Feed the Future Innovation Laboratory for Small Scale Irrigation

Semi -Annual Report

October 1, 2016 – March 31st, 2017
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I. Feed the Future Innovation Lab on Small Scale Irrigation in Ethiopia, Tanzania and Ghana

Semiannual Report for October 1, 2016 to March 31, 2017

II. Foreword

The Feed the Future Innovation Laboratory for Small Scale Irrigation (ILSSI) is led by the Borlaug Institute for International Agricultural at the Texas A&M University System (BI/TAMUS). Partners in the cooperative agreement include the International Water Management Institute (IWMI), the International Food Policy Research Institute (IFPRI), the International Livestock Research Institute (ILRI), North Carolina A&T State University (NCA&T) and Texas A&M AgriLife Research (TAMAR). National universities and other institutions, participating actively in field and household survey research, are sub-contractors to international center partners.

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

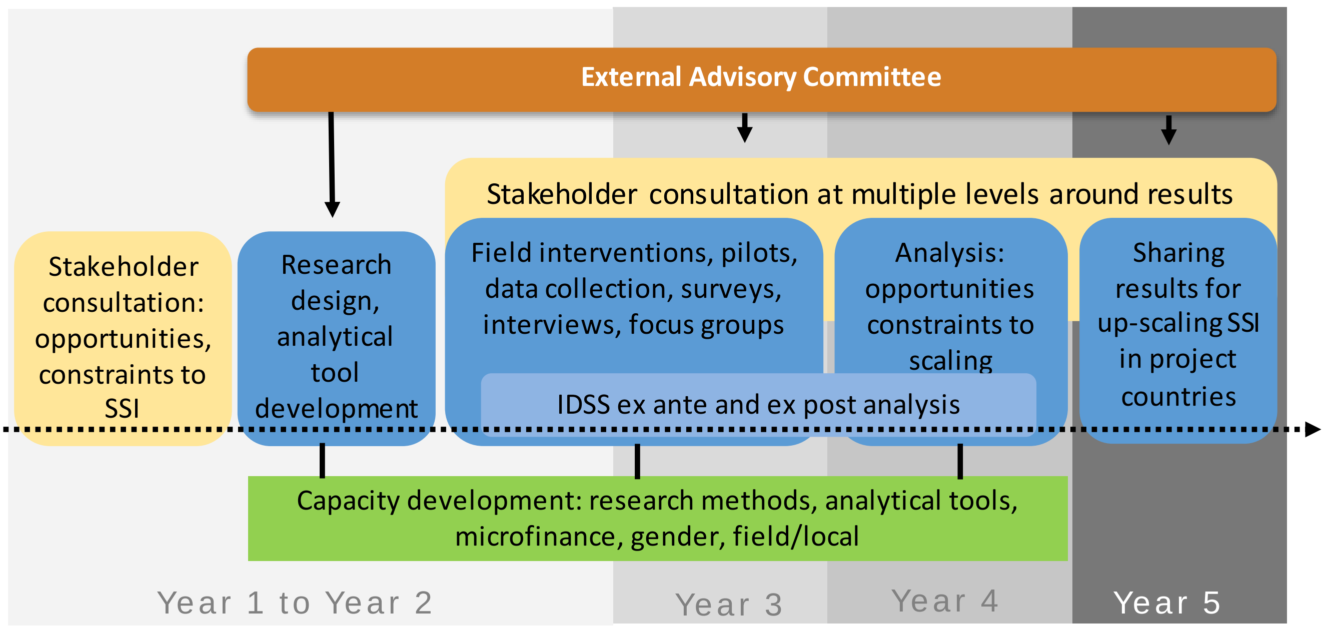
This report covers the first two quarters of the fourth year of the five-year cooperative agreement for the laboratory. The first year focused on stakeholder engagement and planning for research in Ethiopia, Tanzania, and Ghana. Small scale irrigation interventions were defined and regional and local engagements were initiated in year two. In years two and three research was conducted on field studies, household surveys, and analyses of the consequences of small scale irrigation interventions using the Integrated Decision Support System (IDSS). Stakeholder engagement and capacity development were actively pursued.

In accordance with USAID procedures, an external review of the agreement is to be conducted in this fourth year. This review contributes to the Agency decision on renewal of the agreement for an additional five years. The mid-term report was prepared in the first quarter. It was organized to provide a comprehensive review of progress at the halfway point as well as a vision for the way forward, including the exit strategy. It provides a detailed set of references to reports and publication that this document and a subsequent annex prepared in the second and third quarters be used as a principle input to the external review and to the Agency deliberations on renewal. These reports are found at the ILSSI website (http://ilssi.tamu.edu/).

The remaining 1.5 years of the first phase of ILSSI will involve the completion of studies in farmer's fields on small scale irrigation (SSI) innovations, mostly in the remainder of year four. Household surveys involve baseline studies done early in the project and corresponding endline studies, which will be completed in years four and five to determine economic, nutrition and gender related consequences of SSI interventions. The Integrated Decision Support System (IDSS) will continue to be used in the evaluation of field studies, ex post studies of consequences of SSI interventions, including development of strategies to alleviate constraints identified by national stakeholders to the adoption and use of SSI and in scaling these results to watershed and national levels. Synthesis of results across the four project components commenced in year four and will increasingly be the ILSSI focus for the remainder of phase I. Year five will involve consolidation of findings across the four ILSSI components into a comprehensive phase I report aimed at relating results to stakeholder communications at multiple levels of scale leading to adoption and use of SSI in farmer's fields and in the application of analytic methods for planning and evaluation of national policies and strategies to enhance the livelihood of farmers,

ones showing progress to the mid-term. The recommendation to the Agency is

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



III. Research Progress Summary

A. Summary of Research Progress During Reporting Period

This summary and the following detailed elements of the report are explicitly organized around the one and five year work plan objectives for ILSSI and the revised format for this report as mandated in new USAID guidance.

Integration of Results: In year four and continuing into year five, the products of component research are being organized into an integrated framework that brings them together to provide important insights on the potential use of small scale irrigation technology and related knowledge that will enhance the use of precious water resources to support the livelihoods of smallholders in the three countries where this work is being conducted.

Field Research: Field Research: Research in farmer's fields has been conducted in all three countries in the first two quarters of FY 17. Second and third repetitions of field trials are being completed. The most comprehensive results are coming from studies in Ethiopia with studies in Tanzania and Ghana somewhat delayed. Environmental, economic and social consequences of the local introduction of SSI are being evaluated in analyses that complement those being done in other parts of ILSSI. These studies include development of related infrastructure such as microfinance and insights on manufacture and maintenance of equipment. Ongoing advice and training of participating farmers and others in their villages are being pursued. Stakeholder engagement is being maintained at local, regional, and national levels to convey results, receive advice and develop capacity. Major emphasis is being placed on preparation of final data sets from field notes to be used in further analysis using the Integrated Decision Support System.

Household Surveys: In Ethiopia, total agricultural income increases significantly with access to irrigation, total land holdings, total number of livestock owned and the use of chemical fertilizers and improved seeds. Analysis of ILSSI data from Ethiopia also shows that access to irrigation significantly improves both household income and the diversity of crops that farmers produce. Increasing household income, in turn, leads to higher dietary diversity, an important measure of nutrition. Households sell additional crops produced under irrigation in the market and use this income toward purchasing foods that improve nutrition, at least in the four districts where this study is taking place. Surveys in selected households in Ethiopia are being expanded through collaboration with SIPSIN, a companion project also funded by USAID via SIIL. In Tanzania, total agricultural income increases significantly with access to irrigation, total land holdings, total number of livestock owned and the use of chemical fertilizers and improved seeds. Dietary diversity, an important indicator for nutrition, is responsive to increased agricultural income but not to increased diversity of agricultural production. However, the relationship between access to irrigation, changes in agricultural incomes and production diversity was not statistically significant.

Analysis: In collaboration between IFPRI and the IDSS, a GIS based multi-criteria suitability analysis was used as input to a new agent based modeling method at the national level to show that two promising small scale irrigation areas are suitable for development in Ethiopia; one in the Oromia region to the north of SNNP and the other in the Amhara region around Lake Tana. The potential area for new small scale irrigation development overall in Ethiopia is estimated to be 800 thousand hectares. River basins prone to water scarcity with water directed to small scale irrigation were also mapped. The SWAT model was used to predict surface water runoff in areas where field studies are being conducted. The FARMSIM (economic and nutrition) model in the IDSS, coupled with cost benefit analyses done based directly on field studies were used to estimate profitability and sustainability of the interventions studied. Proper irrigation in respect to amount and timing is critical for shallow-rooted crops like onion. To understand the effectiveness of irrigation, the calibrated APEX model was further used to simulate onion and tomato with two-day irrigation intervals and to develop estimates of optimal irrigation strategies. Analysis and comparison of economic and nutritional consequences of the use of water lifting and delivery devices at various locations was continued in the first half of FY17 for multiple horticultural crops. TAMUS also developed detailed soil data for biophysical modeling for the entire African continent based on data from the African Soil Information System (AfSIS). The soil data is evaluated in the Lake Tana basin and provided satisfactory results for calibrating stream flow. The actual evapotranspiration simulated by the SWAT model was compared with the MODIS actual evapotranspiration data and satisfactory agreement was found in most of the areas during the wet season. The findings from this study have been submitted for publication in the Journal of Hydrology. Following stakeholder workshops held in June-August 2016 to identify constraints to the use of SSI methods, the IDSS was used in the first half of FY 17 to evaluate options for the mitigation of these constraints in small holder farming systems. These studies are ongoing and will be completed in year five.

Mission Engagement: ILSSI leadership meets with USAID Mission staff on each country visit to further understand their needs and to report on how ILSSI products are finding traction in the country. The next engagements with the Tanzania and Ethiopia Mission staff are scheduled for mid-May 2017. Ethiopia Mission staff will visit field research sites in Bahir Dar.

External Advisory Committee: ILSSI's External Advisory Committee met jointly with its Program Management Committee in Addis Ababa in October 2017. Plans for the development of the Mid-Term Report and Annual Report were discussed. Plans for the committee to visit field research sites were developed. Members of the committee agreed to active participation with ILSSI leadership in engaging key stakeholders in their countries.

B. Issues or Concerns Encountered During the Reporting Period

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

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

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

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

Three of the four major ILSSI components are performing on schedule with delivery of results as planned. The mid-term report shows a high level of productivity with good results over the preponderance of the project. It is expected that a comprehensive final product will be achieved at the end of year five. The exit strategy that is being prepared in conjunction with the external review identifies the transition from phase I to phase II and provides the proposed way forward to fill in any deficiencies and apply the product of the first agreement to the next phase.

Collaboration with other FtF and Related Programs

In Ethiopia, active collaboration with Africa RISING (AR) continues at several sites involving field studies ILSSI partners and the FtF Nutrition Innovation Laboratory, along with Bahir Dar University in Ethiopia were awarded a contract by the FtF Sustainable Intensification Laboratory to study the impact of sustainably intensified production systems on household nutrition. As part of this collaboration, ILSSI is also works with the SIIL Appropriately Scale Mechanization Consortium (ASMC). A pilot study with the FtF Horticulture Innovation Laboratory to apply the IDSS to the analysis of results of farm level studies in Uganda is continuing with expected first application of the IDSS to field data in August 2017. ILSSI has been collaborating with the ILRI's Canadian funded study on Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) in the application of the IDSS to field and survey results. Initial discussions are underway with the FtF Soybean Innovation Lab for collaboration to evaluate the IDSS in assessing the impact of their genetic research in Ghana.

Human and Institutional Capacity Development:

Long and Short Term Training

IDSS week long training workshops were held in Tanzania and Ethiopia during this reporting period. A total of 132 university students and other users were involved. These workshops included sessions on advanced use of IDSS models. These training workshops are sponsored by either national universities or national water management related organizations that bear the cost of the meetings. ILSSI scientists serve as mentors to students they have trained as they pursue their advanced degrees. ILSSI scientists serve as members of graduate committees in national universities for students whose thesis project involves use of ILSSI model components. Field research in all three countries involves employment of graduate students whose participation provides motivated collaboration in ILSSI's project as well as materials which are being used for their theses. At the local farm and village levels, training on the use of SSI interventions is ongoing and is a key component of successful technology transition. The Ethiopian Agricultural Transformation Agency has requested a special workshop on the IDSS to train their staff to use the system. Details on numbers of students trained are found in the full report which follows.

Five international students from Bahir Dar University in Ethiopia and Sokoine Agricultural University in Tanzania completed 90 day training courses in the use of the IDSS in residence at Texas A&M at the beginning of this reporting period. They have returned to their parent universities and are actively engaged in research using the IDSS. Several publications have been written and are being published on their research.

Innovation Transfer and Scaling Partnerships

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

Future Work

For the remainder of year 4 and year 5 major emphases will be on integrating and organizing the results of phase I and using this to engage stakeholders at all levels in the three countries to assure concerns have been addressed and that there is full awareness of results in the context of their possible application. An internal workshop will be held at Texas A&M in June 2017 to finalize the format and approach for presenting the ILSSI product as an integrated package that shows how the components come together to provide a unique perspective on small scale irrigation technologies and know-how. Field research will be mostly completed in the remainder of year 4 and the final endline household surveys will be completed in years four and five. The ex post and constraints analyses for all three countries will be completed in year five. Application of new national level natural resources assessments will be continued with government agencies such as the ATA in Ethiopia in support of their policy and planning endeavors. ILSSI will provide all necessary support to the USAID External Review scheduled to be completed in July 2017. The full ILSSI team will visit the Bureau of Food Security in Washington in July to brief staff and senior administrators on the near final results of the cooperative agreement. ILSSI will continue to actively engage the USAID Missions in all three countries to assure their awareness of the product and to explore ways in which both the innovations and the analytic methods can be made useful to the Missions. Plans are being made to have a dedicated ILSSI session at one of the major international water meetings in Africa in year five. The ILSSI mid-term report (November 2016 – http://ilssi.tamu.edu) addresses the exit strategy and current thinking about phase II. Prepared as one input to the review and decision process for renewal, this document presents the conceptual framework and vision for a possible continuation of the agreement.

1. Feed the Future Innovation Laboratory for Small Scale Irrigation

Semiannual Report

October 1, 2016 to March 31, 3017

II. Research Progress Summary

A. Summary of Research Progress During Reporting Period

Field Research: Small Scale Irrigation Interventions

Research in farmer's fields is responsive to stakeholder input on priorities from national to local levels. Regions of the three countries where research is being done correspond to feed the future zones of influence. Within the limits of available funds, multiple research sites have been studied. Field studies are relatively mature and will mostly be completed at the end of this year. Studies in Ethiopia are more comprehensive than in Tanzania and Ghana, partly because Ethiopia is the "pilot country" for the overall effort.

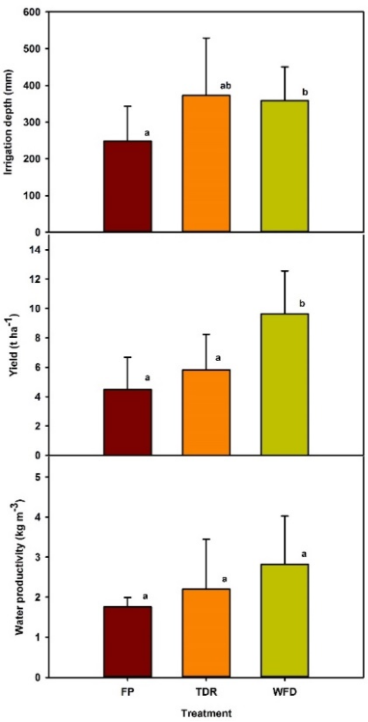


Figure 1: Total irrigation depth, onion yield and water productivity obtained in Dangila (during the dry season of 2016). FP refers to farmer practice, TDR to soil moisture based irrigation and WFD to wetting front detector based irrigation.

Ethiopia

Interventions

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

Water management trials in combination with manual water lifting technologies in Ethiopia have helped to improve crop productivity for high value crops. In Dangila, where farmers are relatively new to irrigation it has increased water application by 30% while doubling onion yield. The increase of water supply measured from both Time Domaine Reflectometer (TDR) and the Wetting Front Detector (WFD) indicates that farmers tend to under-irrigate the onion crop, due to constraints such as experience, labor constraints, etc. (Figure 1)

In Robit, where farmers have over 10 years of experience with irrigation, differences between farmers practice and irrigation scheduling advice resulted in no significant differences in applied irrigation depth; this suggests that there is a learning time frame needed to introduce new technology and management, further study may be needed to understand this time frame.

Additionally, the total water applied during the cropping season was on average 476 mm, 590 mm and 575 mm for Crop Water Requirement (CWR), Soil Moisture Based Scheduling (TDR) and Farmers Practice (FARM), respectively. There was a difference in irrigation depth applied in the various treatments in the development, mid- and end-stage (Figure 2).

These different irrigation depths resulted in different tomato yields. Traditional irrigation scheduling produced significantly lower yields than the two treatments which used the improved irrigation scheduling (CWR, TDR and FARM yields were 33.2 t ha^{-1}, 31.7 t ha^{-1} and 20.8 t ha^{-1}, respectively). Farmers applied on average 118 kg of N ha^{-1} through application of Urea and in rare occasion applied DAP or compost in all three treatments of scheduling. Hence, in many of the fields the source for phosphorus (P) and potassium (K) comes from the irrigation water, although small, they assist by compensating the nutrient removal at the end of the season through the produce and the residual biomass. Despite the small addition of phosphorus and the low uptake in plants the P-balance was not negatively affected. However, the higher yield obtained in the two water management treatments (CWR and TDR) resulted in higher amounts of N and K being removed from the system, thus negatively affecting the nitrogen and potassium balance in the soil compared to traditional practices (Figure 3). This verifies common knowledge that increasing crop productivity through irrigation scheduling requires appropriate fertilizer use to best synergize effects between water and nutrient management and hence helping to ensure sustainability in the long term and avoid soil degradation. In the Ethiopian highlands the expansion of smallholder irrigation land is

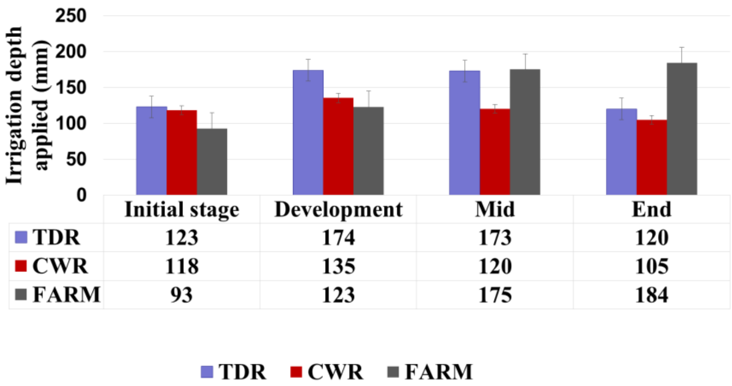


Figure 2: Differences in irrigation depth applied (mm) for each of the 4 tomato cropping stages following three water management practices: soil moisture based scheduling (TDR), FAO- crop water requirement (CWR) and farmers practice (FARM).

