understanding of household related water activities and other social factors that affect adoption potential.

ILRI: Small landholdings, usually around 0.5 (small farmer) to 1.5 ha (large farmer) are very serious constraints in Ethiopia, much more severe than in Tanzania where small farmers own up to 2 ha and large farmers more than 6 ha and Ghana where small holders farm up to 5 ha and large holdings farm more than 15 ha. Consequently successful use of small-scale irrigation interventions is more urgent but also more difficult in Ethiopia than in Tanzania and Ghana. FEAST studies in Ethiopia showed that while livestock contributed significantly to income, livelihood and risk mitigation, per animal productivity, such as daily milk yield, were low (1.5 to 2.5 kg/d). Hence the impact of irrigated fodder was moderate when the benefit accrued from feeding these high quality forages to their own – low yielding –livestock. While it is unlikely that many smallholders will, or can, invest in higher yielding cross bred animals, intensifying and commercially oriented dairy producers exist and will very probably increase in number. These dairies will have a high demand for quality forages, providing a ready market for smallholders to produce and sell forages as cash crop. Such business models will substantially increase the demand for small-scale irrigation technologies.

Tanzania

IWMI: Baseline surveys and FGD's suggest there are a number of limitations to irrigation based on existing practices and capacity, the most significant of which are: long walking distance while carrying the pumps to the field from home and back and during maintenance; prices for pumps accessories are high; fuel price is high and its quality is questionable; lack of enough capital to purchase fuel and agricultural inputs; lack of proper field water application devices (e.g. sprinklers, drip, etc.); pests and diseases; and transportation and market of outlets. In relation to gender there are a number of complex interactions across cultural, economic and physical domains, such as access to land, labor needs and strength to transport pumps.

3.2. IDSS model outputs to increase the use inform decisions on adoption of small scale new irrigation technology

TAMAR: In project year one, IFPRI and TAMAR developed methodologies for ex ante irrigation suitability analysis and for irrigation technology adoption scenario development appropriate for the available data. These methodologies were implemented during the reporting period in Ethiopia, as described above. Implementation in Tanzania and Ghana are underway and slated for completion in project year three. In project year one, IFPRI and TAMAR developed methodologies to conduct economic modeling to support cost-benefit analysis of irrigation under shifted supply and demand conditions. These methodologies are implemented each time the IDSS is used to evaluate baseline and small scale irrigation scenarios.

TAMAR has added functionality to FARMSIM by endogenizing prices to allow the model to be scaled up to larger regions. For example, if crop production increases due to small scale irrigation, we can simulate the impact of increased supplies on the price received for the crop.

In IDSS workshops in project year two, TAMAR verified and validated FARMSIM's ability to simulate small-holder farms through the use of a Touring Test. The inputs and assumptions for small-holder farms were given to knowledgeable persons and then the FARMSIM model results were discussed as to their reasonableness. This is a verification test for economic models that are forecasting inputs on farms and businesses.

TAMAR: Ex ante analyses for four sites in Ethiopia and their respective watersheds were completed during the reporting period. Simulations of the sites with integrated and interactive IDSS models allowed us to evaluate:

- the amount of land appropriate for the cultivation of selected irrigated dry-season double crop(s) following selected wet-season cereal crops
- the amount of irrigation water required to produce the irrigated dry-season crop(s)
- the complete hydrology of each watershed with and without irrigated dry-season crop production
- the soil erosion associated with current and alternative cropping systems
- the amount of surface water and ground water recharge that drains below the root zone to refill each shallow aquifer and that aquifer's contribution to stream flows

- in those cases where years of shallow tillage with animal traction have created hardpan soils, the estimated impacts on crop yields and watershed hydrology of using deep tillage to break the hardpan
- the potential of different fertilization rates to increase yields of both cereal and dry-season crops
- the estimated impacts on farm economies of using deep tillage to break hardpan soils, where such soils exist, and
- the economic viability and nutritional benefits to typical farm families of implementing farming systems involving irrigated dry-season double crops after wet-season cereal crops, with and without increased fertilizer rates.

We also examined the costs and benefits of five different water-lifting devices to extract shallow groundwater. Simulations demonstrated that the labor requirements of traditional water-lifting technologies (pulley-and-bucket irrigation and hand-operated pumps) can put very large time and energy demands on farm families. Animal-powered pumps reduce human labor with fairly low initial and maintenance costs, since most farms already own and maintain a large animal like a horse or a bullock. Motor and solar pumps require significantly less human labor but have higher initial and (in the case of motor pumps) maintenance costs. The most economically advantageous technologies varied from site to site, however, depending on water requirements of the dry-season crops and other site-specific land, soil, weather, and management practices (1).