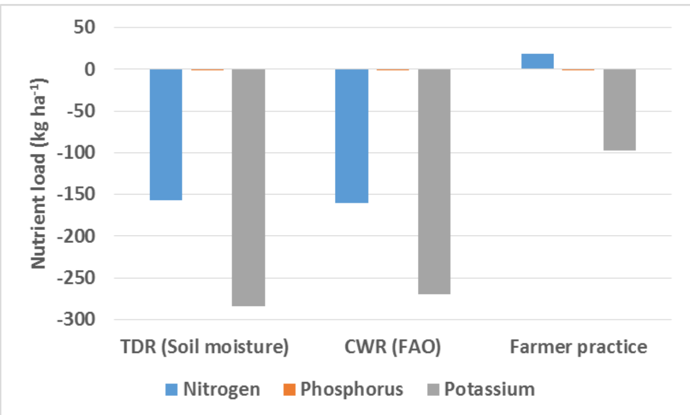


Figure 3: Nutrient balance (kg ha^{-1}) for nitrogen, phosphorus and potassium at the end of the season under three water management practices: soil moisture based scheduling (TDR), FAO- crop water requirement (CWR) and farmers practice (FARM).

constrained by the decrease of available irrigation water during the dry season. The decrease of available water during this period is due to the low recharge of ground water. Further research is needed on the recharge rate to better manage long-term sustainable use of groundwater for dry period irrigation, especially as it relates to the potential to enhance recharge through infiltration and through the management and use of that water for irrigation. IWMI with its national partner (Bahir Dar University) selected three areas within Lake Tana Basin: the Fogera plain, and upland watersheds of Robit Bata and Dangishta to assess potential differences in groundwater recharge and availability in the dry season. Shallow groundwater wells were selected to monitor their ground water level in the rainy period in each study areas: 30 wells in the Fogera plain, 50 wells in Robit and 30 wells in Dangishta. In addition, the amount of irrigation water needed to produce vegetables in the dry period using the shallow groundwater was monitored for 50 farmers. The specific yield of the wells ranges from 2.5% at Fogera plain to 8.9% at Dangishta watershed. The average ground water recharge at the Fogera plain was 850mm while the recharge in Robit and Dangishta watershed were 400mm. The spatial variation of the recharge in the upland watersheds (Robit and Dangishta) indicated that greatest recharge amounts were found in wells at the plains of the foot of the hills (500mm) as opposed to those at upslopes (300mm). These results indicate that plains at the valley bottoms are important resource areas for irrigation (Seifu A. Tilahun, et al. 2016). Also, it is found that the average rate of irrigation water withdrawal in this watershed needed to produce tomato and onions varies from 300mm to 600mm annually indicating the current use of groundwater seems sustainable for one irrigation season.

A new intervention considered during the reporting period was the purchase of additional on-farm irrigation water delivered by a tractor pulled tank for irrigation of multi-cut oats-vetch mixture in Lemo. However due to poor road infrastructure the Ex-ante estimates suggest that the economics are unfavorable as water transport to farmers could be too costly.

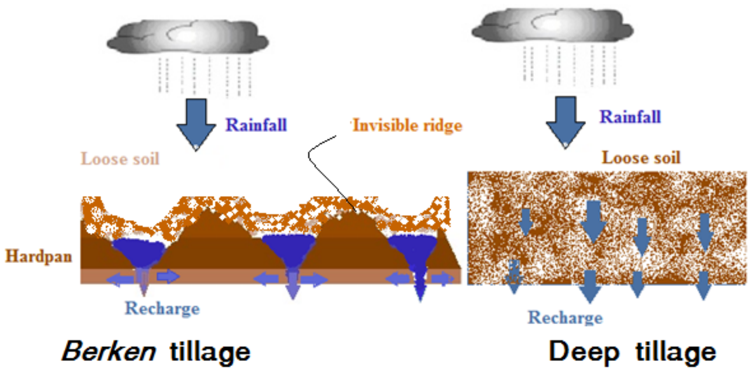


Figure 4: Schematic of the effect of Berken plough and deep tillage on sub-surface infiltration.

The *Maresha* plow, a conventional plow pulled by oxen, forms a restrictive layer, thereby limiting water movement and aeration as well as root zone penetration in the soil profile. Studies have shown that improved tillage practices can positively affect infiltration and aeration resulting in increased rainwater use efficiency and agricultural production. There is limited information about the use of the *Berken* plough as an alternative for tillage practices in this context. ILSSI studied the impact of improved tillage practices on infiltration, erosion, runoff and maize productivity during the rainy period of 2016 in Robit-Bata watershed located in upper Blue Nile, Ethiopia. The experiments were carried out in maize fields on heavy clay soils where four tillage treatments were compared: (i) no-till (NT), no ploughing; (ii) conventional (CT), plots tilled three times using oxen driven *Maresha*, (iii) deep (DT), manual digging up to 60 cm using a *mattock* and (iv) *Berken* tillage (BT), plots tilled three times using an oxen driven *Berken* plough (Figure 4). Soil physical parameters (e.g. penetration resistance, bulk density) were measured before tillage treatment and after the cropping season. Crop performance (plant height, yield, residual biomass and root depth) and measurements on infiltration, sediment yield and runoff were collected. Tillage depth was significantly higher in DT (60 cm) followed by BT (28 cm) and CT (18cm). At the end of the season, the measured penetration resistance was significantly ($p<0.01$) lower at 20 cm depth in the DT and BT plots compared to the NT and the CT treatments. Destruction of the restrictive layer in DT and BT treatments could be the reason for the observed increase infiltration and the reduction of runoff and soil loss. On the other hand, the rooting depth under DT was (> 50cm) followed by BT (>40cm) and NT and CT (both < 30 cm). Grain yield of maize was significantly lower in the NT (2.6 t ha^{-1}) compared to yields measured in the CT (3.8 t ha^{-1}), DT (3.8 t ha^{-1}) and BT (4.0 t ha^{-1}) treatments ($p < 0.05$). Results show that improved tillage practices such as deep tillage or *Berken* plough could increase permeability and therefore root penetration and agricultural productivity whilst decreasing erosion and runoff in the Ethiopian Highlands (Table 1). The adoption of these techniques in the Ethiopian highlands could improve the sustainability of intensification and reduce the environmental impacts associated with traditional tillage practices, thereby helping to address the issues noted above. Further consideration must be given to the impact of labor constraints of farm households.

Treatments (T)	**Infiltration (mm hr^{-1})**	**Runoff (mm)**	**Sediment yield (ton ha^{-1})**
NT	115 ± 20^{a}	99 ± 28^{a}	7 ± 1^{a}
CT	120 ± 18^{a}	71 ± 14^{a}	6 ± 1^{a}
DT	242 ± 18^{b}	30 ± 5^{b}	3 ± 1^{b}
BT	262 ± 18^{b}	34 ± 6^{b}	3 ± 1

Table 1. improved tillage practices such as deep tillage or Berken plough could increase permeability and therefore root penetration and agricultural productivity whilst decreasing erosion and runoff in the Ethiopian Highlands

In addition to the assessment of groundwater use and recharge for sustainable intensification, the economic benefit of water lifting technologies was also analyzed for Ethiopia, notably the impact of water lifting technologies on poverty (Gebregziabher et al 2017). This was based on data collected from 400 households across 4 projects sites in Robit-Bata and Dangila in Amhara, Lemo in SNNPR and Adami-Tulu in Oromia regional states; 233 households practice purely rainfed agriculture and 161 households practice irrigated agriculture using different water lifting and application technologies (29 motor pump, 55 rope and washer pump, 69 pulley, 4 each solar and drip technologies).

When food poverty is examined between households with and without access to irrigation, households with access to irrigation have a lower food poverty index (by about 19%) than households without access to irrigation. The difference in the food poverty gap and the severity of food poverty (squared poverty gap) between households with and without access to irrigation is also significant. Households with access to irrigation have a lower food poverty gap and less severity to food poverty. In short, irrigation by the household does improve food security and reduce food poverty.

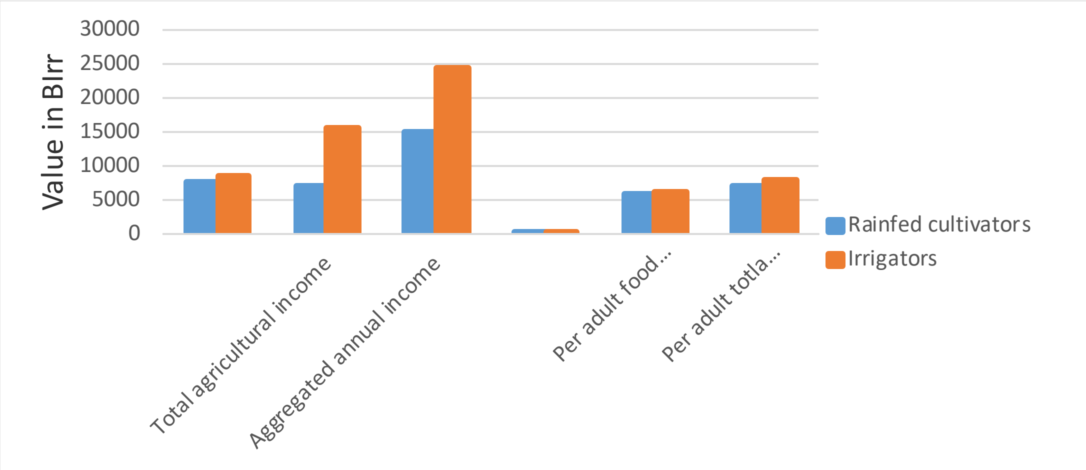


Figure 6: Comparison of rainfed to irrigating farm household income, consumption and expenditure

Smallholders that adopt water lifting technologies have higher consumption expenditure than non-adopters, as depicted in the Figure 6 above.

Category	Food Poverty Indices			Absolute Poverty Indices		
	PO	P1	P2	PO	P1	P2
All sample households (N=344)	0.285 (024)	0.083 (0.009)	0.037 (0.006)	0.389 (0.026)	0.097 (0.008)	0.035 (0.004)
Female headed households (N=66)	0.333 (0.058)	0.096(0.024)	0.046(0.015)	0.394(0.061)	0.109(0.022)	0.043 (0.011)
Male headed households (N=278)	0.273(0.027)	0.080 (0.010)	0.035(0.006)	0.388 (0.029)	0.094 (0.009)	0.033(0.004)
Z-statistics	6.810***	4.676***	5.029***	0.591	4.407***	5.960***

Table 2. Overall sample and gender disaggregated estimate of poverty indices

Gender disaggregated analysis showed that practice of irrigation is linked to the magnitude of poverty reduction (Table. 2), where our data suggest poverty reduction effect is higher in female-headed households than male headed, when poverty reduction is defined in terms of consumption expenditure and not cash income alone. Examining poverty across households based on consumption and expenditure showed that only 12% of the female-headed sample households were poor and 20% of male-headed sample households were poor. This suggests that female-headed households that use irrigation technologies spend more on consumption than male-headed irrigating households. These findings ultimately suggest that women farmers that have control over technologies (productive assets) and control over the benefits from the technologies are able to allocate a greater share of household resources to activities that promote human capital formation and development.

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

There is also anecdotal evidence on the benefits to individual farmers, such as in Robit. One youth farmer gave up chat production and started vegetable production, which suggests adequate profit to incentivize farmers to produce vegetables rather than chat. One female farmer stated she made around 100 dollars in one season from tomato and pepper, enabling her to pay back debt on other productive investments; and allowing her family to increase vegetable consumption from their produce. While the 'success stories' are illustrative, cost-benefit analyses now underway in year 4 will provide quantitative estimates of benefits for specific crops and water-lifting technologies in the sites to document improvements to livelihoods. A cost-benefit analysis is being done on tomato and water lifting technologies in Robit; onion, rope and washer, and pulley in Dangila; motor pump and cabbage in Adami Tulu; and carrot and cabbage production with rope and washer in Lemo. The studies include deeper analysis of labor requirements. For example the use of a pulley and rope and washer pump in Robit and Dangila to extract irrigation water for vegetables (tomato and onions) and animal feed (napier grass) show profitability and nutrition improvement. However, taking into account full labor cost in Dangila to grow onions has shown no profitability (loss) and a decline in the amount of nutrient intake.

While small-scale irrigation clearly showed positive impact on reducing poverty and improving food security at household level, there are constraints to expanding the number of households using water lifting technologies for irrigation. One critical constraint identified by stakeholders is the lack of access to credit by smallholder farmers. Though policies favor expansion of credit access, this goal has not been realized. In response to that identified gap, analysis was conducted on the relationship between access to credit and adoption of irrigation technologies by smallholders (Hagos 2017). The study was based on survey data from 400 households (197 irrigating, 203 controls) across 4 project sites, being Robit-Bata and Dangila in Amhara, Lemo in SNNPR and Adami-Tulu in Oromia regional states. The results showed that access to credit is a positive factor in technology adoption, including proximity to a microfinance organization. The study showed a negative effect of distance to a farmer training center and district markets. As a household has more female adults, the use of capital-intensive technologies declines, suggesting female adults are filling the role of labor in manual irrigation or agronomic practices. However, as the children leave the household and the age of the household held increases, this result in increased interest in adopting technologies. Qualitative research for the same study also found that microcredit services of some type are accessible to about 72% of the households; however, this does not always include lending for irrigation, and the range of products is limited. Additional data is being collected through key informant interviews with cooperatives, microfinance institutions and regulatory bodies to further explore the potential of expanding access to irrigation technologies through access to microfinance products.

Ghana

Interventions

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

In Ghana, evaluation of the agro-climatic conditions in the White Volta Basin showed opportunity to enhance sustainable intensification through small- and medium-scale irrigation (Kadyampakeni et. al. 2017). Climate analyses showed that average annual rainfall is close to 1,000 mm y^{-1} with no significant trend being observed during the last 30 years. Temporally, water surplus occurs about every 3 months, with only one month providing a significant surplus. Farmers in all three watersheds typically grow cereal crops (rice, maize, millet) during the rainy season for home consumption, whereas vegetable production during the dry season is typically sold at the local markets. Irrigation in the three sites is done between November and June, where sources of water for dry season irrigation come from shallow wells and small reservoirs, which dry up at the end of the dry season. Subsequently farmers in the Bihinaayili watershed have year-round access to water from the releases from Libga reservoir. Water quality from wells, reservoirs and rivers in the three watersheds is of good for irrigation and domestic use. The soil chemical parameters across the study sites show that soil salinity is not a concern and the soils suitable for irrigation and crop system intensification, albeit it requires substantial fertilizer inputs. The textural classification suggests that soils in all sites would be ideal for surface irrigation and other pressurized irrigation systems because they are dominated by clay loam and sandy clay loam soils. Further analysis is currently underway on water quality across the sites in each of the three watersheds studied.

An economic study that showed profitability for small-scale irrigation, but with some conditions (Katic, 2017). Initial price analysis showed strong seasonal fluctuation in price in the major markets of northern Ghana for typically irrigated crops such as tomatoes and onions. Not surprisingly crop prices are higher between November and February when irrigated vegetable supply is lower; supply increases and contributes to product gluts in the market from mid-February into the rainy season. Net returns are lower (489 USD ha^1) than for corchorus production (3251 USD ha^{-1}) for Irrigated onion (using motorized pumps for water lifting with storage tanks and hoses). This is of note because earlier research under ILSSI on gender and irrigation showed that women prefer growing leafy vegetables under irrigation compared to onion; women perceived leafy vegetables to be more profitable and allowed them to harvest over time rather than in 'lumps' (Abujaja, A and E. Odonkor 2016). However, as Kadyampakeni et. al. al. (2017) note, farmers often mix crops under irrigation with faster producing leafy vegetables that can be sold to cover costs of more input intensive vegetables such as onion and tomato. Most of the farmers in the Zanlerigu project decided to increase their plot size under irrigation, with one farmer looking at increasing from 10 plots to 100 plots in this season. First season economic analysis, is being followed by additional cost-benefit analysis under different water use scenarios, on corchorus in Bihinayiili; onion in Zanlerigu; and Dimbisinia and mixed crop amaranthus in Zanlerigu.

Tanzania

Interventions

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

In Tanzania research Rudewa, eggplant and tomato yields were obtained in furrow irrigated plots as opposed to drip irrigation. Different trends in water use efficiencies were observed for tomato and eggplant when comparing different irrigation scheduling treatments under both drip and furrow. For tomato, treatment T2 (80% of crop water requirement) produced higher tomato yields compared to T1 (100% of crop water requirement) and T3 (60% of crop water requirement) under both drip and furrow irrigation. On the other hand, for eggplant, a higher yield was obtained in the T3 treatment for both irrigation systems. This confirmed that both crops have different tolerances towards deficit irrigation and that under the prevailing climatic conditions of Rudewa, irrigation could be reduced by 40 % for eggplant and by 20% for tomato.

The comparison of water consumption using pocket gardens compared to conventional plots showed a decrease in water application and therefore a decrease in labor by 50-75% depending on the farmer. The pocket gardens showed a spatial production pattern with higher yields obtained at the top of the pocket garden and lowest yields obtained at the bottom. Comparing production variability with soil moisture levels shows that better drainage in the top of the pocket garden influences better yields. Further analysis on comparison between the pocket and conventional garden is ongoing.

Farmers reported that they could generate about 25 USD from one pocket garden per season, which had enabled them to pay for school expenses and some medical costs for children, as well as fulfilling household consumption of the vegetables produced. Women stated that they have full control over income generated from commercial sales from the pocket gardens. For the youth group in Rudewa using the motor pump, only

4 of the original 8 farmers continued to participate. This appears to be related to challenges with sharing a pump across 8 farmers, but appears to be relatively successful with 4 farmers that cultivate on a common piece of land. According to interviews with project participants, those remaining have generated enough income to acquire their own plots for residential building. While the youth group did establish a bank account, they have repaid only about 125 USD (about half) of the cost of the pump, despite reporting profits. In Mkindo, farmers using the motor pumps have produced two crops per dry season, predominantly tomato which they perceive to be more profitable than other crops. However, this site also experienced collective action challenges with sharing a pump. Each farmer is expected to pay per pump use, but the coordinator appointed by the group to manage the funds is not using the fees collected to maintain the pump. National partners have not intervened in repayment lapses because they did not want to disrupt the data collection related to irrigated production. IWMI is therefore supporting qualitative research on repayment issues with the national partner. As with the other project countries, IWMI has begun a cost-benefit analysis, beginning with the question of whether farmers in the experimental consortium can be considered representative of the average farming households in Tanzania.

Fodder Livestock Systems

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

Ethiopia

During the reporting period participation in irrigated forage work increased to a total of 217 farmers: 69 farmers in oat-vetch technologies in Lemo, 87 farmers in oats-vetch and Napier/Desho-legume intercropping in Angacha and 61 farmers in Robit Bata with labor technologies. In Lemo interventions continued to be focused on oats-vetches mixes, which the farmer preferred as forage (oats, vetch) and management (intercropped) option. Oat-vetch yield and fodder quality analysis suggested that planting of 100 m^2 and single cut would result in either 47.2 kg of meat or 280 kg of milk, assuming all forage is used for production and none for maintenance purposes. The comparisons of single and three cut oat-vetch mixture management suggested that's 3-cut management would increase milk and meat production by a factor of 2.3 and widen the time window of fodder management from one harvest after 85 days to harvests after 40, 85 and 120 days. The preferred option emerging during the current reporting period was a 2-cut option leaving the field free for the main cropping season. In preparation for the March 2017 planting it emerged that farmers wanted to increase land allocation to oats-vetch mixes from the initial $100m^2$ to anywhere between 250 to $1000m^2$. Seed demand increased from about 100 kg to 400 kg. These are clear indication that oats-vetch mixtures as irrigated forage takes off, and ILRI has started discussion with ATA and FHI to further explore scaling of this irrigated forage technology.

Other than oats and vetch mixes, which is an annual forage option, Napier is the perennial option preferred by farmers in Robit Bata. Our findings show that Napier could be harvested during the course of a year between 6 and 9 times resulting relative to a 12 month growing period in a dry matter yield of a minimum of 17.9 t/ha and a maximum of 23 t/ha. A series of laboratory fodder quality analysis performed in the ILRI laboratory in Addis Ababa of Napier forages collected from 19 farmers is summarized in below Table.

Crude protein (CP) and neutral (NDF) and acid (ADF) detergent fiber, acid detergent lignin (ADL), in vitro organic matter digestibility (IVOMD) and metabolizable energy (ME) in Napier forage samples were collected from 19 farmer in Robit Bata

	CP (%)	NDF (%)	ADF (%)	ADL (%)	IVOMD (%)	ME (MJ/kg)
Mean	12.3	73.5	49.5	6.2	51.4	6.7
SD	1.9	2.8	3.5	0.9	1.5	0.16

Table 3. In vitro organic matter digestibility (IVOMD) and metabolizable energy (ME) in Napier forage samples

While Napier is inferior in fodder quality to oat-vetch mixes (see previous reports) is approximately on par with Desho in terms as far as average digestibility is concerned (about 50%) though crude protein content in Desho was in the higher range (15 to 20%).

Ex-ante analyses are currently under way to predict potential livestock performance from Napier based on yield and fodder quality analogously to what was reported in the previous report for oats-vetch mixes and Desho grass.

During the reporting period 30 new farmers started Napier cropping in the Robit Bata.

Ghana

In 2016, there was demonstration of irrigated fodder production in the project sites in Northern Ghana. Ten farmers (including 7 women) in Bihinayili and 14 farmers (including 7 women) in Zanlerigu were involved. The plot size for each farmer was 5m x 20m. Two forage grasses: Brachiaria ruziziensis and Sorghum almum (forage sorghum) were cultivated with one forage legume (Lablab purpureus). A total of 100 m^2 size plot was mapped out and divided into two 50 m^2 for grass and legume. Cajanus cajan was planted as hedges on pilot farmers' plots. The irrigated method was pump and hose. There was a general acceptance by farmers of irrigated fodder production. Small scale irrigated fodder established better at Bihinayili than Zanlerigu. Brachiaria and Sorghum regenerates well after several cutting regime and during the dry season where there moisture. However, there is the challenge of producing enough biomass for animal production as this requires a large area of land. The farmers tended to prefer rain fed fodder production to irrigated fodder because of the low cost of inputs. . The protein content of both forages (*Brachiaria ruziziensis:* 7.6%; *Sorghum almum*: 8.3%) would suffice to provide for minimum microbial protein content in the diet (6 to 7%) but has to considered poor for a green forage. Similarly metabolizable energy (ME) contents were low (*Brachiaria ruziziensis:* 6.16 MJ/kg; *Sorghum almum:* 5.84 MJ/kg). Based on feedback from farmers the prospects of growing irrigated forages in Bihinayili and Zanlerigu for feeding of own livestock seemed less attractive than selling in fodder markets. This promoted the project to initiate fodder market surveys. Preliminary results show that legume haulms from cowpea and groundnut are strongly traded and attractively priced. Both crude proteins and ME in groundnut and cowpea haulm are superior to the one observed in *Brachiaria ruziziensis* and *Sorghum almum* raising serious questions about which fodder technology to invest in: forages or food-feed crops. Ex-ante assessments are currently under way to predict livestock productivity from *Brachiaria ruziziensis* and *Sorghum almum* yield and fodder quality.

Tanzania

Napier accession	Mean Yield (Kg DM/ha)	Yield range (Kg DM/ha)		SD	Leaf: Stem Ratio
ILRI 14984	6.2	6-8		0.6	0.9
ILRI 16803	6.3	6-7		0.4	0.7
ILRI 16835	11.3	10-12		1.0	0.4
ILRI 16837	14.8	14-17		1.1	0.7
Kakamega 2	16.6	14-19		1.3	0.6
Overall	**12.1**	**6-19**	**4.3**	**0.7**	

Table 4, Yield performance (T/ha) and leaf stem proportions of different accession of Napier grown at 3 sites in Tanzania

A total of 54 farmers of which 30 were women participated in the irrigated forage trials in 4 villages across the 3 districts of Kilosa, Mvomero and Babati. Three grasses were explored: Napier, Buffel grass and Rhodes grass with a yield preference of farmers in the same order. Emphasis was therefore given to Napier of which different accessions were tested. Yielding best followed by Tradeoffs were observed between total biomass yield and leaf proportion with the highest yield Kakamega and ILRI 16836 consisting to 60 and 70% of stem material, respectively (Table 4.) However machine chopping can compensate for this morphological disadvantage.

Commercial Vegetable Home Gardens

Commercial vegetable home garden under drip irrigation have been introduced to a total of 44 farmers through our activities (14 farmers in Ethiopia, 15 farmers in Tanzania and 15 farmers in Ghana). Experimental sites in Ethiopia are in two Kebele: Robit (7 plots/sites) and Dangishita (7 plots/sites). Both Robit and Dangishita Kebeles are located in Amhara Regional State, Northern part of Ethiopia. The Kebeles have sub-tropical climate. Farmers in Robit and Dangishita 186 use shallow groundwater wells for irrigation during dry season and manual pulley system as water lifting techniques to fill 187 water storage tanks. In Tanzania, the experimental sites/plots are located in Mvomero District, north east of Morogoro Region. Mvomero District have tropical climate. Farmers in Mvomero use surface water through pipes to fill the water tank in dry season. Experimental sites/plots in Ghana are located in Yemu, Savelugu-Nanton District, and Northern Region of Ghana. Yemu community farmers use nearby river pond for fetching water to fill the tank in the dry season.

Ethiopia

In Robit farmers have grown cabbage for the third season. The average cabbage yield is 4.5 % higher under Conservation Agriculture (CA) than Conventional Tillage (CT), the cabbage in one of the farmers CA plot affected by disease. If this plot removed from the analysis, the average cabbage yield under CA becomes significantly higher (6.2 %) than CT (α= 0.05). We have observed significantly lower cabbage irrigation water use (by 10 %) under CA than CT. MS students in Bahir Dar University monitored soil moisture during cabbage growing period observed higher moisture under CA than CT. In addition, reduction in labor and weeds has been observed under CA treatment. Likewise in Dangeshta Farmers have planted tomato for the third season. However, unusual frost occurred in Dangishita which damaged every type of crops and vegetables including our tomatoes. Reduced irrigation water use and labor was observed before the frost damage.

Drip irrigation on raised bed, Yemu, Ghana

Tanzania

In Tanzania farmers have grown night shade and amaranth for the second vegetable cycle using drip irrigation and conservation agriculture. The average night shade and amaranth yields were found 30 % and 22 % higher under CA than CT respectively. However, the increases in the vegetable yield were not statistically significant (α= 0.05). The vegetable plots have been affected by diseases and hot temperatures.

Ghana

In Yemu Farmers have grown sweet potato, cucumber and green pepper; the average sweet potato and green pepper yields were found 20 % and 50 % higher under CA than CT respectively. A one tailed, paired t-test showed that sweet potato and green pepper yields were significantly higher under CA (α= 0.05). The average sweet potato and green pepper yield was found significantly higher under CA than CT. Farmer's harvested cucumber only from CA plots due to relatively poor stacking in the CT plots hence not used in the statistical analysis. Very hot temperature was reported from Ghana. There is a high chance for water stress to occur. However, soil moisture and temperature was observed higher and cooler under CA plots by human touch. In addition, fewer weeds were observed in the CA plots as compared to CT.

APEX Modeling and Data:

In commercial vegetable home gardens (CVHGs) data collection is ongoing in the three countries using a standard template for APEX modeling needs. In addition, summarized data is being uploaded using 'iFarmCA a mobile application for smart phones used to save and share data between users of conservation agriculture, in all three countries. Data can be queried at: http://www.conservationagricultureandagroforestry.org/ifarmca/index.php/search.

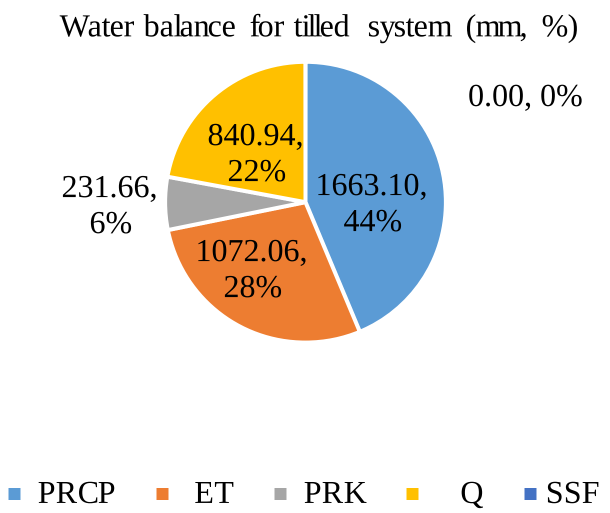


Figure 7: Water balance component of APEX model output in Dangishita, Ethiopia Where: PRCP -precipitation, ET-evaporation, PRK- percolation below the root zone, Q-runoff and SSF is return subsurface flow

The APEX model setup has started for Dangishita, Ethiopia. Recent daily weather data has been obtained from nearby Dangila meteorological station. The detail irrigation and management practices were included in the model setup by building the operation file for the first two vegetable seasons. Initial model run was performed for the conventional tillage system. The water balance component of the model output is shown below (Figure 7) before calibration. APEX model setup for CA in Dangishita and for the two treatments in Robit is in progresses.

Household Surveys

In this reporting period ILSSI is between base and endline surveys and reports. The endline survey for Ethiopia was contracted in late 2017 and the implementation of the endline household survey started in February 2017 is currently in the field. While the baseline survey had been implemented on paper, the endline was moved to electronic data entry, which required a substantial time investment for programming and training of enumerators. But the programmed modules can then be quickly adapted to the Tanzania and Ghana endlines. The endline survey was coordinated with the SIPS-IN baseline survey. SIPS-IN uses the key modules of the ILSSI survey but includes a more detailed nutrition module and will collect bio-markers for detecting anemia and iron-deficiency. While this component of the project is on schedule, it is intended for the last endline survey to shift to year five to provide more time interval between base and endline for the last country

Integration of Results: Analysis of Small Scale Interventions

The Integrated Decision Support System (IDSS) is a suite of proven, interaction and spatially explicit agroecosystem models: The Soil and Water Assessment Tool (TSWAT); the Agricultural Policy/Environment eXtender (APEX); and the Farm Scale Nutrition and Economic Simulation Model

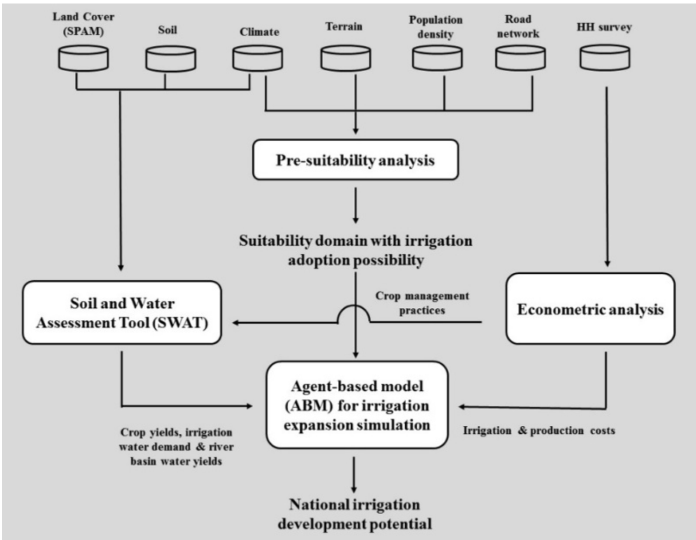


Figure 8. Methodological framework for assessment of national SSI Development potential

(FARMSIM). Together, these models predict short and long term changes in production of crops for people and livestock, farm economies and environmental services produced by changing land uses agricultural technologies and policies, climate, and water resource management (Figure 8).

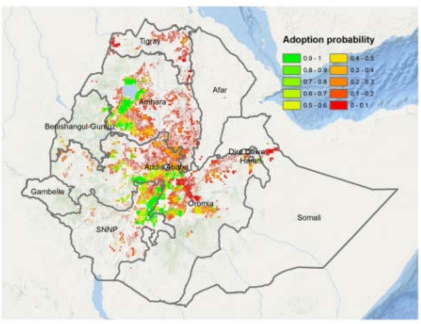


Figure 9 - adoption probability or transferability of small-scale irrigation technologies across the country

Water Resource assessment for small-scale irrigation in Robit, Lemo and Dangishta

The IDSS analysis and the multi-criteria GIS suitability analysis were used as an input to an Agent Based Mode (ABM to assess national development potential of small-scale irrigation and also map adoption probability or transferability of small-scale irrigation technologies across the country (Figure 9). Adoption of small-scale irrigation technologies could occur over a large spatial area in the Ethiopian highlands creating two small-scale irrigated agriculture centers within Ethiopia. The first center is in the Rift Valley of Ethiopia, which is located to the south of Addis Ababa and stretches from central Oromia region to northern SNNP region. The Second is located in the Amhara region around Lake Tana.

	Vegetables(ha)	Pulses & Root crops(ha)	Total(ha)	Net revenue (million USD/yr)
Affar	55	0	55	0.015
Amhara	200,068	118,102	318,170	92
Benishangul-Gumuz	11,182	419	11,601	2.6
Gambella	320	9	329	0.12
Harari	194	398	592	0.13
SNNP	87,942	41,111	129,053	50
Tigray	9,847	457	10,304	3.2
Oromiya	179,885	150,908	330,793	101
Somali	413	83	496	0.4
Total	489,905	311,487	801,392	249.5

Table 5. Estimated small-scale irrigation adoption potential in Ethiopia

expected area with small-scale irrigation development potential by region and by crop class and the expected economic return for irrigated farmers are further summarized in Table 5. The national total expected area with small-scale irrigation development potential in Ethiopia is 0.8 million hectares, which is much smaller than the estimate derived from the preliminary irrigation suitability analysis which was solely calculated using environmental suitability criteria and serves as a refinement to that estimate. It was projected that among the 0.8 million hectare newly developed irrigation area, 0.5 million hectares can be used for vegetable crop production and 0.3 million hectares can be used for pulse and root crop production. The net income generated from the irrigation development to farmers who adopt the small-scale irrigation technologies will be around 250 million USD/yr. Not surprisingly, three regions with largest small-scale irrigation development potential in Ethiopia are Amhara, Oromia and SNNP. The

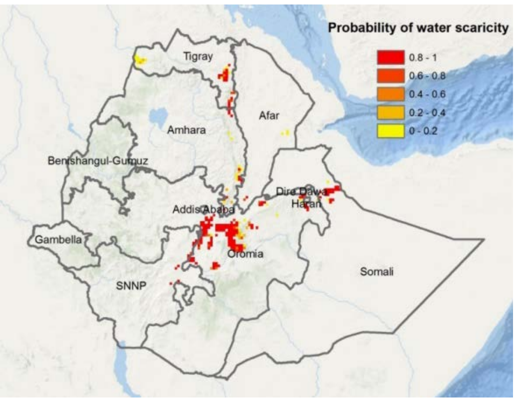


Figure 10. Risk of water scarcity associated with small-scale irrigation development

expected potential area in the three regions are 0.2 million, 0.18 million and 0.09 million hectares, respectively.

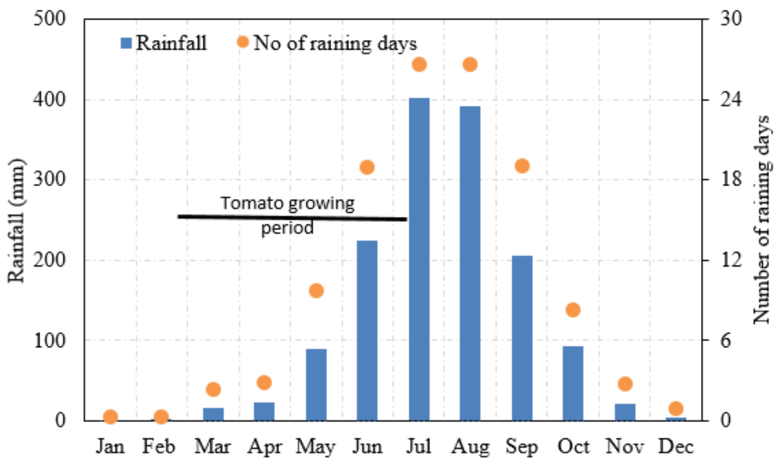


Figure 11: Long-term monthly rainfall and number of raining days for Robit site (Bahir Dar rainfall station 1994 to 2015).