Results indicated that there is great potential for additional small-scale irrigation of dry-season crops in Lemo. A complete hydrologic analysis of the watershed found that the average annual rainfall in the watershed from 1990 to 2013 was 1193 mm. About 34% of the annual rainfall was turned into stream flow and 57% was evaporated back into the atmosphere. Stream flow was derived almost equally from surface runoff (48%) and base flow (52%). Mean annual recharge of shallow groundwater varied from 287 mm to 316 mm, and mean annual surface runoff from 186 mm to 194 mm, depending on land use and topography of the watershed subbasins. Thus, both shallow groundwater and surface water captured and stored in small ponds might be used to irrigate high-value dry-season crops.

Excessive irrigation from shallow groundwater can deplete aquifers that contribute to stream flow, potentially reducing those flows; however, our analysis indicated that production of irrigated onion on appropriate watershed lands (540 ha) would use less than 10% of the annual shallow groundwater recharge in the entire watershed. Moreover, it would reduce stream flow by only 5.6%. This suggests that small-scale, dry season irrigation can be practiced in a sustainable manner without compromising the environmental health of the watershed.

Economic analyses were conducted to estimate the effects of improved cropping systems and selected irrigation technologies on farm families' net present value, net cash farm income, and ending cash reserves after five years. The most economically advantageous systems were those that grew a maize, teff, or wheat in the wet season, followed by dry-season onion and fodder irrigated with solar pumps. Irrigation with animal-powered and motor pumps was also more profitable than traditional technologies, and they might be considered if initial capital costs limit purchase of solar pumps. The two lowest-performing scenarios were the baseline scenario, with no irrigation, and the scenario that utilized pulley-and-bucket irrigation—with the baseline scenario frequently outperforming the pulley-and-bucket scenario.

Of the alternative scenarios examined, solar pumps could meet irrigation water requirements for all 540 ha of irrigable land, but with high entry costs. Though the solar pumps cost roughly 2.5 times more than the motor pumps, the comparatively lower operating and environmental costs of solar pumps may make them more promising for the long-term. Individual farmers might benefit by spreading entry costs over more irrigated area, perhaps by having two or three farmers share a solar pump.

We would recommend expanding the area and types of crops irrigated in the dry season in order to increase family nutrition and net cash income, while mitigating soil erosion and other reduction in environmental benefits provided by the land.

Component 4: Capacity Development and Stakeholder Engagement and Dialogue

4.1. Capacity Development

IFPRI: A gender training with a nutrition focus is being co-developed between IFPRI and USAID to support capacity building on ILSSI activities. The USAID objective is to conduct a pilot to "train the trainers", to introduce key gender people (e.g. gender advisor and M&E people, plus other interested people in the mission and, potentially, partners as well) to use WEAI and gender integration framework. Their key audience is in the mission. IFPRI's key audience under ILSSI is national government agencies and universities. The joint training is expected to last three or four days and to take place in early 2016.

4.2. Trainings for farmers and local stakeholders

Ethiopia

IWMI: IWMI organized a second round of credit and savings training in Ethiopia (Dangila and Robit). This included data collection and analysis on whether households have adopted savings practices to enable them to repay loans taken to purchase technologies. IWMI facilitated agronomic training in all the sites where farmers were guided on several aspects of crop management through the growing season.

IWMI implemented a second round of irrigation training was in Dangila during May at the mid-point of the irrigation season; the focus was on irrigation scheduling and use of wetting front detectors. Woreda officials from Addisu provided training on best management practices. Individual follow-up on trainings continued throughout the season to ensure correct uptake of new practices. Farmer feedback was collected on the water lifting technologies as well as the wetting front detector at the end of the training.

In all sites, training was conducted by IWMI and sub-national partners on the correct use and maintenance for each water lifting device after installation. Two selected farmers per site obtained an additional detailed training on operational maintenance to ensure that water lifting technologies can be repaired on site as a service to other farmers in the area. In addition, farmers still access (especially for the rope and washer) after-sales support from the manufacturer, as well as the data collectors and students involved within the project who frequently visit sites. Throughout all the trainings development agents, woreda officials and village leaders were present.

ILRI: Twenty farmers (18 men, 2 women) from Robit-Bata (project site in Amhara) were provided with practical training on improved forages management and utilization in February 2015. Thirty six farmers (31 male and 5 female) from Angacha were given training on challenges and opportunities of agricultural development, modern dairy development, feeds, feed management and irrigation in August 2015. Sixteen farmers (5 female and 11 male) from Robit-Bata made an experience sharing visit to Koga irrigation scheme and livestock (dairy) development work by famers in Mecha district. This visit raised farmers' interest for improved forage development and consequently farmers requested increased forage development with additional land allocation for fodder production.

Ghana

IWMI: Training was conducted in all three sites in Ghana during September 2015 by UDS with IWMI on the use of technologies and related agronomic practices. The project has trained three plumbers and one UDS student to fabricate the UDS Drip system. Three Ministry of Food and Agriculture (MoFA) staff were trained on installation and reading of measurement of piezometers for monitoring groundwater fluctuations. These three MoFA staff were also trained to collect biophysical data. Three field assistants were trained on recording rainfall readings from a rain gauge. A revised engagement plan will be completed with recommendations for activities at different levels by mid-November with input from ILRI based on the revised stakeholder maps and analysis report.

ILRI: Twenty four farmers including 12 women were trained by ILRI postdoctoral scientist and ARI scientist in techniques for fodder production. The objective of the training was to introduce the participants to fodder cultivation. The training was conducted on 28th and 29th of May, 2015, in the two project communities (Zanlerigu in the Nabdam District and Bihinayili in the Savelugu District of Northern Ghana). The training included demonstration of fodder planting plot management.

4.3. Stakeholder engagement and dialogue

IWMI: In Ethiopia IWMI has continuous engagement with woreda representatives in each site during the implementation of the project. In Ghana, sites were selected, interventions validated and households identified with input from sub-national institutions. District officers were trained on UDS drip technologies for Zanlerigu so district officers were informed of progress on the project. In Ghana, IWMI has regular engagement with district officials, extension and customary authorities in the project sites. Through Sokoine University as well as the connections through to the Africa Rising project both IWMI and ILRI are working with a number of sub-national organizations, most noticeably, the two zonal irrigation units, local extension officers, irrigation engineers as well as the river basin offices.

Ethiopia

ILRI: ILRI and IWMI arranged stakeholder meetings with key livestock stakeholders to develop understanding on the opportunities and constraints to small-scale irrigation for livestock feeding and to build a community of practice in each country which helped to introduce the project to the livestock and irrigation stakeholder communities and highlighted the various opportunities around irrigated feed production in Ethiopia. This led to some early suggestions on intervention options mainly focused on production of off-season planted forages for small-scale dairy and ruminant fattening enterprises. IWMI and ILRI worked together on the selection of project sites in Ethiopia although IWMI took the leading role. In Ethiopia, ILRI opted to work in two sites: Lemo/Angacha in SNNP Region (with some links to Africa RISING) and Robit Bata in Amhara Region. Focus group discussions were held in both Lemo/Angacha and in Robit Bata which highlighted some of the key community level constraints around irrigated forage production. FEAST assessments were also conducted in both Lemo/Angacha and in Robit Bata. Collaboration with IWMI in the two forage intervention sites was strengthened with the development of an agreement for data collection to be conducted by IWMI in the forage intervention sites. Parallel agreements were developed with both the Southern Agricultural Research Centre and the Amhara Regional Research Centre for the implementation of irrigated forage interventions.

IWMI has a number of entry points into validation and alignment with national priorities; these extend beyond ILSSI and represent 'added value' to the project. For example, IWMI acts as secretariat for the MoA Agricultural Water Management Platform. This existing national dialogue platform run by the Ministry offers the most appropriate channel to validate demand and alignment with national priorities. Furthermore in relation to capacity needs for small-scale irrigation IWMI staff is working closely with Canadian consultants, AgriTech, on the Small-Scale Irrigation Support program alongside MoA. This project will utilize information from this project and will also feed into ILSSI.

Ghana

ILRI: Activities in Ghana have followed a similar path to those in Ethiopia but are less mature. ILRI organized a stakeholder meeting for livestock stakeholders in Tamale in October 2014. The meeting was designed to develop a community of practice around irrigation for livestock feed and to brainstorm with experts on possible sites and interventions. Clearly, the meeting showed that the prospects for use of irrigation for livestock feed are less obvious in Ghana than in Ethiopia, because demand for livestock products is not as strong and there is less seasonal scarcity of biomass than in Ethiopia. Nonetheless, potential study sites and interventions were discussed and useful relationships built. This exercise was followed by a joint planning meeting and field visit with IWMI in Feb 2015 to develop more concrete plans for interventions. ILRI opted to work in two ILSSI Ghana sites in Year 2 of the project and to focus interventions around irrigated high-yielding grasses along with planting of a shrubby legume (Cajanus cajanus) around field margins. The sites are Savelugu and Zanlerigu Districts of Upper East Region. A research agreement has been developed with the Animal Research Institute for roll out of activities in the current financial year. In Ghana, there are early plans to initiate a further consultation by the end of 2015.

Tanzania

ILRI: In Tanzania the stakeholder workshop held in May with representatives from farmers, Tanzania Irrigation Commission as well as regional authorities was the second consultation to ensure the proposed interventions are in line with country needs and national plans. Again, activities in Tanzania are following the same pattern as in Ethiopia but on a later timetable. A stakeholder meeting with prospective partners was arranged in Morogoro on May 21-13, 2015. ILRI invited representatives from the proposed partner, the Tanzania Livestock Research Institute (TALIRI) and this provided the opportunity to develop research activity plans and to think through site selection. ILRI opted to work in the Africa RISING Babati site in Year 2 of the project and to this end developed a research agreement with TALIRI for implementation of an initial set of activities to be complete by Sept 2015.

Across all three countries dialogue has been initiated with a number of implementing organizations, such as iDE to ensure alignment and maximization of synergies between similar pieces of work.