While Small Scale Irrigation has the potential to impact large areas, the introduction of Small Scale Irrigation in water scares areas would be non-sustainable. River basins that are prone to water scarcity arising from the small-scale irrigation development in Ethiopia are shown in Figure 10. Overall, the Rift Valley in Oromia region is exposed to higher risk of water scarcity. Appropriate institutional arrangements should be developed hand-in-hand with irrigation investment to prevent water conflicts which possibly occurs during the course of small-scale irrigation development in this region.

Using data provided by the International Water Management Institute, ILSSI was able to estimate the water resource potential of Robit, Dangishta and Lemo to grow vegetable and fodder during the dry season in three sites in Ethiopia. IDSS was used to assess the water resources at multiple levels of scale in order to identify potentials and limitations. Daily rainfall data from the nearby stations were analyzed to understand the rainfall pattern and the monthly number of rain days from 1994 to 2015. The analysis indicated a large rainfall contribution during the growing season of irrigated crops. For example, in Robit, during the tomato growing period (March to mid-June), on average rainfall contributes approximately 245 mm with a standard deviation of 70 mm.

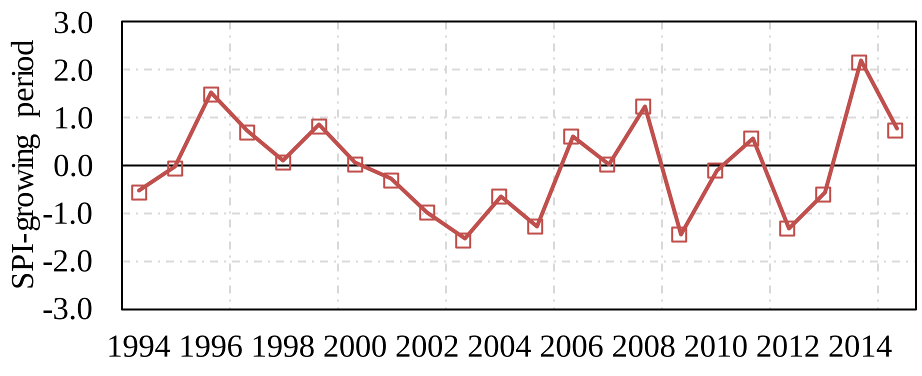


Figure 12: Standardized Precipitation Index (SPI) of Dangishta rainfall for onion growing period from 1994 to 2015.

Figure 11 indicates the long-term average monthly rainfall and number of raining days. Rainfall patterns in the growing season of the three sites were further analyzed to measure the severity of wet or dry events using the Standard Precipitation Index (SPI). The World Meteorological Organization adopted the use of SPI for characterizing metrological drought. SPI is a normalized index representing the number of standard deviation by which the observed anomaly deviated from the long-term mean. SPI value between -1 and 1 represents a near normal season, while SPI value between 1 and 2 represents moderately wet. Extremely wet situation is represented by SPI greater than 2 while SPI value between -1 and -2 represents moderately dry. Extremely dry situation is represented by SPI value of less than -2. The SPI index for the growing season indicated that 86% of the time the rainfall is above normal while in Lemo it is 78% of the time. Figure 12 indicates the SPI temporal distribution for the growing time-scale. The watershed scale model (SWAT) was used to estimate the available water resource potential for irrigation. The model was calibrated using observed stream flow at the outlet of the watersheds. The calibrated models helped to estimate the spatial and temporal distribution of available surface runoff and shallow groundwater. Estimating the potential water resources (including type of water resources) at across spatial locations was useful to identify suitable sites for implementing small scale irrigation and also to select appropriate irrigation technologies. In

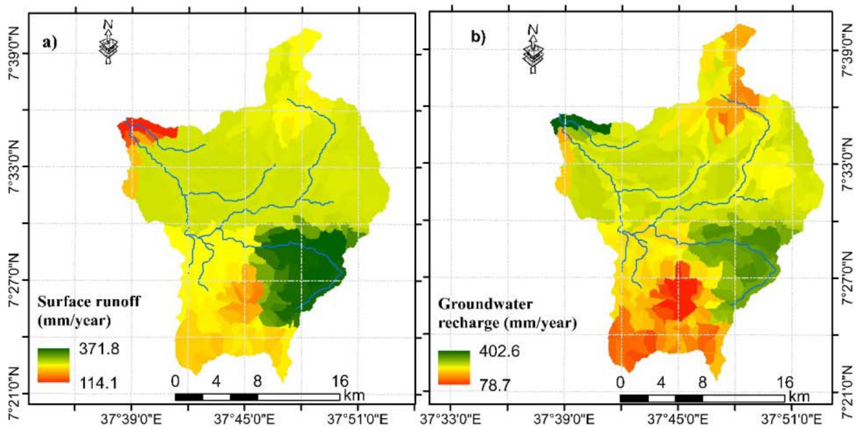


Figure 13: Water resource potential of Robit watershed; (a) annual average surface runoff (mm/year) and (b) annual average groundwater recharge.

Robit, the surface runoff varies between 440 to 535 mm/year (Figure 13a), and the annual average groundwater varies between 250 to 320 mm/year (Figure 13b). In Dangishta, the surface runoff ranges from

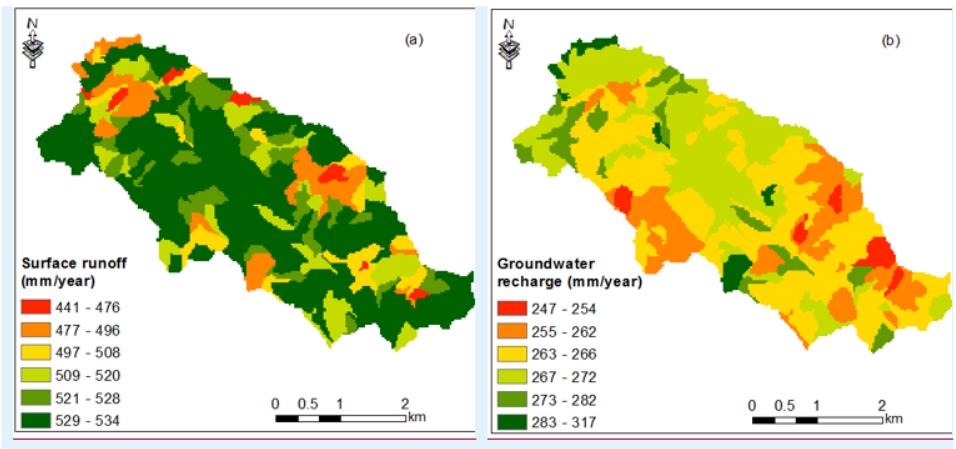


Figure 14: Water resource potential of Lemo watershed; (a) annual average surface runoff (mm/year) and (b) annual average shallow groundwater recharge.

385 to 522 mm/year, and the annual average groundwater varies between 240 to 320 mm/year. In Lemo, the average annual surface runoff ranges from 115 to 370 mm/year (Figure 14a), and the annual average groundwater recharge varies between 80 to 400 mm/year (Figure 14b). The availability of rainfall together with availability of abundant surface and shallow groundwater resource in Robit, Dangishta and Lemo sites suggested that there is high potential to use small-scale irrigation (SSI) technologies to grow crops in dry season. The IDSS analysis showed that about 50% of the area in each watershed was suitable for small scale irrigation. The substantial amount of water resources (generated from the suitable irrigable land as well as from unsuitable land) can be used for small scale irrigation to cultivate vegetable crops with minor reductions on downstream flows. The IDSS analysis suggested the integrated use of groundwater and surface runoff to further reduce the negative externalities on the environment. Outputs from SWAT (e.g. on the extent of suitable area and availability of water in each watershed) and APEX (e.g. long term crop simulations) models were key inputs for the FarmSIM model to estimate the household economy and nutrition outcomes from the implementation of small scale irrigation.

Farm economic and nutrition outcome for small-scale irrigation in Robit, Lemo and Dangishta

The introduction of small-scale irrigation (SSI) technologies was studied in field trials with local farmers beginning in 2015 in Ethiopia, Ghana and Tanzania. Biophysical and socio-economic data were collected in 2015 and 2016 on several irrigated crops: tomatoes, onions, carrots, cabbage and fodder (napier grass and oats and vetch) in Robit, Dangeshta, and Lemo sites in Ethiopia. Irrigation tools such as a pulley-bucket/hose, a rope and washer and solar pumps were used to extract water from wells (Table 6). A farm level economic and nutrition simulation model (FARMSIM) was used to evaluate the nutrition impacts and profitability of the SSI technologies at the household level. Scenarios analysis comprised a baseline with current farming conditions (non-intervention farmers) and several alternative scenarios implementing the SSI technologies (with intervention farmers). Based on a water productivity function generated by APEX, that links the amount of irrigation water to crop yields, two scenarios of irrigation water supply were considered. Optimal irrigation conditions that supply 535 mm of irrigation water for optimal growth of tomatoes and Napier grass in Robit and under-irrigation conditions that supply minimal irrigation water of 100 mm to crops. The same scenarios were considered for the Dangeshta site. For Lemo site, in addition to evaluating SSI technologies on vegetable production, fodder was as well evaluated as an animal feed and its impact on animal performance in terms of milk and meat production. Nutritional outcomes for families resulting in milk and meat consumption were also analyzed. Only optimal level of irrigation was analyzed in Lemo. In all the sites, optimal fertilizer quantities were varied in the model input in addition to irrigation. The difference in performance between the baseline and alternative scenarios was mainly due to increased irrigated area under different water lifting technologies, input costs and increase in yields due to irrigation and optimal fertilizer applications (see input data tables in Annex IV). Grain crops input costs and revenue were kept constant for the baseline and alternative scenarios.

Scenarios	Robit		Dangeshta		Lemo	
	Irrigated Crops	Technolog y	Irrigated Crops	Technolog y	Irrigated Crops	Technolog y
Baseline	No or minimal irrigation	Current conditions: mix	No or minimal irrigation	Current conditions : mix	No or minimal irrigation	Current conditions : mix
Alternative : Alt. 1 . . . . Alt. n	-Tomato -Fodder (napier grass)	-Pulley & tank -Rope & Washer pump	-Onions	-Pulley & tank -Rope & Washer pump	-Cabbage -Carrots -Fodder (Oats & Vetch	-Rope & Washer pump -Solar pump

Table 6. Irrigated crops and water lifting technologies for different scenarios, Ethiopia

In Robit, the annual net profit or net cash farm income (NCFI) which represents the economic profitability at the household level indicates that the alternative scenario under the rope and washer pump (Alt. 2) outperformed all other scenarios (figure 15 & 16) with an average NCFI of 49422 Birr in year 5 of the five-year planning horizon. Under this scenario there is about 35% chance that the net income will be greater than 40,000 Birr and about 61% chance that it will range between 18,000 and

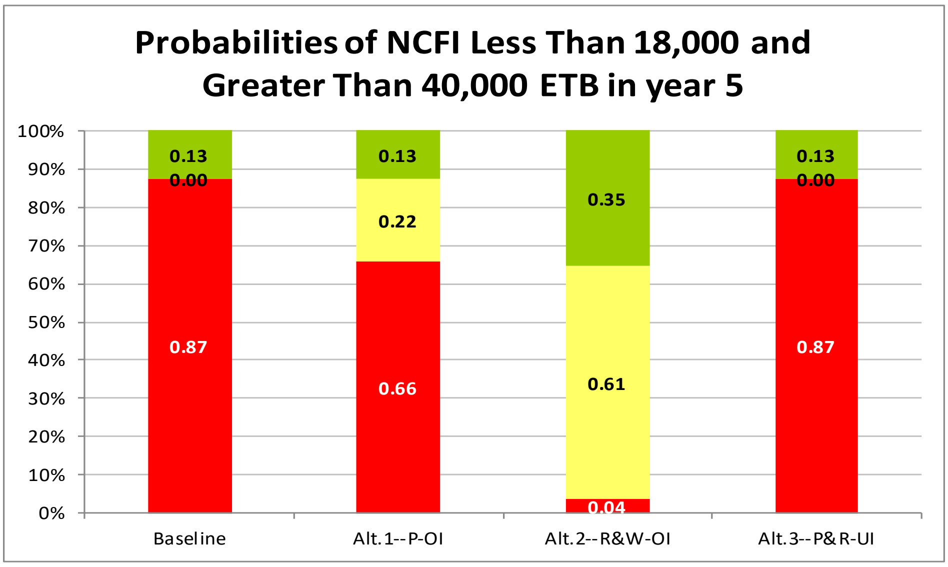


Figure 15. Probabilities of Net Profit (Net Cash Farm Income) being Less than 18000 and Greater than 40,000 Birr for the Baseline and three Alternative Irrigation Technologies in Robit kebele, Ethiopia

Legend:
Baseline: No or minimal irrigation;
Alt.1--P-OI: Pulley used in optimally irrigated systems;
Alt.2--R&W-OI: Rope & Washer pump used in optimally irrigated systems;
Alt.3--P/R&W-UI: Pulley or Rope & Washer pump used in under-irrigated systems

40,000 Birr in year 5. Both the baseline and the alternative scenario in under-irrigated systems (Alt. 3) have on average a net cash farm income of 17000 Birr in year 5 with a 13% probability of having a net income greater than 40000 Birr and an 87% probability of having the net income less than 18000 Birr. The net income distribution shows a 15% probability that the baseline and Alt. 3 scenarios will have a negative net income (loss).

	Baseline	Alt. 1--P-OI	Alt. 2--R&W-OI	Alt. 3--P/R&W-UI
Averages values in Birr/family in year 5				
Net present value	103605	167219	243332	110087
Avg. net profit	16444	29680	49422	17671
Avg. ending cash reserve	85043	169211	270817	95834
Averages daily nutrients in year 5				
Energy (calories/AE)	2696.6	2773.7	2773.7	2685.9
Proteins (grs/AE)	64.1	67.9	67.9	63.6
Fat (grs/AE)	26.6	27.4	27.4	26.4
Calcium (grs/AE)	0.15	0.19	0.19	0.14
Iron (grs/AE)	0.02	0.02	0.02	0.02
Vitamin A (grs/AE)	0.0016	0.0026	0.0026	0.0014

Figure 16. Economic and nutrition impact of the SSI in Robit
Note: -AE-Adult Equivalent -Values highlighted in red color show deficiencies or profit losses

As for the nutritional outcome, simulation results showed improvements in terms of quantity intake, from the baseline to the alternative scenarios, for all nutrition variables (calories, proteins, fat, calcium, iron and vitamin A) except for the scenario associated with the pulley/rope & washer systems in under-irrigated systems (Alt. 3).

In Dangeshta, the annual net profit or net cash farm income (NCFI) results show a higher net profit for Alt. 4 (rope and washer pump under optimal irrigation conditions with no labor cost) followed by Alt. 3 (pulley) (figures 17 &18). The average profit for Alt. 4 is 8698 Birr in year 5 of the five-year planning horizon followed by Alt. 3, which has an average NCFI of 1470 Birr. The remaining alternative scenarios (associated with labor cost) and the baseline had negative average profits. Under Alt. 4, there is 56% chance that the net profit will be greater than 8000 Birr and a 44% chance that it will range between -8000 and 8000 Birr in year 5. Alt. 3 has a 2% probability that the profit will be greater than 8000 Birr and a 98% probability that the profit will range between -8000 and 8000 Birr in year 5. Large cash losses are observed for the pulley and rope & washer pumps under optimal irrigation conditions with labor costs (Alt. 1 and Alt. 2) which have respectively an average net profit of -11936 and -11259 Birr. Both scenarios have on average

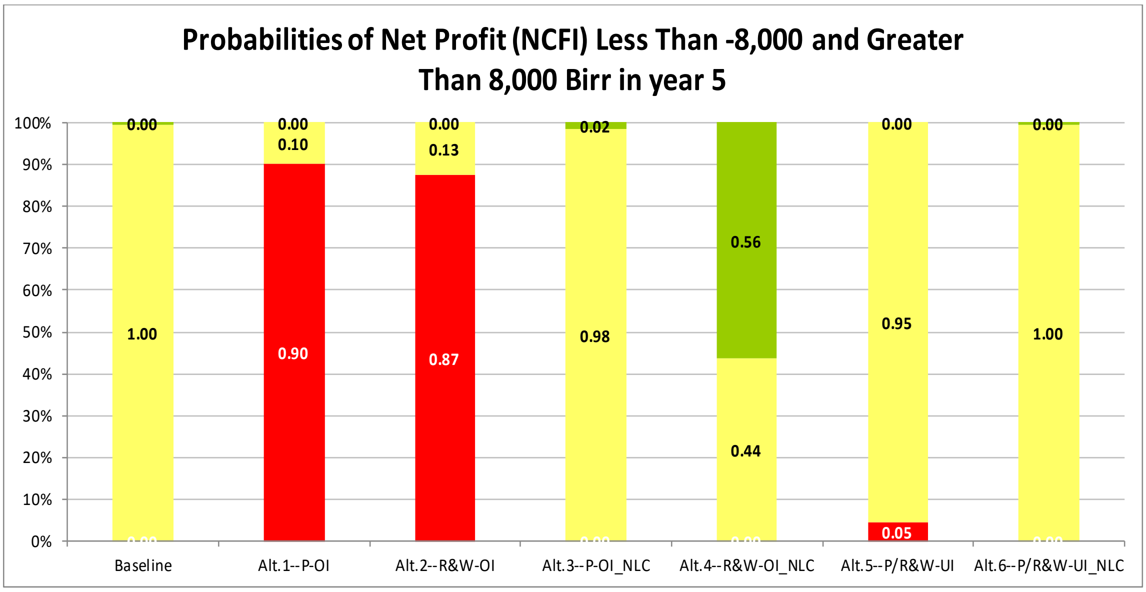


Figure 17. Probabilities of Net Profit (Cash Farm Income) being Less than -8000 and Greater than 8,000 Birr for the Baseline and three Alternative Irrigation Technologies in Dangeshta kebele, Ethiopia

Baseline: No or minimal irrigation;

Alt.1--P-OI: Pulley used in optimally irrigated systems with labor costs;

Alt.2--R&W-OI: Rope & Washer pump used in optimally irrigated systems with labor cost;

Alt.3--P-OI_NLC: Pulley used in optimally irrigated systems-no hired labor: used family labor

Alt.4--R&W-OI_NLC: Rope & Washer pump used in optimally irrigated systems-no hired labor: used family labor

Alt.5--P/R&W-UI: Pulley or Rope & Washer pump used in under-irrigated systems with labor cost

Alt.6--P/R&W-UI_NLC: Pulley or Rope & Washer pump used in under-irrigated systems- no hired labor: used family labor profit less than 8000

88% probability of having a net Birr and a 12% probability of having the profit range between -8000 and 8000 Birr. Note that the baseline and the alternative scenarios related to under-irrigated systems recorded losses; they outperformed the scenarios Alt. 1 and Alt. 2. Simulation results for nutrition indicate a decline in calories, proteins, fat, calcium, iron and vitamin A daily intake per adult equivalent (AE), from the baseline to alternative scenarios associated with labor input cost and under irrigated systems (Alt.1, Alt. 2 and Alt. 5). However, they show an increase in those variables for alternative scenarios without labor costs in optimally irrigated systems (Alt. 3 and Alt. 4). In general, the difference in performance is due to the availability of adequate cash in the household to purchase food to supplement the food consumed by the family.