B. Issues or concerns encountered during the reporting period

Ethiopia

Challenges with the lack of coordination across numerous partners and stakeholders were addressed by a partner evaluation meeting for work in Ethiopia (20 – 21 August (4, 5) convened by IWMI to review progress and plans for year 3 field level activities. This included district experts involved in the ILSSI project, national research partners (TAMAR, BDU, SARI and ARARI), NGOs (Send A Cow/ SEDA) and participating CGIAR centers. The workshop achieved the following: 1) introduced and familiarized all partners with past & ongoing ILSSI activities within & across sites; 2) assessed the activities of the past year (year 2) with all partners; 3) identified challenges and gaps to be taken into account for the year 3; 4) refined current & identified further research questions within the scope of the ILSSI project; 5) defined and prioritized partner specific activities related to each of the defined research question within and across sites; 6) standardized reporting mechanisms (data collection, reporting, capacity development etc.); and 7) shared the Environmental Monitoring and Mitigation Plan (EMMP) with all partners across sites.

IWMI noted some instances of disadoption of technologies in some Ethiopian sites. In response, IWMI has facilitated access to preferred technologies for those farmers for subsequent seasons. As disadoption is a critical issue, IWMI will be implemented in-depth interviews in the ILSSI sites and other project sites to better understand factors related to adoption and disadoption so these factors can be considered in scaling analyses.

Ghana

Potential site selection, identification of participating families, and installation of water-lifting technologies in Ghana were delayed in Year 2 as a result of the Ebola outbreak in West Africa and associated travel restrictions. The IDSS workshop in Ghana was accordingly postponed until Year 3, and the commencement of ex ante analyses in Ghana were postponed until the first quarter of Year 3.

Tanzania

IFPRI could not implement the baseline survey in the Babati region of Tanzania as information on households under ILSSI interventions did not become available on time. ILSSI discussed with the Africa RISING team if they could add the Babati households to their next survey round.

Finding input data for the IDSS in Ghana and Tanzania is a challenge. As in Ethiopia, quality of the data is often poor or scarce. IWMI's efforts to implement field sites, make agreements, and start the data collection process have proved helpful in Ethiopia and should be helpful in Ghana and Tanzania as well.

C. Data Sharing and Dissemination

TAMAR: Data required implementing IDSS models were provided by cooperating institutions and students in Africa and by international sources. These data, as well as model code, documentation, and results, are being provided free of charge to all collaborators and any others who request them. TAMAR has provided SIMETAR to six cooperating scientists, in addition to all FARMSIM short course participants.

During the reporting period, the ILSSI project was highlighted at the 2015 International SWAT Conference in Sardinia. Several publication and technical reports are listed in the selected references section following the report.

IV. Human and Institutional Capacity Development

A. Short-term training

An IDSS training workshop was held July 27-31, 2015, at Sokoine University of Agriculture (SUA) in Morogoro, Tanzania. The first day consisted of an overview of the IDSS and its three component models (SWAT, APEX and FARMSIM). Days two - four provided participants with the opportunity to delve deeper into one of the three component models. On day five, participants were presented with a case study of the integrated capabilities of the IDSS.

A total of 51 participants attended the workshop, of which 23 attended the SWAT workshop, 15 attended the APEX workshop, and 13 attended the FARMSIM workshop. Nine of the 51 participants were women (with six attending the SWAT workshop and three attending the APEX workshop). 36 participants were affiliated with a university in some capacity (whether as students, professors/lecturers, or researchers)—27 with SUA, eight with other Tanzanian universities (University of Dar Es Salaam, Mzumbe University and Moshi Cooperative University), and one from the University of California Davis. The remaining 15 participants represented a range of research institutes and government ministries. Most of the participants reported holding master in science or doctorate degrees in engineering, economics/business, agronomy, horticulture, hydrology, water resources management, environmental sciences, geology, ecology, agriculture, natural sciences, or forestry. According to surveys of the participants, none of the students had significant knowledge of the IDSS prior to the workshops. None of the students indicated that they could use any of the IDSS models prior to the class, and all students answered either "disagree" or "strongly disagree" to statements indicating prior model knowledge (e.g., knowledge of model setup, purpose, interface).

Introductory SWAT and advanced SWAT training was presented by Yihun Dile and based on a dataset at the Robit watershed in Ethiopia. Introductory SWAT training covered theory of the SWAT modelling paradigm, data preparation (e.g., building a database, spatial data projection, and the weather generator), watershed delineation, HRU definition, implementation of ex ante interventions, and model simulations. The introductory training used publicly available QSWAT (which uses QGIS-Quantum GIS). Even those who previously used ARCSWAT were pleased with some of QSWAT's added features.

The APEX workshop, presented by Javier Osorio, was divided into three components: 1) an introductory/theoretical section; 2) a hands-on section where participants could familiarize themselves with the WinAPEX interface; and 3) a section on model evaluation and demonstration of the APEX Calibration and Uncertainty Estimator (APEX-CUTE) tool. Participants responded well to the instructors as they participated in the hands-on exercises and queried instructors with highly relevant questions.

The FARMSIM workshop was presented by Jean-Claude Bizimana and addressed the following topics: 1) an introduction to the concept of risk; 2) the use of EXCEL and SIMETAR to analyze risk; 3) the fundamentals of statistics and econometrics to estimate risk; 4) a FARMSIM model overview; and 5) data source and entry in FARMSIM. The final day was dedicated to a hands-on exercise whereby a "virtual farm" was simulated assuming the adoption of a selected irrigation technology. Participants in the workshop demonstrated great interest in the FARMSIM model and its usefulness in analyzing the risks of agricultural interventions.

IWMI:

Country	**Site**	**Trainer**	**Subject**	**Producers Government Prvt sector Civil soc**	**Fem.**	**Male**	**Total**
ETH	Dangila - Dangeshita	IWMI	Irrigation scheduling with wetting front detectors	Producers	8	14	22
ETH	Dangila - Dangeshita	IWMI and extension	Water lifting technology and agronomy (onion)	Producers	8	14	22
ETH	Upper Gana/Lemo	IWMI	Irrigation scheduling with wetting front detectors	Producers	3	4	7
ETH	Upper Gana/Lemo	IWMI	Water lifting technology and agronomy	Producers	1	8	9
ETH	Angacha	IWMI	Irrigation scheduling with wetting front detectors	Producers	2	4	6
ETH	Angacha	IWMI	Water lifting technology and agronomy	Producers	5	31	36
ETH	Bochesa	IWMI	Water lifting technology and agronomy	Producers	11	15	26
ETH	Robit	IWMI	Water lifting technology and agronomy	Producers	10	23	33
ETH	Bochesa	IWMI	Water lifting technology and agronomy	Government		1	1
ETH	Robit	IWMI	Water lifting technology	Government	2	3	5

			and agronomy				
ETH	Bochesa	IWMI		Civil Society		2	2
GHA	Zanlerigu	UDS	Fabrication of UDS drip system (plumbers)	Private sector		3	3
GHA	Zanlerigu	UDS	MoFA staff trained on piezometers	Govt		3	3
GHA	Zanlerigu	UDS	MoFA staff trained on collecting biophys data	Govt		3	3
ETH		IWMI	Credit and savings for SSI	Producers	38	61	99
ETH		IWMI	Credit and savings for SSI	Govt	2	12	14
ETH		IWMI	Credit and savings for SSI	Private sector		2	2
TOTAL					**90**	**203**	**293**

B. Long-term training

IWMI has engaged several students for the project, and no changes were made in Ethiopia from the previous reporting period. For BDU, five out of eight students (seven M.Sc. and one Ph.D.) were expected to complete their theses in September, while two M.S. are expected to complete in January 2016; the Ph.D. student will complete work in 2017. For TAMAR, two M.S. students were expected to finish their theses by the end of September 2015; two Ph.D. students are currently developing their Ph.D. proposals. Three M.S. economics student draft theses on Technical efficiency, Cost-Benefits and Farmers' Willingness to pay for Irrigation technologies have been submitted to their respective departments. Once they are defended and approved by their respective academic boards by end of October 2015, they are expected to submit full data set and copies of the theses.

In Ethiopia, three socio-economic students, three engineering students and one agronomy student (all male) have completed data collection for their theses, including the topics:

- Evaluating an easy farmer`s irrigation tool to improve crop and water productivity of onion (Melaku Tesema, BDU)
- Performance of manual water lifting technologies for irrigated tomato based on the soil water balance, Robit Kebele in Bahir Dar Zuria (Tesfaye Ewenetie, BDU)
- Production, water use and development of crop coefficient for Napier grass underground water irrigation in Robit (Hanibal Mulugeta, BDU)
- Assessment of the water demand, water and crop productivity of selected fodder varieties under smallholder irrigated farming practices. Case studies in Lemo and Angacha areas of SNNP Region (Desalegn Tegegne, TAMAR)
- Analysis of Technical Efficiency of Small Scale Irrigation Technologies (Teshager Assefa Sisha, BDU)
- Cost-Benefit Analysis of Small-Sclae Irrigation Technologies (Mihret Dessie, BDU)
- Farmers Willingness to Pay for Smallholder Water Lifting Irrigation Technologies: A contingent Valuation *Method (Meneyahel Zegeye, TAMAR)*
- In Ghana, two recent graduates have been contracted to work as interns on the project with IWMI; one on biophysical and one on economic. One post-doctorate researcher has been identified to work with IWMI to implement the protocol on finance and credit for small scale irrigation.

TAMAR is supporting two postdoctoral fellows and one MSc student, hired in June of 2015. NCA&T is supporting one PhD student. IFPRI is supporting one postdoctoral fellow. See the attached chart entitled "Long-term Training" for additional details.

C. Institutional capacity development

National partner institutions such as Bahir Dar University, University of Dar Es Salaam, and Sokoine University of Agriculture are actively engaged in the project. TAMAR is supporting graduate students and staff at these institutions in their research. See section II.A. (Activity 4.1.3) for a detailed description.