The use of a pulley or a rope and washer pump in Robit and Dangeshta to extract irrigation water for vegetables (tomato and onions) and animal feed (napier grass) show profitability and nutrition improvement. However, taking into account the labor cost in Dangeshta to grow onions has shown no profitability (loss) and a decline in the amount of nutrient intake. Also according to several unpublished and anecdotal reports from IWMI field workers, farmers in Robit seem to have rejected the rope and washer pump in favor of a pulley-bucket/hose system while farmers in Dangeshta embraced both irrigation tools.

		with labor cost		without labor cost		with labor cost	without labor cost
	Baseline	Alt.1--P-OI	Alt.2--R&W-OI	Alt.3--P-OI_NLC	Alt.4--R&W-OI_NLC	Alt.5--P/R&W-UI	Alt.6--P/R&W-UI_NLC
Averages values in Birr/family in year 5							
Net present value	43082	21828	22781	73338	74454	28197	39234
Avg net profit	-1392	-11936	-11259	1470	8698	-5520	-1257
Avg ending cash reserve	1505	-31386	-29493	17546	53728	-16974	801
Averages daily nutrients in year 5							
Energy (calories/AE)	2712.1	2512.1	2510.8	3099.3	2903.8	2502.5	2698.6
Proteins (grs/AE)	56.8	50.7	50.7	67.8	62.5	50.5	56.4
Fat (grs/AE)	30.9	30.1	30.1	32.1	31.6	30.1	30.9
Calcium (grs/AE)	0.15	0.14	0.14	0.29	0.17	0.13	0.14
Iron (grs/AE)	0.019	0.018	0.018	0.021	0.02	0.018	0.019
Vitamin A (grs/AE)	0.00128	0.00002	0.00002	0.00227	0.00227	0.00009	0.00121

Figure 18. Economic and nutrition impact of the SSI in Dangeshta
Note: -AE-Adult Equivalent values highlighted in red color show deficiencies or profit losses

In Lemo, the annual net profit or net cash farm income (NCFI) which represents the economic profitability at the household level shows relatively small and close profit values among the three scenarios: the Baseline, Alt. 1 (rope and washer pump) and Alt. 2 (solar pump) (figures 19 and 20). Their respective average profit

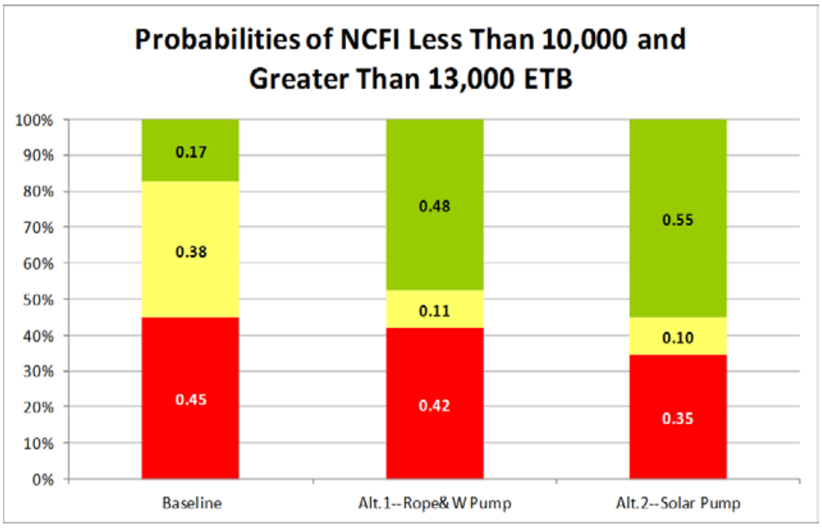


Figure 19. Probabilities of Net profit (Cash Farm Income) being Less than 10,000 and Greater than 13,000 ETB for the Baseline and two Alternative Irrigation Technologies in Lemo woreda, Ethiopia

<u>Legend:</u>
Baseline: No or minimal irrigation;
Alt.1--R&W-P: Rope & Washer pump used in optimally irrigated systems
Alt.2--Solar-P: Solar pump used in optimally irrigated systems

NCFI values are 10564 Birr for the Baseline, 12846 Birr for Alt. 1 and 15039 Birr for Alt. 2 in year 5 of the five-year planning horizon. Under Alt. 2, there is about 55% chance that the net profit will be greater than 13000 Birr and 35% chance that it will be less than 10000 Birr in year five. Similar results were observed under Alt. 1 where there is 48% probability of having a net profit greater than 13000 Birr and 42% probability of having a net profit less than 10000 Birr in year five. As for the baseline, there is only 17% chance of having a net profit greater than 13000 Birr and 45% chance of having a net profit less than 10000 Birr in year five. The net profit distribution (illustrated by the cumulative distribution function, CDF) shows however, a 10% probability of having a net profit (NCFI) equal or less than zero (loss) for Alt. 1 and Alt. 2 due to high production costs. The CDF indicates as well a 32% probability of having net profit for Alt. 1 and Alt. 2 equal or less than the profit in the Baseline scenario (9536 Birr). Assuming that all the farming activities are carried out by family members (no opportunity cost), profit calculations after the removal of the labor cost in the model, shows a four to five times increase of the profit in year five.

	Baseline	Alt. 1--R&W-P	Alt. 2--Solar-P
Averages values in Birr /family in year 5			
Net present value	84552	206388	221224
Avg net profit	10564	12846	15039
Avg ending cash reserve	53569	106387	120062
Averages daily nutritients in year 5			
Energy (calories/AE)	2141.0	2715.2	2756.4
Proteins (grs/AE)	54.4	72.5	73.8
Fat (grs/AE)	14.2	17.2	17.4
Calcium (grs/AE)	0.20	0.80	0.84
Iron (grs/AE)	0.013	0.019	0.019
Vitamin A (grs/AE)	0.0051	0.0539	0.0574

Figure 20 Economic and nutrition impact of the SSI in Lemo

Note: -AE-Adult Equivalent -Values highlighted in red color show deficiencies or profit losses

The nutritional outcome in Lemo showed significant improvements from the baseline to the alternative scenarios in terms of quantity intake, for all nutrition variables (calories, proteins, fat, calcium, iron and vitamin A). However, the minimum requirements for calcium and fat were not met in all scenarios (e.g. of calcium in figure 21).

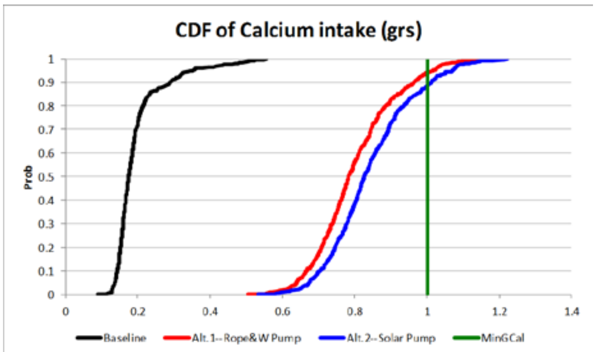


Figure 21 CDF of daily calcium consumption per AE on a farm in Lemo woreda

Specifically for calcium, with the increase of 68% in quantity of milk demanded by family in alternative scenarios, the deficit in calcium at the household level was cut by 75%. The average calcium intake per adult equivalent (AE) is 0.19 g and 0.8 g respectively for the Baseline and both alternative scenarios, falling short to the daily minimum requirement of 1 g per AE. There is however a 6% and 12% probability that the average calcium intake would be greater than the minimum respectively for Alt. 1 (Rope & washer pump) and Alt. 2 (Solar pump) (figure 22).

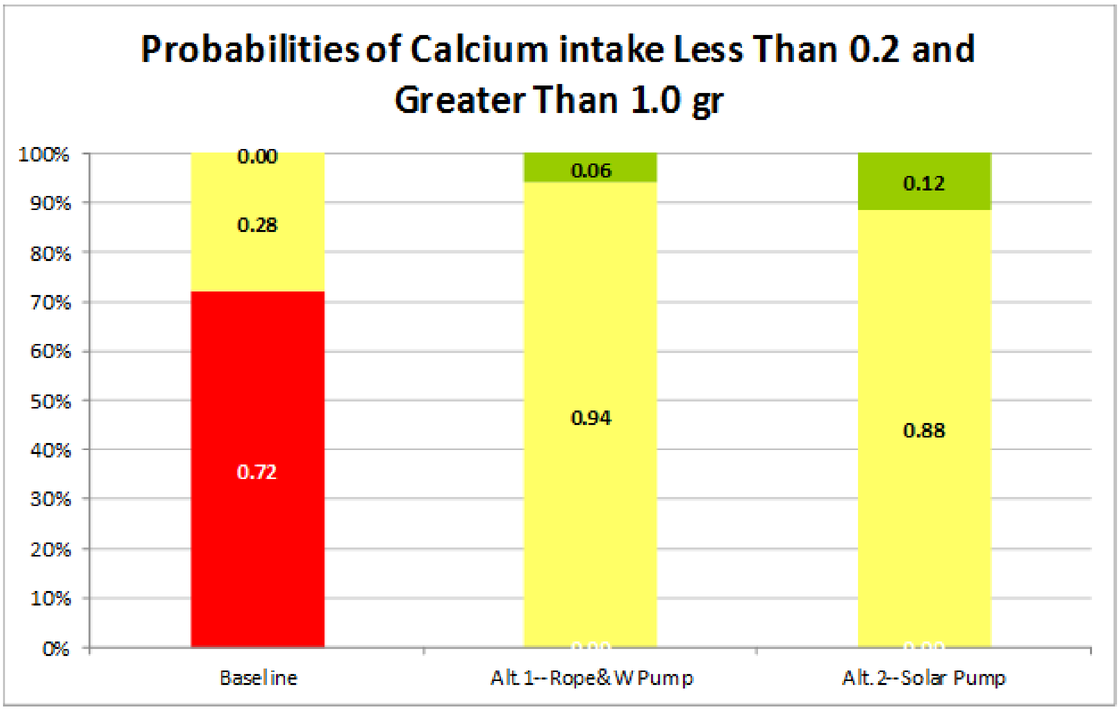


Figure 22 Probabilities for daily calcium consumption per AE on a farm in Lemo woreda

In Lemo, the use of a rope and washer and solar pumps to provide irrigation water for cabbage, carrots and fodder (oats and vetch) indicate a low level of profitability due to high production costs. However the increase in fodder production provided supplemental animal feeding which increased the amount of milk produced and consumed at the household level and subsequent nutrition improvement.

Gaps and constraints analysis on small scale irrigation for vegetable and fodder production in Robit, Dangishta and Lemo

Based on lesson learned from the ex-ante analysis and using field observed data, the IDSS analysis was used to conduct ex-post, gaps and constraint analysis. Large scale watershed information was obtained from the SWAT model and detailed cropping system analysis was simulated using the APEX model. The field data was collected by the International Water Management Institute. The IDSS was used to understand the gaps and constraints of small scale irrigation to produce vegetable and fodder in three sites in Ethiopia. APEX model parameters were calibrated using field observed crop height, yield and soil moisture. Then the calibrated and validated model was used to study water and fertilizer use efficiency of crops. Based on the calibrated model, several alternative scenarios were simulated and the economic and nutrition outcomes were estimated using the FARMSIM model.

Proper irrigation in respect to amount and timing is critical for shallow-rooted crops like onion. To understand the effectiveness of irrigation, the calibrated APEX model was further used to simulate onion and tomato with two days irrigation intervals by applying 100 mm to 850 mm volumes of water at 150 mm interval. Results of the 22 years of

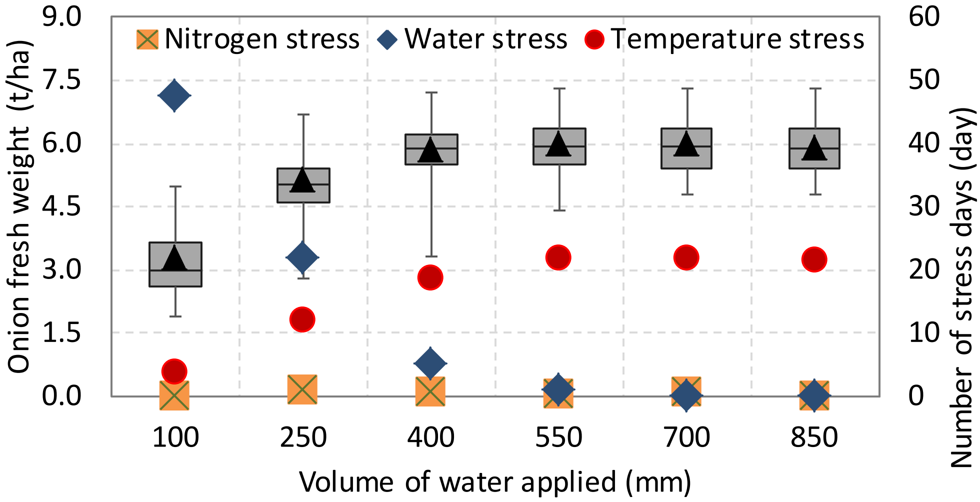


Figure 23: Onion irrigation production function simulated from 1994 to 2015 plus rainfall. The rectangle box represents the first and the third quartile, the median is represented by a segment inside the rectangle, and whiskers above and below represent minimum and maximum.

onion simulated yield with number of water, temperature and nitrogen stress days are shown in Figure 23. (Stress days are days where there was limitation of a particular nutrient (e.g. water, nutrient, temperature, etc.). When onions were grown with 100 mm of irrigation, yield was limited by water, with plants experiencing an average 46 stress days. As irrigation increased to 250 mm the number of water stress days declined by 53%, and yields increased by 56%. As irrigation approached 400 mm and beyond, yields were not significantly increased; and the principal factor-limiting yield was temperature stress.

Similar to onion, water production function was developed for tomato crop in Robit watershed. The result indicated an optimal water of 500 mm. However, the primary data collected indicates that farmers have different levels of knowledge/understanding on how to optimize tomato production. Irrigation water management was highly variable from farmer to farmer where traditional practices Is that of over irrigation. Over irrigation leads to increased surface runoff and percolation, which causes leaching and nutrient loss through runoff. The water balance components such as potential evapotranspiration (Eto), actual evapotranspiration (ETA), plant transpiration (ETC) runoff, percolation below root zone (PRK) and rainfall (Prcp) for the onion growing season with irrigation amounts of 250, 400, 700, and 800 mm is illustrated in Figure 24.

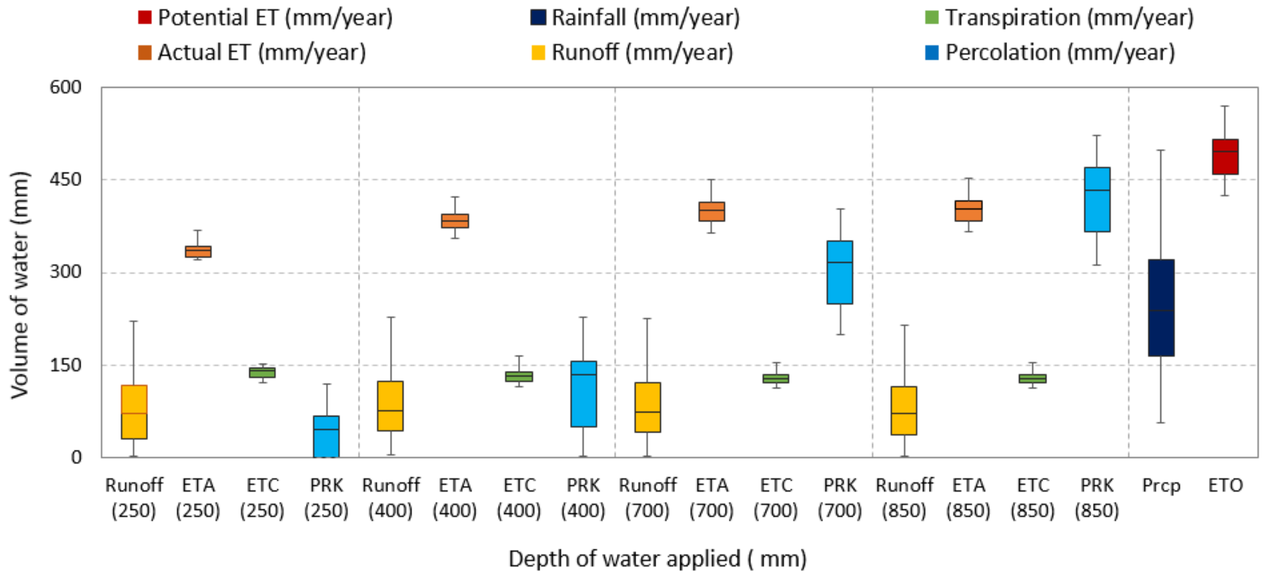


Figure 24: Surface runoff, actual evapotranspiration, transpiration, percolation and potential evaporation of the five alternative irrigation volumes to grow onion in Dangishta watershed (1995 to 2015).