TAMAR has provided IDSS software (SWAT, APEX, and FARMSIM/SIMETAR) to course participants. This software has also been provided to several cooperating scientists at each cooperating ILSSI institution.

During the reporting period, a short course on use of the IDSS was conducted in Tanzania above. This training involved capacity building for both students and faculty at the host and other universities, as well as government agencies. TAMAR is also supporting students and faculty in Ethiopia, Tanzania, and Ghana. TAMAR has also provided SIMETAR to six cooperating scientists, in addition to all FARMSIM short course participants.

V. Technology Transfer and Scaling Partnerships

In Ethiopia we have started exploring links with the national capacity building program of MoA under the Small Scale Micro irrigation Support program, LIVES and the University Water Sector Partnership (see 4.2.4)

National partner institutions such as Bahir Dar University, University of Dar Es Salaam, and Sokoine University of Agriculture are actively engaging in the project. TAMAR is supporting graduate students and staff at these institutions in their research. See section II.A. (Activity 4.1.3) for a detailed description.

TAMAR has provided IDSS software (SWAT, APEX, and FARMSIM/SIMETAR) to course participants. This software has also been provided to several cooperating scientists at each cooperating ILSSI institution.

Seeds of *Chloris gayana*, *Lablab purpureus*, *Brachiaria ruziziensis* and *Sorghum almum* were procured from National Animal Production Research Institute (NAPRI), Zaria, Nigeria for demonstration in the two project communities in Ghana. NAPRI also provided technical guidelines for the planting of the forage species.

VI. Future Work

Ethiopia

<u>IWMI</u>:

- Continuation of hard pan research, with irrigated fodder introduced as an additional treatment. Specific fodder species are able to penetrate the hard pan.
- Study on irrigation water quality and its effects on crop development and soils in the rift valley region of Ethiopia
- New season of high value crops in all sites, aiming at an early start and having two dry season crops this year. Note that rainfall is below average in some of the sites, which may affect water availability in the shallow wells and lead to insufficient water availability.
- Continuation of research on WFDs for irrigation scheduling in Dangila; effect of WFD depth on water management and crop performance.
- Adapting the mechanisms to improve conveyance of water in the rope and washer intervention field sites.
- Change of technologies for farmers in Robit and Dangila based on preference.
- Additional training for farmers on credit and savings; analysis of previous trainings and potential business case for small scale irrigation finance.
- Deepening engagement with iDE (possibly others)

Ghana

<u>IWMI</u>:

- Implementation of the irrigation trials
- Installation of wetting front detectors for irrigation scheduling
- Monitoring water quality in wells, reservoirs and tanks

- Training farmers on water management
- Comparison of the economic performance of the selected technologies
- Implementation of FGD protocol (gender and adoption issues)
- Implementation of finance and credit protocol

Tanzania

IWMI:

- Initiation of field intervention (lifting technologies- diesel and solar pump characteristics of purchase, operation, maintenance and use for differ crops)
- Installation of measurement equipment (second automatic weather station, soil moisture, river flow monitoring and groundwater measurement)
- Collection of spatial and temporal data from sites relating to biophysical, social and economic parameters
- Trainings for farmers in small scale irrigation technologies and practices including demonstration/ farmer field days
- Refining the work on shallow SRI to enhance the innovative element of Sokoine work plan, including the possible trailing of WFD (wetting front detectors) to enhance irrigation scheduling
- Exploring the potential for establishing community 'rotating fund' to facilitate pump expansion to other non-project households.
- Piloting work on groundwater availability as a constraint to expanding use of shallow groundwater for multiple use.
- Strengthening the links between irrigated and fodder interventions and with Africa Rising.

IFPRI:

Household surveys. Initial IFPRI household surveys will be completed in Ghana in the first quarter of Year 3, and the results of initial surveys will be aggregated, analyzed, reported and used in ongoing IDSS analyses. Plans and preparations for the second round of household surveys will be developed based on initial results and further engagement with stakeholders.

IFPRI will also implement the Focus Group Discussions in Tanzania, work with USAID on the finalization of the gender training and implement it in at least 2 of the 3 ILSSI countries, finalize the upscaling protocol and develop results together with TAMAR, present results from the ILSSI survey at the Dupont Summit in Washington DC as a part of a series of presentations on irrigation and develop a series of papers, specifically:

- Paper on irrigation nutrition linkages in Ethiopia and Tanzania
- Paper on irrigation and women's empowerment in Ethiopia and Tanzania

ILRI:

Four major adjustments are envisaged. First, ex ante assessments will be used in a more structured way to further refine and prioritize context (and site specific) forage interventions. Second, to pay more attention to the potential of irrigated forages as cash crop by generating demand scenarios for such forages, studying feed and fodder value chains and by creating linkages between small-holder forage producers, middlemen, fodder markets and purchasers of forages. Third, the multi-purpose potential of forages in terms of N-fixation, breaking hardpans, improving water retention and increasing over all area productivity by intercropping will be exploited in a more targeted way. Fourth, natural resource use demand for forage production particularly water requirements will be paid special attention.

TAMAR:

Field research. In Year 3, field research will move from planning and initial research to analysis and reporting of initial research. Multi-year field studies will continue. Studies in Ethiopia will be in their second and third years, studies in Tanzania will complete their first year, and studies in Ghana will be well underway. Results from IWMI, ILRI and NCA&T will be reported separately and aggregated for a consolidated interim report on field studies. Year 3 will include ongoing engagement of field researchers with stakeholders at farm, village, and larger levels of scale. Field research will begin to develop data that will help inform the next round of IDSS analyses.

Ex ante analyses using the IDSS. Initial ex ante analyses of small scale irrigation interventions in Tanzania and Ghana will be completed in the first quarter of Year 3. Evaluation of Africa RISING and LIVES research sites, initiated in Year 2, will continue in Year 3, with Africa RISING collaboration extending from Ethiopia to Tanzania and Ghana in Year 3. Collaboration with other Innovation Labs will move from planning to implementation. Preparations for a subsequent round of ex ante analyses will begin in Year 3. These analyses will use improved input data from field and survey studies to re-evaluate the effects and constraints of irrigation technologies, and means of mitigating these constraints. TAMAR and IFPRI will begin working jointly to scale up results from the farm and local watershed levels to larger levels of scale.

Communications and stakeholder engagement. Active, multi-level stakeholder engagement, used in planning and implementing ILSSI studies, will continue in Year 3 as results from all three target countries become available. Engagement with relevant governmental organizations and USAID Missions will be active and ongoing. Communications with farmers, farmer organizations and other stakeholders will be informed by the results of field studies and the application of IDSS modeling products.

Training and education. In Year 3, ILSSI will conduct its first IDSS training workshop in Ghana (slated for February 2016) and its second and third IDSS training workshops in Tanzania and Ethiopia, respectively. ILSSI will continue to support students from partner universities, as well as other stakeholders and partner institutions, in applying the IDSS. Postdoctoral fellows will continue to gain experience in the IDSS through direct participation in research at IWMI, ILRI, IFPRI, TAMAR and NCAT. Training of graduate students—including students from Tanzania and Ghana—will continue in Year 3 at TAMAR and NCAT.

Issues and problem solving. The number and diversity of stakeholders, varying geography across and within selected sites, and multiple disciplines involved in ILSSI make research, training and technology transfer both exciting and challenging. As unexpected issues arise, minor delays have and will likely continue to occur; however, we expect to achieve the project's goals and objectives within the five-year framework of the agreement. In Year 3, the project will shift from the planning, preparation and initiation of research to the generation of product, analysis and synthesis of results, and broad communication with stakeholders. Because of the relative complexity of the product, communications within ILSSI and with its stakeholders will require special attention.

Long-Term Degree Training[3]

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[4]	Major	Graduation Date	Home Country	Home Institution[5]
Prossie Nakawuka	Female	Washington State University	Post-Doctoral	Biological and Agricultural Engineering	May 2013	Uganda	IWMI
Laia Domenech	Female	Universitat Autonoma de Barcelona	Post-Doctoral	Environmental Sciences	February 2011	Spain	IFPRI (until 12/2014)
Dawit Mekonnen	Male	University of Georgia	Post-Doctoral	Agriculture and Applied Economics	May 2013	Ethiopia	IFPRI
Abeyou Wale Worqlul	Male	Cornell University	Post-Doctoral	Biological & Environmental Engineering	June 2015	Ethiopia	TAMAR
Sintayehu Alemayehu Teshome	Male	Texas A&M College of Agriculture and Life Sciences	MS	Ecosystem Science and Management (Range management)	Summer 2015	Ethiopia	TAMAR
Tewodros Assefa	M	N.C. A&T	Ph.D.	Energy and Environment	December 2017	Ethiopia	Bahir Dar University
Marianna McKim	F	N.C. A&T	M.Sc	Agricultural Education	May 2016	USA	N.C. A&T

[3] 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.
[4] B.S., M.S., Ph.D., other (specify)
[5] Fill out for foreign students only. Specify if the student is from a NARS, an educational institution, the private sector, etc.

VI. Selected Reports and Publications for Reference

A. Completed Reports and Publications

1. Ex Ante Analyses of Small Scale Irrigation Interventions - Integrated Decision Support System – September 2015 http://ILSSI.tamu.edu.