In all cases, the potential evapotranspiration and the rainfall for the growing season were similar, on average approximately 495 mm/year and 240 mm/year. The evapotranspiration demand could not be met when 250 mm of Irrigation water was applied. In this situation, very small runoff was generated. Actual Evaporation (ETA) was satisfied when irrigation of 400 mm was applied. Yet, runoff generated for 400 mm of irrigation did not differ significantly compared to 250 mm irrigation. As the irrigation increased from 400 mm to 700 mm (and 850 mm), more water was lost through percolation below the root zone (300 mm to 400 mm). Figure 24 also illustrates that for onion production, a significant amount of water was lost from soil evaporation (actual evapotranspiration minus transpiration). Approximately 60% to 65% of the actual evapotranspiration is due to soil evaporation resulting from low leaf area indices providing sufficient shading of the soil throughout the growing period. Hence, adding a protective layer to cover the soil, such as vegetative mulch to protect the soil from sunlight or using efficient irrigation techniques such as drip irrigation to minimize soil wetting and evaporation could extend the limited amounts effectiveness of shallow groundwater for producing onions in the dry season.

Using field data together with the IDSS models, fertilizer use efficiency was modeled by varying the quantities of urea (NPK ratio of 46-0-0) and DAP (NPK ratio of 18-46-0). The fertilizer production function was developed by applying the optimal amount of irrigation (400 mm of water for onion). When tomatoes were simulated with no fertilizer, very low yield, ~8 t/ha (1995 to 2015) was obtained. On average, tomatoes experience nitrogen stress for 67 days and 9 days for phosphorus. Simulating tomato response to increasing N (urea) while keeping DAP at zero kg/ha, 50 kg/ha and 100 kg/ha is presented in Figure 9. The fertilizer production function indicated that tomato yield is limited by nitrogen and phosphorus. Increasing the nitrogen fertilizer alone while DAP is zero did not provide sufficient tomato yield. Addition of 50 kg/ha of

DAP and increasing urea, increased tomato yield subsequently; however, after a certain amount of fertilizer, the yield response to a change in fertilizer is insignificant (Figure 25). For example, increasing the urea amounts after 250 kg/ha and 50 kg/ha of DAP did not increase tomato yield.

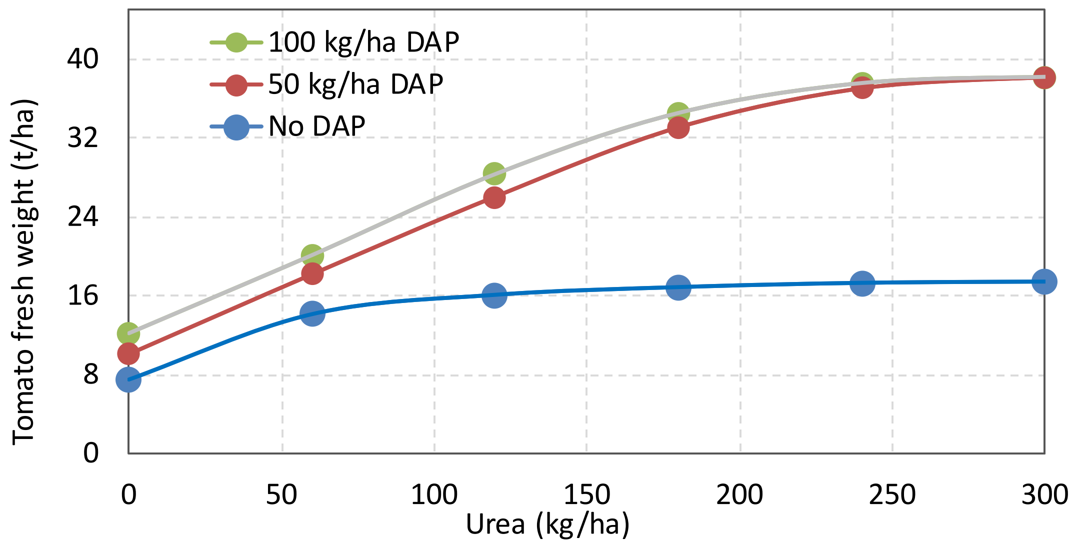


Figure 25: Fertilizer production function tomato in Robit watershed. The production function is developed for increasing urea while keeping DAP at zero, 50, 100 kg/ha for plot 1202.

Data acquisition and processing for upscaling analysis

ILSSI has been collecting hydrological data for the calibration of the biophysical models for upscaling analysis.

Remotely sensed evapotranspiration data was collected and processed to calibrate/validate the evapotranspiration from the biophysical models. The data that was processed and used for the analysis were evapotranspiration data from Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectrometer (MODIS).

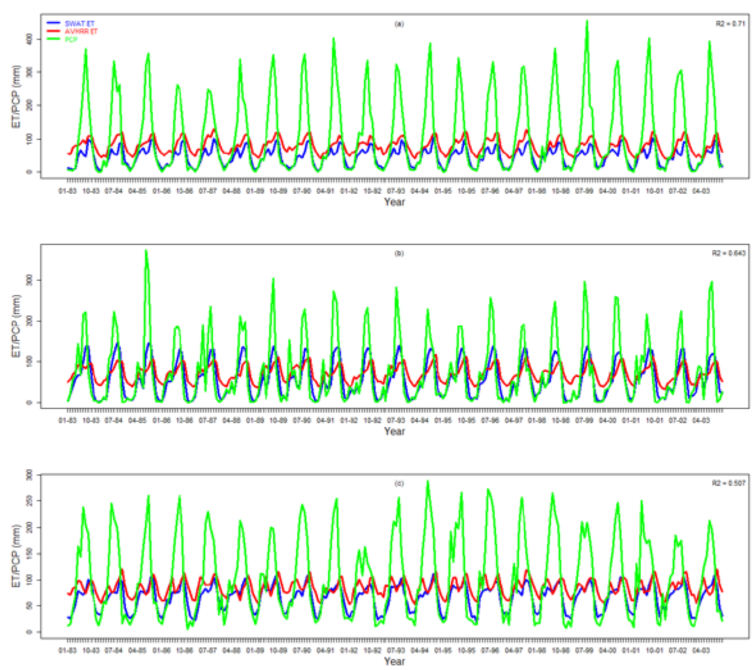


Figure 26. Plot of evapotranspiration estimation using SWAT model (SWAT ET), evapotranspiration data from AVHRR (AVHRR ET) and rainfall data at three randomly selected locations in Ethiopia: (a) Upper Blue Nile basin, (b) Awash basin and (c) Omo-Ghibe basin.

SWAT estimated actual evapotranspiration (AET) for all spatial locations in the country at 10 km by 10 km resolution. The AET data used from the AVHRR has 54 km by 54 km resolution and the MODS ET data has

1 km by 1 km. SWAT simulated AET and MODIS AET were processed and represented at a similar resolution as that of AVHRR AET (i.e. 54 km by 54 km resolution) for a reasonable comparison. Our findings showed that there is a good agreement between SWAT simulated AET and AVHRR AET on agricultural fields. Selected plots at the Upper Blue Nile basin (Figure 26a), Awash basin (Figure 26b) and Omo-Ghibe basin (Figure 26c) showed that there is a reasonable agreement between SWAT simulated actual ET and AVHRR actual ET. Evaluation between simulated SWAT AET and AVHRR AET using R^2 goodness-of-fit evaluation criteria provided more than 0.5 in most of agricultural dominated landscapes. The pattern for the time series SWAT simulated AET and observed rainfall agreed reasonably well in agricultural landscapes. Therefore, this suggested that the SWAT model is developed reasonably well to represent the biophysical conditions in Ethiopia and to use it to further study impacts of upscaling small scale irrigation on agricultural production, environmental sustainability and economic and nutrition outcomes.

TAMUS also developed detailed soil data for biophysical modeling for the entire African continent based on data from the African Soil Information System (AfSIS). The soil data is evaluated in the Lake Tana basin and provided satisfactory results in simulating the stream flow. The actual evapotranspiration simulated by the SWAT model was compared with the MODIS actual evapotranspiration data and satisfactory agreement was found in most of the areas during the wet season (Figure 27). The findings from this study have been submitted for publication in the Journal of Geoderma.

Outcome from the upscaling analysis

The suitability of lands for irrigation using groundwater in Ethiopia was assessed using GIS-based Multi-Criteria Evaluation (MCE) techniques Slope and rainfall deficit were found to be the most important factors in assessing suitability for irrigation, followed by population density and soil characteristics. A large portion of the irrigable land is located in the Abbay (Blue Nile), Rift Valley, Omo Ghibe, and Awash River basins. These basins have access to shallow groundwater (i.e., depth of groundwater less than 20 m from the surface) making it easier to extract. The comparison between available groundwater and total crop water requirements indicate that groundwater alone may not be sufficient to supply all suitable land. If both the groundwater and surface runoff are used in an integrated manner they may provide sufficient amount of water to have a full-fledged irrigation on the suitable irrigation land.

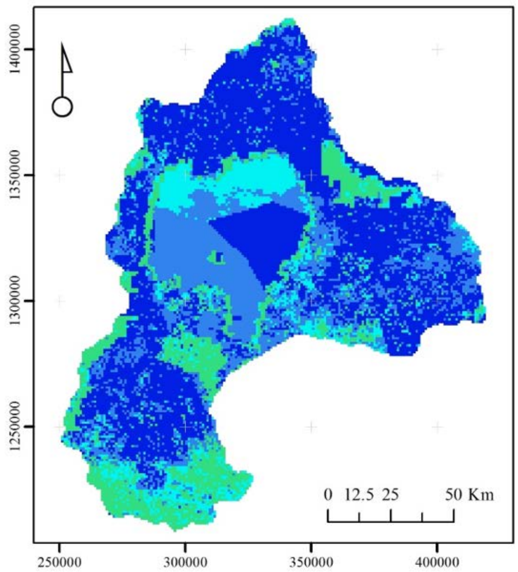


Figure 27. Coefficient of determination (r2) between MODIS actual evapotranspiration and SWAT simulated evapotranspiration for the wet seasons.

The SWAT model was developed and used to simulate crop yield for 9 major rain fed crops and 8 dry season irrigated crops. The crop yield for vegetable crop was simulated and provided to the Agent Based Model (ABM) for socio-economic analysis. Results indicated that substantial amount of vegetable yield can be produced in agricultural lands using irrigation water during the dry season. For example, the crop yield for tomato ranges from <1 ton/ha to 3 ton/ha depending on its location and agroclimate conditions (Figure 28a). The available water resources including groundwater recharge and surface runoff generation for the entire Ethiopia was estimated (Figure 28b). The available water resources found to be highly variable both spatially and temporally. The highest water resource was found in the Amhara and Oromia regions.

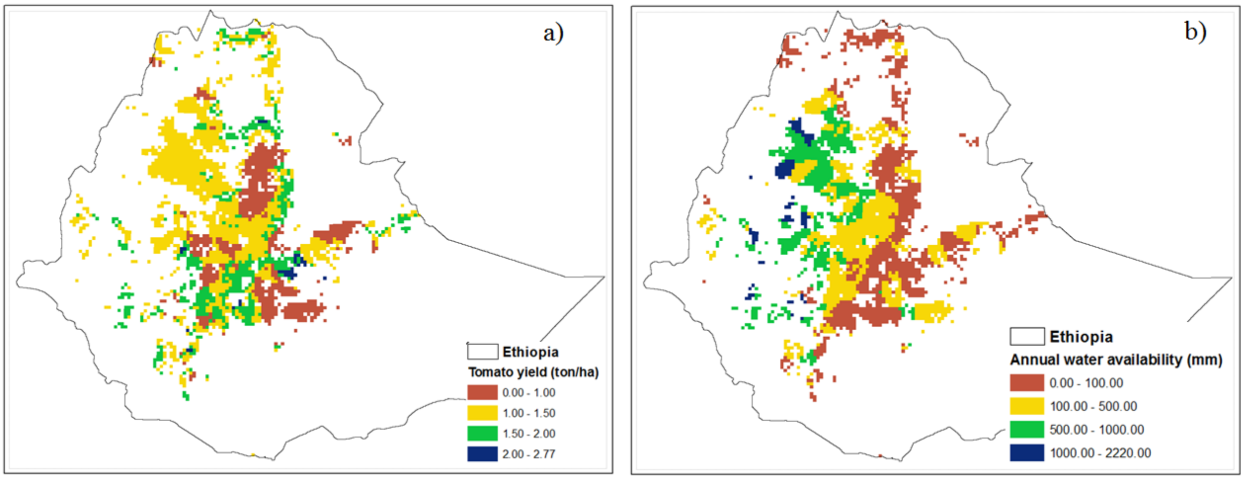


Figure 28. a) Spatial tomato production across agricultural lands, and b) available water resources, including surface runoff generation and groundwater recharge on agricultural lands.

Future Analysis

The IDSS analysis and the multi-criteria GIS suitability analysis of Small Irrigation Intervention in Ghana and Tanzania are scheduled to be completed in Quarter 4 of this year and will be included in future reports. Like Ethiopia, this further analysis will help to assess national development of potential of small-scale irrigation and also map adoption probability or transferability of small-scale irrigation technologies across these two countries.

Constraints and opportunities to improving access to SSI

Ethiopia

The overriding, consistent constraint in Ethiopia is small landholdings, usually around 0.5 (small farmer) to 1.5 ha (large farmer). This constraint is less severe in Tanzania where small farmer 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 small scale irrigation interventions have a higher urgency in Ethiopia than in Tanzania and Ghana.

The 2016 droughts in Ethiopia continued to cause serious problems for several reasons. The shortfall in rainfall in delayed planting and germination in most planted fodder trials and wells, ponds etc. ran dry so that even survival irrigations were often not feasible. Recharge of water sources only reached an acceptable level for forage planting in about February 2017 after some rainfall occurred. Crop losses in 2016 led to income losses of farmers and cash shortages and constraints to invest in new technologies.

Pre-season farmer meetings were held in Ethiopia in September. Bahir Dar University conducted meetings with 17 farmers of Robit and 30 farmers from Dangishita, as well as kebele administrators. The meetings addressed the lessons learned and gaps identified from the previous season and ended with the end work schedule for the next season of vegetable production.

Additionally, IFPRI contributed an article titled "Beyond the Drinking Glass: Expanding Our Understanding of Water-Nutrition Linkages" to Field Exchange which explores the major potential pathways through which irrigation can influence nutritional status (an online and print technical publication on nutrition and food security in emergencies and high burden contexts http://www.ennonline.net/fex/). (page 21, February 2017 edition (Issue 54). The article is expected to expand ILSSI's reach to a wider nutrition community.

B. Issues or Concerns Encountered During the Reporting Period

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

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

The CGIAR centers are undergoing very substantial budget issues which have resulted in loss of key staff to the ILSSI project and a high demand on remaining staff to take responsibility for more tasks and to participate in fund raising. For ILSSI, this is manifest mostly in IWMI where key leadership at the project level will turn over a second time in the life of this project in June. Key scientific personnel are also moving to new locations. IWMI management remains committed to successful performance in ILSSI – everyone is stretched and trying to do more with less.

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

Three of the four major ILSSI components are performing on schedule with delivery of results as planned. The mid-term report shows a high level of productivity with good results over the preponderance of the project. A comparison of contract objectives and achievements has been prepared and is available for review (enter title and ref). It is expected that a comprehensive final product will be achieved at the end of year five. The exit strategy that is being prepared in conjunction with the external review identifies the transition from phase I to phase II and provides the proposed way forward to fill in any deficiencies and apply the product of the first agreement to the next phase.

III. Human and Institutional Capacity Development

Stakeholder Engagement and Dialogue

TAMAR

TAMUS scientists have been continuously providing technical support on the use of IDSS tools to graduate students who are affiliated with IWMI/ILRI. TAMUS have also been providing data and software to graduate students who are supporting CGIAR partners in the ILSSI project.

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

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

In Ethiopia, TAMAR is supporting two male students at Bahir Dar University (BDU) in use of APEX. TAMAR is also supervising three Ph.D. students at Addis Ababa University (AAU). Gebrekidan Worku

Tefera, a Ph.D. student from AAU's College of Development Studies, is preparing a Ph.D. thesis on "Watershed Management Scenarios under Changing Climate in Jemma Sub Basin, Blue Nile Basin" using the SWAT model. Achenafi Teklay, Ph.D. candidate at the Addis Ababa University at the Integrated Water Resources Management Institute is studying the impact of land use change on hydrological variables. Temesgen Gashaw, a Ph.D. at AAU's Center for Environmental Science, is preparing a thesis on "Valuation of land use/land cover change effects on stream flow patterns in the Upper Blue Nile Basin, Northwestern Ethiopia." There are several IDSS users in Ethiopia who regularly receive support from TAMAR scientists (Table x). Additionally, TAMAR has been in discussion on the use and integration of FARMSIM in thesis research with three male students from Ethiopia. One is currently pursuing his PhD in Germany (Getachew Legese Feye). While Birhanu Tefera is admitted to pursue a PhD in the department of Agricultural and Resources Economics at the University of Connecticut. The third one is called Kaleb Shiferaw. Kaleb was working for the ILRI-LIVES project (Livestock and Irrigation Value chains for Ethiopian Smallholders) and submitted an application for admission into a PhD program in New Zealand and was planning to start in February 2017.

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

These Tanzanian SWAT users have been applying the model to study the impacts of small scale irrigation on social-ecological systems. Four former students from Sokoine Agriculture University have contacted TAMAR scientists to support them in the use of FARMSIM in their research work. Andrew Rogers a lecturer in the Department of Policy, Planning and Management at Sokoine University of Agriculture (SUA) will use the FARMSIM model to conduct his research on "Economic Viability of Newly Introduced Tropical Adapted and Improved Chicken Ecotypes at Village Level, Tanzania". He is currently collecting the data and setting-up the model.

Charles Malaki, a lecturer in the Department of Agricultural Economics and Agribusiness at the Sokoine University of Agriculture, wants to use FARMSIM in a research study on economic analysis and farm productivity in Tanzania. Ibrahim Kadigi is a research assistant at Sokoine University of Agriculture. He is planning to use the FARMSIM model in the implementation of the "Scale-N" project (http://www.scale-n.org), a collaborative research project between Germany and Tanzania through Sokoine University of Agriculture. The project is funded by the German Federal Ministry of Food and Agriculture (1,381,825 €) for 3 years (2015-2018).

The main objective of Scale-N project is to safeguard food and nutrition security for the local population in Tanzania by supporting the development of diversified and sustainable agriculture. The project is implemented in four villages: 2 villages from Dodoma region and 2 villages from Morogoro region. Lutengano Mwinuka, a lecturer in the Department of Agricultural Economics and Agribusiness at the Sokoine University of Agriculture, has applied the FARMSIM model in two research papers. One paper was published in the African Journal of Science, Technology, Innovation and Development in 2016. The second one is under review.

A list of professionals/students who have been receiving support on the use of IDSS from TAMAR scientists can be found in Annex IV

IWMI

In Ethiopia: IWMI and national partners presented to stakeholders in Ethiopia at the Amhara Agricultural Forum hosted by the Small Scale and Micro Irrigation for Ethiopian Smallholders (SMIS), a Canadian-Dutch funded project that aims to improve capacity in small-scale irrigation to support upscaling and out-scaling across Ethiopia.

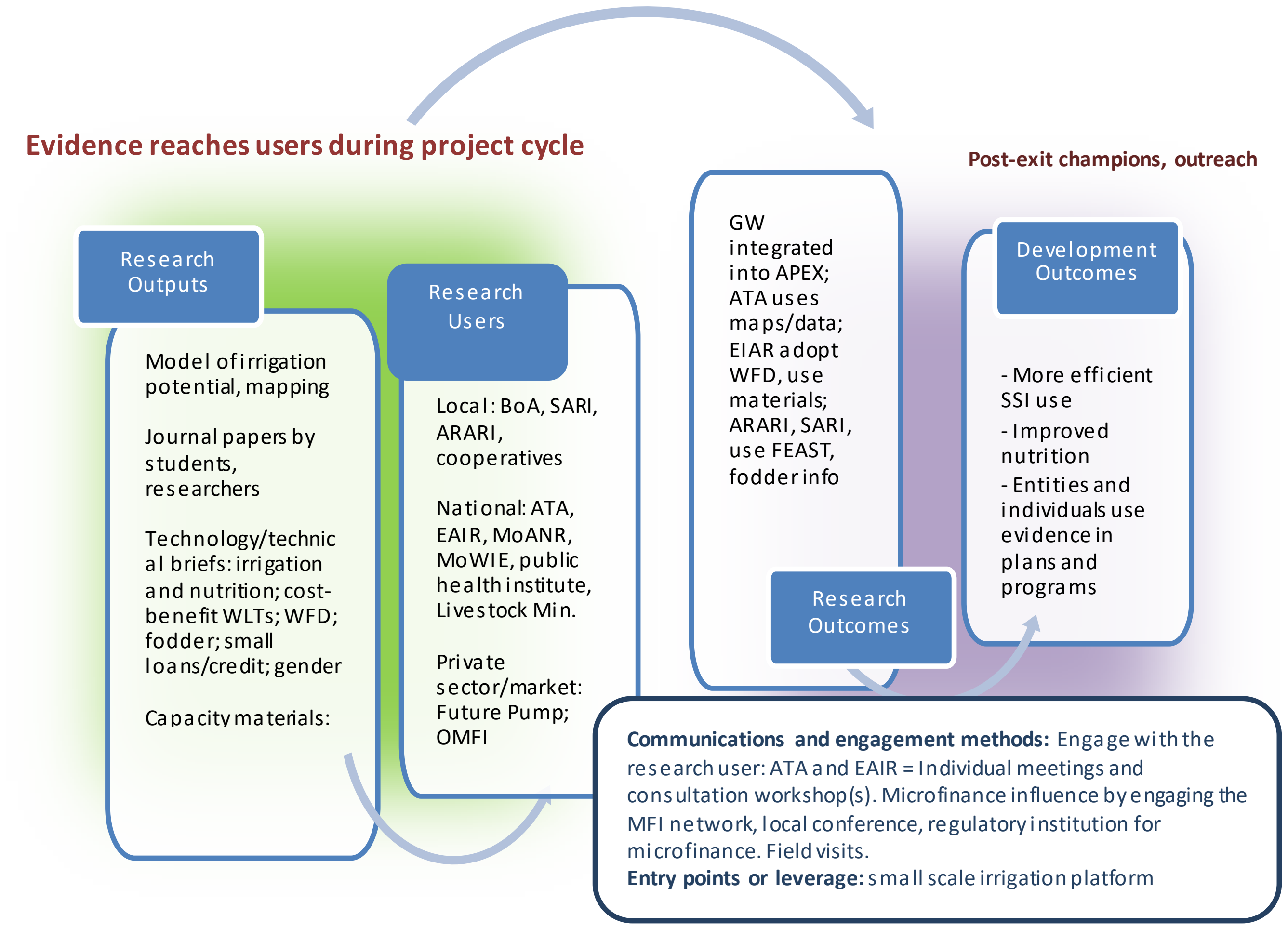
In Ghana, the period corresponded to parliamentary and presidential elections, which resulted in a change in political party in government. This was a constraint to engaging with government institutions at policy level, as many of the institutions were being reformed and reconstituted during the reporting period. Additionally, Pre-season farmer field forums were held in Ghana in October to discuss lessons from previous dry season irrigation and plan for new season. The project shared price analysis that showed higher prices for onion and tomato before mid-February, and farmers decided to plan early to gain from residual moisture following rainy season and also take advantage of higher prices with earlier harvest.

Date	Subject/Purpose	Male	Female	Location
October 2016	Geochemistry & Isotope Hydrology applications in Water Resources Management (introduced the applications of geochemistry and isotopes in hydrology, sampling of waters for lab analysis, how to present data, applications of Isotope hydrology using 18O-2H : H2O; 15N-18O: NO3; 222Rn; 13C-DIC; 3H; 14C and mass balance of geochemistry parameter (such as chloride) to separate baseflow from surface runoff.	15		Bahir Dar University in partnership with IWMI and Addis Ababa University
January/February 2017	Irrigated agronomy and irrigation scheduling with wetting front detectors	22	25	Ghana project sites: Dimbasinia, Zanlerigu and Bihinayiili

Farmer exchange field visits were held in February in Ghana. Participant farmers visited different field sites to observe different irrigation practices and varieties of crops under irrigation. An updated list of graduate students whose field work is supported under ILSSI is found in Annex 1.

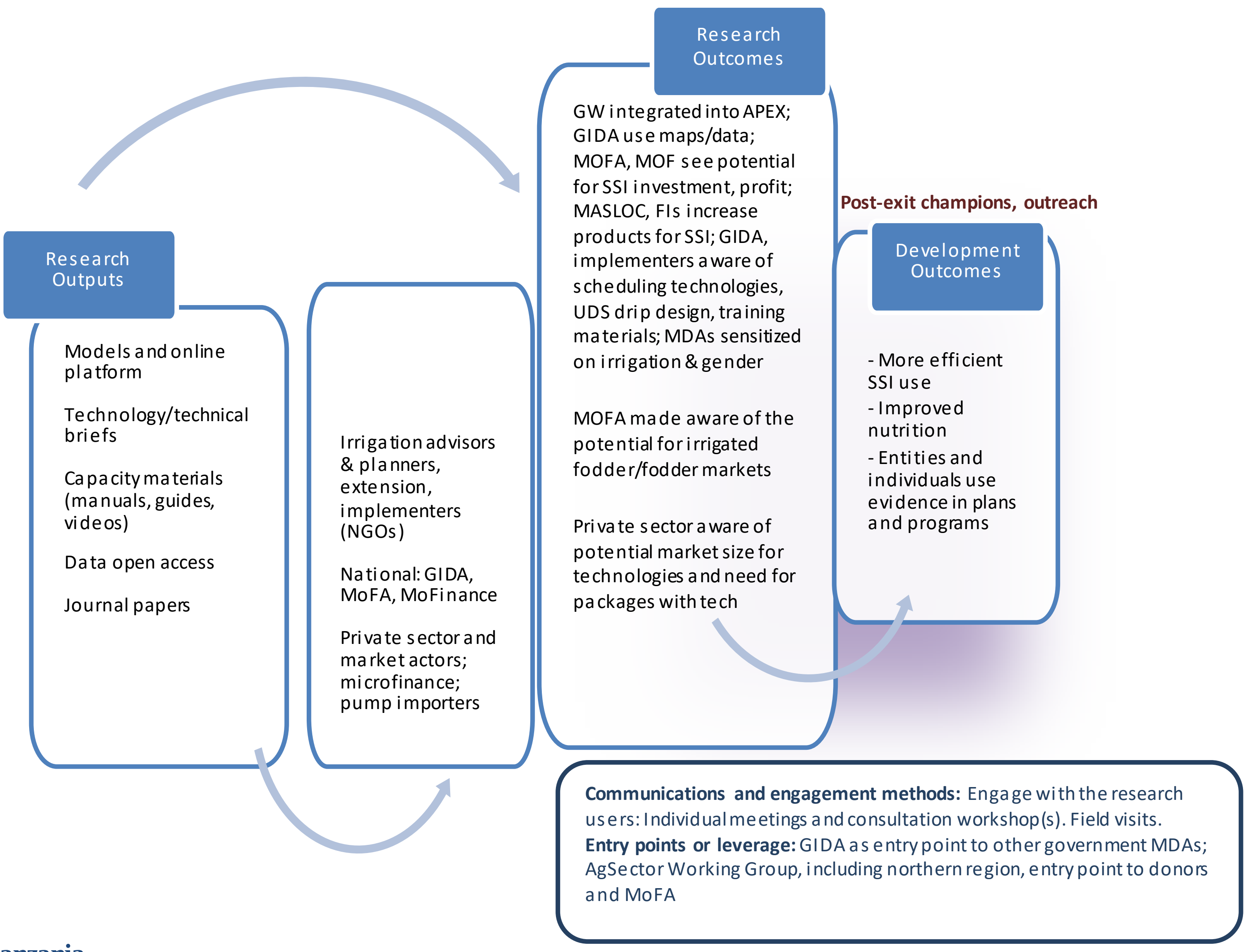
Further, in October 2017, IWMI refined the process from project activities to impact post-exit. The following impact pathways were developed to guide the project toward sustainable outcomes from the project activities and investments, including after project exit:

Ethiopia



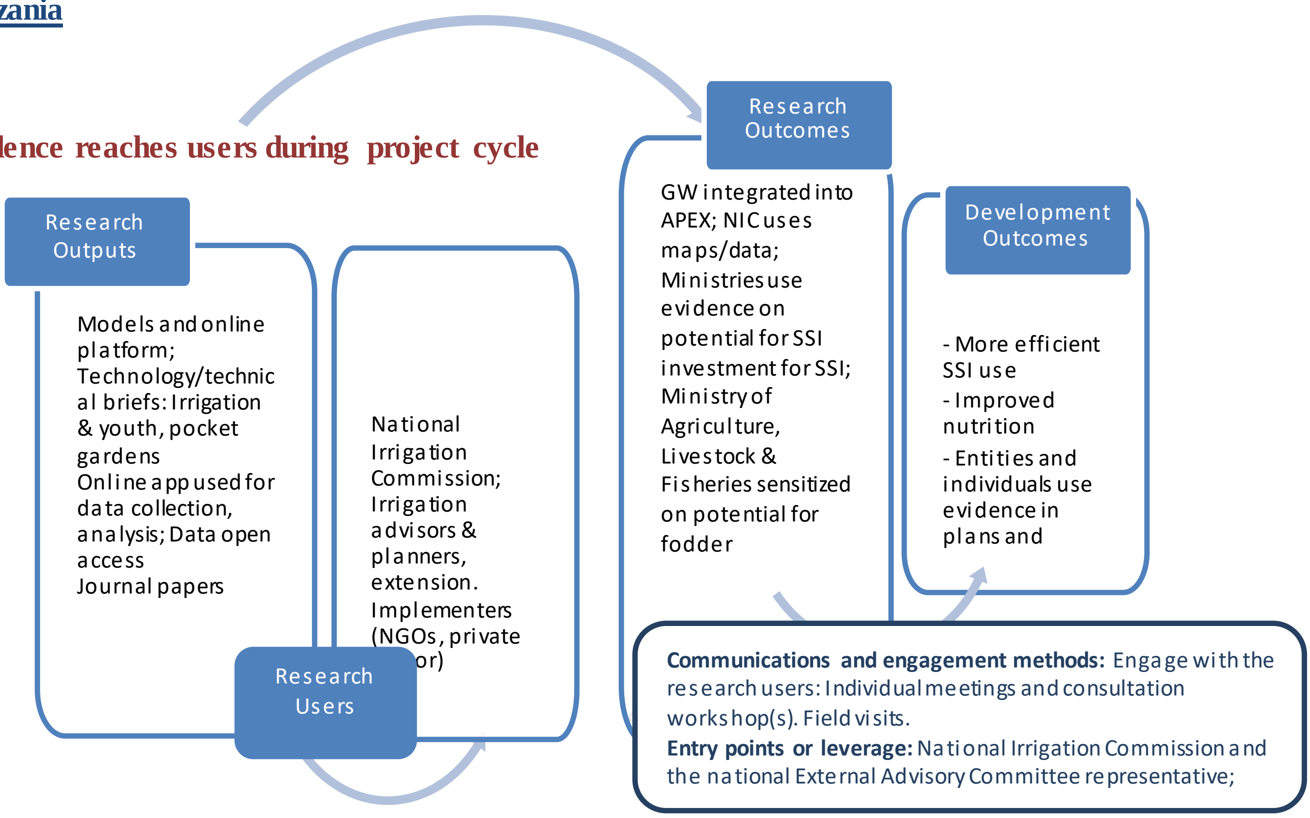
Ghana

Evidence reaches users during project cycle



Tanzania

Evidence reaches users during project cycle



ILRI

Ethiopia

In Robit Bata Bahardir Zuria Woreda 2-day training was conducted for 11 new farmers intend on irrigated forage adoption including 5 Kebele and 4 Woreda agriculture experts and extension workers. Napier sole and intercropped with Desmodium, Rhodes grass establishment and management and their feeding were topics of the training.

Irrigated fodder field day was held in Robit Bata Bahardir Zuria Woreda

A field day was conducted at Bahardir Zuria Woreda to create awareness about irrigated fodder and its potential impact with participation of 62 farmers (unfortunately only 6 were female) and 23 experts. The field day was attended by high level officials (Ato Tesfahun Menigistie the head of the regions livestock agency and Dr. Tilaye t/Wolde the vice director of the Amhara Regions Agricultural Institute). Scale out of irrigated forage technologies was recommended and pertinent plans were drawn up.

Ghana

Twenty one farmers were trained in irrigated fodder production in the two project sites.

Prepare and Conduct Short Courses on Use of the IDSS

TAMAR

From the October 2016 to March 2017 period, TAMUS provided Integrated Decision Support System (IDSS) training and Advanced Soil and Water Assessment Tool (SWAT) training at the University of Dar es Salaam and Addis Ababa University.

TAMUS provided IDSS training at the University of Dar es Salaam from 23-27 January 2017. TAMUS also provided an advanced training on the Soil and Water Assessment Tool (SWAT) from January 18-20, 2017 at the University of Dar es Salaam. The trainings were hosted by the Water Resources Engineering Department (WRED) of the University of Dar es Salaam and the Tanzania Water Partnership (TWP). The total number of participants for both the IDSS and advanced SWAT were 73 people (Table 6). The total number of participants for the IDSS were 48 people (i.e. 34 males and 14 females) and the number of participants for the advanced SWAT were 25 (19 male and 6 female participants).

The IDSS workshop in Addis Ababa University was held on January 30 to February 3, 2017. Advanced SWAT rather than the introductory SWAT was offered as part of the IDSS training. The Addis Ababa Institute of Technology (AAiT) department of Civil Engineering hosted the training. A total of 59 participants attended the IDSS workshop, of which 43 attended Advanced SWAT, 12 APEX and 4

FarmSIM. Of the 59 participants, 11 were women, with 4 women attending the SWAT workshop, 6 women attended APEX and 1 attending the FarmSIM workshop.

Workshop Participants Dar Es Salam Tanzania, January 2017

In these IDSS workshops, the trainees were introduced to three models: the Soil and Water Assessment Tool (or SWAT, at http://swat.tamu.edu), the Agricultural Policy/Environmental eXtender (or APEX, at http://epicapex.tamu.edu) and the Farm Income and Nutrition Simulator (or FarmSIM, at http://afpc.tamu.edu).

The first half-day of training consisted of an overview of the IDSS, with examples drawn from the ILSSI project in the respective country (Tanzanian case at the University of Dar es Salaam IDSS training and Ethiopian case at the Addis Ababa University). Participants were provided a detailed description of the capabilities of each of the three component models. From the afternoon of the first day through the fourth day, the participants attended individual model training in either SWAT, APEX or FarmSIM.

	University of Dar es Salaam			Addis Ababa University		
Model trained	Male	Female	Total	Male	Female	Total
SWAT	17	10	27	3	1	4
APEX	9	3	12	6	6	12
FarmSIM	8	1	9			
Advanced SWAT	19	6	25	39	4	43
Grand Total	**53**	**20**	73	48	11	59

Table 6. Number of participants: for the IDSS training

In the SWAT training session, participants were taught the theory of SWAT model development and its application. Participants received hands-on training in data preparation, watershed delineation, hydrological response unit definition, model setup and simulation, model calibration, and scenario development (including crop rotation, irrigation and fertilizer application, and tillage practices). The participants also learned how to pass calibrated hydrological parameters to the APEX model and how to report results (such as suitable areas for irrigation) to the FarmSIM model.

The general objective of the APEX training session was to introduce users to the WinAPEX model and its application. Trainees learned to prepare input data, set up and run WinAPEX, edit the APEX database, calibrate APEX for flow, sediment and crop yield, and to pass calibrated crop yield to FARMSIM and calibrated crop parameters to SWAT. The participants also learned to prepare management schedules of manual and automatic irrigation, crop rotation, multiple cropping and fertilizer applications.

The purpose of the FarmSIM training session was to teach participants how to use the model to simulate potential benefits of adopting new agricultural technologies, including small-scale irrigation technologies. The workshop mainly consisted of two parts. First, participants were introduced to the simulation engine used to simulate the FARMSIM model, the Simulation for Excel to Analyze Risk (or Simetar), and it's different analytical tools. Then, they learned to apply Simetar tools (functions) to simulate a farm.

The advanced SWAT training was aimed to advance participants SWAT modeling skill to a higher level. Participants in the Advanced SWAT training were people who attended previous Introductory SWAT training or who have prior SWAT experience. The training includes model calibration, uncertainty and sensitivity analysis, and impact analysis. The participants were given hands on training on SWAT model Calibration and Uncertainty Prediction tool (SWAT-CUP). They also learned the theoretical background on calibration, uncertainty and sensitivity analysis. The training on impact analysis includes impacts of small scale irrigation, climate change and land use change. The participants also learned advanced data manipulation techniques. The advanced SWAT training was given as a standalone training prior to the IDSS training at the University of Dar es Salaam. While at the Addis Ababa University, it was offered as part of the IDSS training.