   Small-Scale Irrigation Applications for Smallholder Farmers in Ethiopia Ex Ante Analysis of Options
   - Ex Ante Analysis of Small-Scale Irrigation Interventions in Robit
   - Ex Ante Analysis of Small-Scale Irrigation Interventions in Dangila
   - Ex Ante Analysis of Small-Scale Irrigation Interventions in Adami Tulu
   - Ex Ante Analysis of Small-Scale Irrigation Interventions in Lemo
2. Stakeholder Consultation Report, Proceedings Documentation, Addis Ababa, January 20, 2014 http://ILSSI.tamu.edu.
3. Annual Stakeholder Consultation, Proceedings Documentation, Addis Ababa, 18-19 June 2014 http://ILSSI.tamu.edu.
4. Partners Workshop Report and Plan for Year 3, Addis Ababa, August 20-21, 2015 http://ILSSI.tamu.edu.
5. Partners Workshop, Bahir Dar University, Status and Plans, Seifu A. Tilahun, August 20-21, 2015.
6. Field Report Household Surveys – BACAS – Sokoine University of Agriculture – Small Scale Irrigation Technologies and Agricultural Water management Practices – (IFPRI – 2015) http://ILSSI.tamu.edu.
7. ILSSI Approach to Gender as a Cross Cutting Issue – Claudia Ringler, IFPRI and Nicole Lefore, IWMI – working paper August 2015 http://ILSSI.tamu.edu.
8. Stakeholder Recommendations Report: Small-Scale Irrigation and Irrigated Fodder Research in Ghana, April 2015. http://ILSSI.tamu.edu.
9. Consultation Report, Workshop Proceedings, Tamale Ghana, 15 April 2014. http://ILSSI.tamu.edu.
10. Stakeholder Planning Workshop Proceedings, Morogoro, Tanzania, August 26, 2014 http://ILSSI.tamu.edu.
11. Interim Report on Fodder Development by ILSSI and Africa RISING Projects, Lemo and Angacha, SSNPR, Melkamu Derseh, Aberra Adie and Alan Duncan, June 23, 2014.
12. Domenech, Laia and Ringler, Claudia. April 2013. The impact of irrigation on nutrition, health, and gender: A review paper with insights for Africa south of the Sahara. IFPRI Discussion Paper 1259. Washington, D.C.: International Food Policy Research Institute. http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/127480.
13. Domènech, Laia. 2015. Is reliable water access the solution to undernutrition? A review of the potential of irrigation to solve nutrition and gender gaps in Africa South of the Sahara. IFPRI Discussion Paper 1428. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129090.
14. Review Paper on "Garden Kits" in Africa: Lessons Leaned and Potential of Improved Water Management. Douglas Merry and Simon Langan, IWMI Working Paper 162, March 2015 http://www.iwmi.cgiar.org/Publications/Working_Papers/working/wor162.pdf.
15. Debebe L. Yilak, Seifu A. Tilahun, Petra Schmitter, Prossie Nakawuka, Temesgen Enku, N. Tibebu Kassawmar, and Tammo S. Steenhuis. Determining the groundwater potential for agricultural use in Ethiopian Highlands. 10th Alexander von Humboldt Conference 2015, Water-Food-Energy River and Society in the Tropics, EGU Topical Conference Series, Addis Ababa, Ethiopia, 18–20 November 2015.
16. Debebe L. Yiak, Seifu A. Tilahun, Petra Schmitter, Prossie Nakawuka, and Tammo S. Steenhuis, Groundwater Recharge of Robit – Bata Watershed, Lake Tana Basin, Ethiopia. 3rd International Conference on the Advancements of Science and Technology, Bahir Dar, Ethiopia.2015

17. Debebe L. Yilak, Christian D. Guzman, Seifu A. Tilahun & Tammo S. Steenhuis 2015. Runoff mechanism assessment using SCS-CN method in the Upper Blue Nile Basin of Ethiopia: Anjeni Watershed. Open Water Week, Addis Ababa, Ethiopia.
18. Stakeholders' Meeting on Irrigated Forage Intervention for Ghana, Tamale, Ghana, 21-22 October 2014. http://ILSSI.tamu.edu.
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B. IWMI - Reports in Preparation – October 2015

20. Engaging for Impact in the Innovation Lab on Small Scale Irrigation: Approaches and Lessons for Ethiopia, Ghana, and Tanzania- Outline- in preparation
21. Outline for report/working paper: "Microfinance and credit for small-scale irrigation in Ethiopia: Training and Opportunities" – in preparation
22. Access to credit and finance mechanisms for small-scale irrigation in Ethiopia. Draft report stage. Expected date for final version: December 2015.
23. WLE R4D papers on irrigation potential for Ghana, Ethiopia and Tanzania. Outline stage. Expected date: December 2015.
24. Mapping and analysis of small scale irrigation stakeholders for Ethiopia, Ghana and Tanzania. Outline stage. Expected date: 31 October 2015.
25. Working Paper: Trends, constraints and opportunities of small scale irrigation in East Africa: review on Ethiopia, Kenya, Uganda and Tanzania. The paper will explore why emphasis is put on small scale irrigation, where each country is at in terms of small scale irrigation development, and what challenges small scale irrigation is facing in each country and the opportunities are available for overcoming the challenges and achieving the desired benefits. Abstract stage.
26. Research brief/Paper: Adoption factors for small-scale irrigation in Ethiopia. (Qualitative interviews undertaken at sites, supplemented by work on credit (training) and micro-finance). Abstract stage.