On the fifth day of the seminar, the participants gathered together for an in-depth case study of the integrated capabilities of the IDSS drawn from a case study in each respective country. The three model trainers presented a demonstration of the hands-on integration exercise. Finally, the participants were divided into groups (each consisting of at least one trainee for each of the three models) to work together on the integration of their individual modeling results.

Institutional Capacity Development

TAMAR

TAMUS has very close engagement with the Ethiopian Agricultural Transformation Agency (ATA). TAMUS presented the overview and application of IDSS to program directors at ATA. ATA is interested to receive ATA tailored-IDSS training by TAMUS scientists. ATA is working on the contents of the tailor-made IDSS training and on the formal request. ATA has also requested TAMUS scientists to support them in reviewing reports and providing technical assistance on application of IDSS tools.

In February, The IDSS team from Texas A&M visited the IWMI-ILRI office to discuss the use and implementation of the IDSS tools and as well as the continued data collection efforts by those two partners. During this stay, TAMUS scientists supported IWMI staff on the use of the IDSS tools, gaps and constraints analysis, and upscaling analysis. During this visit, TAMUS scientists provided a seminar on the capability of IDSS tools, gaps and constraint analysis of tomato production in Robit watershed (Ethiopia) and the scale up activity for the case of Ethiopia. Participants included staff from IWMI and ILRI Addis office as well as staff from IWMI Colombo office and IWMI Accra office. Additionally, during this stay, TAMUS scientists provided a one-to-one training to IWMI staff member on APEX model setup, calibration and validation.

Also in February, TAMUS provided presentations to the Ethiopian Agricultural Transformation Agency (ATA) on the capability of the Integrated Decision Support System (IDSS) tools and the findings of gaps and constraints analysis of small-scale irrigation on February 16, 2017. ATA is one of the leading organizations in Ethiopia created to help accelerate the growth and transformation of the country's agricultural sector with a priority of improving the livelihoods of the smallholder farmers across the country. We provided this presentation with the invitation of Seyoum Getachew who is the director for Sustainable and Watershed Development at ATA. Most of the participants were directors of different departments of ATA, program leaders and project coordinators, a list of participants can be found in Annex 3 Following the presentation, TAMUS scientists discussed findings from ILSSI project. For example, TAMUS estimated potential suitable areas for small scale irrigation using shallow groundwater. ATA mapped groundwater potential in two small watersheds in the Southern part of Ethiopia. TAMUS scientist and ATA experts found that the estimates for groundwater potential in these two watersheds agree well even if TAMUS and ATA used different approaches of groundwater potential estimation for small scale irrigation. ATA requested TAMUS's technical support in evaluating project executions and consultant reports. Moreover, TAMUS Scientist and ATA technical specialist have begun working on a tailor-made IDSS training for ATA staff.

TAMUS scientists have been in close communication with the Abay (Blue Nile) River Basin Authority (ABA) and Tana Sub-Basin Organization (TaSBO) officials and experts at Bahir Dar University in Ethiopia. ABA is one of the 12 river basins authority in Ethiopia. TaSBO is one of ABA branch office assisting with the allocation and management of water resource in the Lake Tana Basin. The responsibility of the Authority is to undertake and facilitate the implementation of an Integrated Water Resource Management (IWRM) in the basin. TAMUS scientists visited the recently established automatic river and weather monitoring stations in the basin. Several of the ABA and TaSBO staff members attended the either of the IDSS trainings conducted in Ethiopia. Some of them are using the IDSS tools (especially SWAT) on different project activities. The ABA is planning to use the IDSS models for watershed management practices. Moreover, the organization showed strong interest to host the next IDSS training in Ethiopia to improve the competency of its staff.

The Tanzania Water Partnership (TWP) is one of the partners that organized the IDSS workshop at the University of Dar es Salaam in collaboration with the Department of Water Resources Engineering. TWP and the Water Resources Engineering Department are requesting TAMUS to provide regular regional IDSS workshop at the University of Dar es Salaam. TWP together with TAMUS scientists are writing proposals to attract external funding from the WATERnet to cover the expenses for this workshop. The University of Dar es Salaam hosts regional MSc program in Water Resources Engineering with support from WATERnet. They discuss that such regional workshop will strengthen the MSc program at UDSM and water resources research in the region.

NCA&T

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

Field Level Capacity development and outreach

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

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

IV. Innovation Transfer and Scaling Partnerships

TAMAR has provided IDSS software (SWAT, APEX, and FARMSIM/SIMETAR) to: several cooperating scientists at each cooperating ILSSI institution; participants in the IDSS workshops (detailed in Section X); and graduate students and staff at national partner institutions (such as Bahir Dar University, University of Dar es Salaam, Sokoine University of Agriculture, and Nelson Mandela- African Institute for Science and Technology) who are actively engaging in the project and whom TAMAR is supporting in their research (detailed in Section IX). See Section VIII, above, for a description of the IDSS and its component models.

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

V. Future Work

For the remainder of year 4 and year 5 major emphases will be on integrating and organizing the results of phase I and using this to engage stakeholders at all levels in the three countries to assure concerns have been addressed and that there is full awareness by them of results in the context of their possible application. An internal workshop will be held at Texas A&M in June 2017 to finalize the format and approach for presenting the ILSSI product as an integrated package that shows how the components come together to provide a unique perspective on small scale irrigation technologies and know-how. Field research will be mostly completed in the remainder of year 4 and the final endline household surveys will be completed in year five. The ex post and constraints analyses for all three countries will be completed in year five. Application of new national level natural resources assessments will be applied with government agencies such as the ATA in Ethiopia in support of their policy and planning endeavors. ILSSI will provide all necessary support to the USAID External Review scheduled to be completed in July 2017. The full ILSSI team will visit the Bureau of Food Security in Washington in July to brief staff and senior administrators on the near final results of the cooperative agreement. ILSSI will continue to actively engage the USAID Missions in all three countries to assure their awareness of the product and to explore ways in which both the innovations and the analytic methods can be made useful to the Missions. Plans are being made to have a dedicated ILSSI session on one of the major international water meetings in Africa in year five. The ILSSI mid-term report (November 2016 – http://ilssi.tamu.edu) addresses the exit strategy and current thinking about phase II. Prepared as one input to the review and decision process for renewal, this document presents the conceptual framework and vision for a possible continuation of the agreement.

VI. Annex

Long Term Training

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

Name of Student	Gender	University of Study	Degree[1]	Major	Graduation Date	Home Country	Home Institution[2]
Tewodros Assefa	M	NCA&T State University	Ph.D.	Energy and Environmental Systems	December 31, 2017	Ethiopia	Bahir Dar University
Tsehay Azeref Wondmeneh	M	Bahir Dar University	M.S.	Agronomy	June 2017	Ethiopia	Bahir Dar University
Hailie Alebachew	F	Bahir Dar University	M.S.	Horticulture	June 2017	Ethiopia	Bahir Dar University
Mariana McKim	F	NCA&T State University	M.S.	Agricultural Education	August 2016	USA	N.C. A&T
Sintayehu Alemayehu Teshome	M	Texas A&M College of Agriculture and Life Sciences	M.S.	Ecosystem Science and Management (Range Mgmt)	June 2017	Ethiopia	TAMAR

Belainew Belete	M	Bahir Dar University	M.S.	Economics	October 2016	Ethiopia	Bahir Dar University
Talakie Asnake	F	Bahir Dar University	M.S.	Water resources Engineering	June 2016	Ethiopia	Bahir Dar University
Muluye Gedife	M	Bahir Dar University	M.S.	Water resources Engineering	December 2016	Ethiopia	Bahir Dar University
Adisu Wondimu	M	Bahir Dar University	M.S.	Chemical Engineering	June 2017	Ethiopia	Bahir Dar University
Debebe Lijalem	M	Bahir Dar University	Ph.D.	Water resources Engineering	June 2018	Ethiopia	Bahir Dar University
Misba Abdela	M	Bahir Dar University	M.S.	Water resources Engineering	June 2016	Ethiopia	Bahir Dar University
Abdu Yimer	M	Bahir Dar University	M.S.	Water resources Engineering	June 2016	Ethiopia	Bahir Dar University
Kassaw Beshaw	M	Arba Minch University	Ph.D.	Water resources Engineering	June 2019	Ethiopia	Arba Minch University
Demelash Wendemench	M	Arba Minch University	Ph.D.	Water resources Engineering	June 2019	Ethiopia	Arba Minch University
Tariku Yadeta Fufa	M	Arba Minch University	M.S.	Economics	December 2016	Ethiopia	Arba Minch University
Raymond Tetteh	M	UDS	M.S.				

Short Term Training

Attendees of the ATA IDSS Workshop

Name	Title	Company	Phone	Fax	E-Mail
1. Laketch Mikael (F)	Senior Director	Environmentally Sustainable & Inclusive Agricultural Growth	+251-115-570-668	+251-115-570-668	laketch.Mikael@ata.gov.et
2. Seyoum Getachew	Director	ATA, Sustainable Irrigation and Watershed Development	+251-91-114-2495/93-009-8873	+251-115-570-668	Seyoum.Getachew@ata.gov.et
3. Seblewongel Deneke (F)	Director	ATA, Gender and Nutrition Program	251 930 000	+251-115-570-668	Seblewongel.Deneke@ata.gov.et
4. Dr. Wagayehu Bekele	Director	ATA, Climate change adaptation and mitigation	251 930 000 346	+251-115-570-668	Wagayehu.Bekele@ata.gov.et

Name	Title	Company	Phone	Fax	E-Mail
5. Ayele Gebreamlak	Director	ATA, Commercial and Contract farming, Commercial & Contract Farming	251 911 424 713	+251-115-570-668	Ayele.Gebreamlak@ata.gov.et
6. Retta Gudisa	Director	ATA, Planning and MLE, Planning & MLE	251 911 841 880	+251-115-570-668	Retta.Gudisa@ata.gov.et
7. Kindie Aysheshm	Director	ATA, Cooperative development, Cooperatives Development	251 918 768 375	+251-115-570-668	Kindie.Aysheshm@ata.gov.et
8. Dr. Yitaye Alemayehu	Director	ATA, Research and Extension, Research & Extension	251 912 672 945	+251-115-570-668	Yitaye.Alemayehu@ata.gov.et
9. Addisu Tadege	Director	Agricultural Mechanization, Mechanization	251 918 728 022	+251-115-570-668	Addisu.Tadege@ata.gov.et
10. Mersha Tesfa	Project Team Leader I	Inputs & Crop Protection, Inputs & Crop Protection	251 911 922 877	+251-115-570-668	Mersha.Tesfa@ata.gov.et
11. Belete Bantero	Senior Technical Expert	ATA, Sustainable Irrigation and Watershed Management	+251-913288977 /+251 911861695	+251-115-570-668	Belete.Bantero@ata.gov.et

Name	Title	Company	Phone	Fax	E-Mail
12. Kassahun Teka	Project Team Leader	ATA, Sustainable Irrigation and Watershed Management	+251 920 751 613/ +251 115 570 668	+251-115-570-668	kassahun.teka@ata.gov.et
13. Getachew Mekuria	Senior Project Officer I	ATA, Sustainable Irrigation and Watershed Management	251 912 048 741	+251-115-570-668	Getachew.Mekuria@ata.gov.et
14. Yonas Mulugeta	Senior Project Officer I	ATA, Sustainable Irrigation and Watershed Management	251 911 966 183	+251-115-570-668	Yonas.Mulugeta@ata.gov.et
15. Armaye Hailu (F)	Program Assistant	Program Assistant - Environmentally Sustainable & Inclusive Agricultural Growth,	251911-899610	+251-115-570-668	armaye.hailu@ata.gov.et

Professionals/students who have been receiving support on the use of IDSS from TAMAR scientists

Name	Professional status	Institutional affiliation	country	Objective of the research
Dr. Hassen Mohammend	expert	Water and Land Resources Center	Ethiopia	studying impacts of land management practices on the Ethiopian grand renaissance dam
Gebrekidan Worku	PhD student	Addis Ababa University	Ethiopia	Studying climate and land management change
Temesgen Gashaw	Ph.D. student	Addis Ababa University	Ethiopia	Studying the effect of land use change on stream flow and soil erosion
Achenafi Teklay	PhD student	Addis Ababa University	Ethiopia	Studying land use change
Mulugeta Ferede	Lecturer	Ambo University	Ethiopia	Understanding watershed behavior
Rahel Gezahegne	MSc student	Addis Ababa University	Ethiopia	Impact of land management on stream flow in several watersheds
Nigusu Tarekegne	MSc student	Hawassa University	Ethiopia	Studying climate change
Upendo Eliuze Msovu	PhD student	Dar es Salaam University	Tanzania	Studying impacts of small scale irrigation interventions

Canute Hyandye	PhD student	Nelson Mandela African Institution of Science and Technology	Tanzania	Studying the impacts of land use change on stream flow
Okoko Kossam	Lecturer	University of Dar es Salaam	Tanzania	Studying climate change
Andrew Rogers	Lecturer	Sokoine University of Agriculture	Tanzania	Economic Viability of Newly Introduced Tropical Adapted and Improved Chicken Ecotypes at Village Level
Charles Malaki	Research assistant	Sokoine University of Agriculture	Tanzania	Safeguarding food and nutrition security for the local population
Lutengano Mwinuka	Lecturer	Sokoine University of Agriculture	Tanzania	Writing papers on application of FarmSIM on agribusiness

Knowledge Products

IWMI

1. Kadyampakeni, D., E. Obuobie, M. Mul, R. Appoh, A. Owusu, B. Ghansah, E. Boakye-Acheampong, J. Barron. 2017. Agro-Climatic and hydrological characterization of selected watersheds of northern Ghana. IWMI Working Paper. Forthcoming.
2. Katic, P. 2017. Evidence for upscaling of dry season irrigation technologies: Market opportunities. ILSSI Project Report.
3. Gebregziabher, G., F. Hagos, N. Lefore, A. Haileslassie. 2017. Analysis of poverty impacts of household level water lifting irrigation technologies. ILSSI project report.
4. Hagos, F., G. Gebregziabher, N. Lefore, A. Haileslassie. 2017. Credit access and adoption of irrigation technologies by smallholder farmers: Evidence from Ethiopia. ILSSI project report.
5. Gedfew, M., P. Schmitter, P. Nakawuka, S. Tilahun, T. Steenhuis, S. Langan. 2016. Partial Nutrient Balance at Farm plot level under Different Irrigation Water Management for Tomato production. Poster presented on the Small Scale and Mirco Irrigation for Ethiopian Smallholders project. Amhara Agricultural Forum hosted by the Small Scale and Mirco Irrigation for Ethiopian Smallholders, a Canadian-Dutch funded project. Bahir Dar, 8-9 December 2016.
6. Schmitter, P., A. Haileslassie, Y. Desalegn, A. Chali, S. Tilahun, S. Langan, J. Barron. Improving on-farm water management by introducing wetting front detectors to small scale irrigators in Ethiopia. Presentation on the Small Scale and Mirco Irrigation for Ethiopian Smallholders project. Amhara Agricultural Forum hosted by the Small Scale and Mirco Irrigation for Ethiopian Smallholders, a Canadian-Dutch funded project. Bahir Dar, 8-9 December 2016.
7. Seifu A. Tilahun, Petra Schmitter, Prossie Nakawuka, Abdu Yimer, Debebe Lijalem, Temesge Enku, Tammo Steenhuis, Simon Langan, Jennie Barron. Shallow Groundwater Recharge and its Potential for Smallholder Dry Period Irrigation in Lake Tana Basin Presentation on the Small Scale and Micro Irrigation for Ethiopian Smallholders project. Amhara Agricultural Forum hosted by the Small Scale and Mirco Irrigation for Ethiopian Smallholders, a Canadian-Dutch funded project. Bahir Dar, 8-9 December 2016.
8. Moges M.A., Schmitter P., Tilahun S., Dagnaw D.C., Akale A.T., Langan S., Steenhuisen T. (2016) Suitability of Watershed Models to Predict Distributed Hydrologic Responses in the Awramba Watershed, Upper Blue Nile Basin (Online, Land Degradation & Development, in Press.
9. Muche, H., M. Abdela, P. Schmitter, P. Nakawuka, S. Admasu Tilahun, T. Steenhuis, S. Langan. 2017. Application of Deep tillage and Berken Maresha for hardpan sites to improve infiltration and crop productivity. ICAST conference 2017, Bahir Dar University.

10. Abeyou W. Worqlul1, Jaehak Jeong, Yihun T. Dile, Javier Osorio, Petra Schmitter, Thomas Gerik1, Raghavan Srinivasan and, Neville Clark. Assessing Potential Land Suitability for Surface Irrigation using Groundwater in 1 Ethiopia. Applied Geography (in review).
11. Essayas K. Ayana, Yihun D. Tadelle, Balaji Narasimhan, Raghavan Srinivasan. Flow prediction in ungauged watersheds using efficiency comparison of existing global soil data. Journal of Hydrology (ready for submission).
12. Abeyou Worqlul, Yihun T. Dile, Jean-Claude Bizimana, Jaehak Jeong, Thomas J. Gerik, Raghavan Srinivasan, James W. Richardson, Neville Clark. Multi-dimensional evaluation of small-scale irrigation intervention: a case study in Dimbasinia watershed, Ghana. Ecological Modeling Journal (in preparation).
13. Yihun D. Taddele, Essayas K. Ayana, Abeyou Worqlul, Raghavan Srinivasan, Thomas J. Gerik, Neville Clark. Usefulness of remote sensing products for large scale hydrological modeling. Journal of Hydrology (in preparation).
14. Richardson, James W. and Bizimana, Jean-Claude. "Agricultural Technology Assessment for Smallholder Farms in Developing Countries: An Analysis using a Farm Simulation Model (FARMSIM)." Agricultural and Food Policy Center, Department of Agricultural Economics, Texas A&M University, Research Report 17-1, January 2017. https://www.afpc.tamu.edu/pubs/2/683/FARMSIM.pdf

Student theses completed:

1. M. Gedfew. 2017. Comparing the effect of soil moisture and climate based irrigation scheduling strategies on tomato production and partial nutrient balances: Case study in Robit watershed. Bahir Dar University. Thesis submitted toward requirements for a MSc degree.

2. B. Belete. Impact of small-scale irrigation technology on farm household welfare in Amhara Region: Evidence from Dangila and Bahir Dar Zuria Districts. Bahir Dar University. Thesis submitted toward requirements for a MSc degree.