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

Year 5 (FY 2018) Semi Annual Report

Research Progress Report

October 1, 2017 – March 31st, 2018

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

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

A. Field Research

Ethiopia

IWMI

The hardpan plot experiment was completed in November 2017. The final interventions tested maize on four tillage treatments (i) no-till (NT), (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. Agronomic and biophysical data were collected for the experiments. The data is in the process of data quality checking.

Farmer forum at Bahir Dar University, Bahir Dar, Ethiopia

Additionally, Farmer Exit Interviews were conducted for the Robit Bata and Dangila sites on 11 Mar 2018 with all ILSSI participating farmers (both wife and husband of household). Focus group discussions were held and 6 key respondent interviews were used to document identified success stories. Project coordinators were also interviewed at district level to understand the implementation process and how the implementation contributed to development plans of the district and the livelihoods of project participants.

ILRI

During this reporting period project activities in Ethiopia were characterized by the increased number of farmers adopting irrigated forages, the increase in land dedicated to forages and by exploring multi-use effects of forages. 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 a forage (oats, vetch) and management (intercropped) option. A multi cut management of oats and vetches was introduced in the previous reporting with a two cut management emerging as the preferred options of farmer since the field can be cleared in time for crops. Two cut management continued to numerically (differences were not significant on $P < 0.05$ level) out-yield one-cut management, Table 1, illustrates that yields of oats and oats vetch mixtures under one and a two cut management. Results show that the oat-vetch mix under two cut management produces greater yields and further has the added advantage of higher fodder quality because of the protein component of the vetch.

Figure 2: Farmers participating in discussion conducted during field day program, In Lemo Ethiopia

Table 1: Yields of oats and oats vetch mixtures under one and a two cut management

Treatment	**N**	**Days of harvest**	**Yield (kg/ha)**
Oats: One cut management	3	85	7 610
Oats: Two cut managements	3	60 + 85	8 620
Oats-Vetch: One cut managements	3	85	9 350
Oat-Vetch: Two cut managements	3	60 + 85	12 180

Based on similar consideration Napier was intercropped with the leguminous food-feed pigeon pea, the forage desmodium and the multi-purpose tree sesbania. Pigeon pea and desmodium had a positive effect on Napier yield, while sesbania depressed Napier yield (Table 2). However total biomass yield was consistently higher in intercropped Napier than when sole cropped. The Napier -pigeon pea combination deserves particular interest, because of the positive effect pigeon pea has on penetration of hard pans and water infiltration.

Activities during this period showed that the oat-vetch mix under two cut management produces greater yields and further has the added advantage of higher fodder quality because of the protein component of the vetch. Results also showed that when Napier is intercropped with leguminous feed food such as pigeon pea a higher biomass yield was produced than when planted alone. It was also observed that pigeon pea has positive effects on hard pan penetration and water infiltration, making it an optimal choice for farmers.

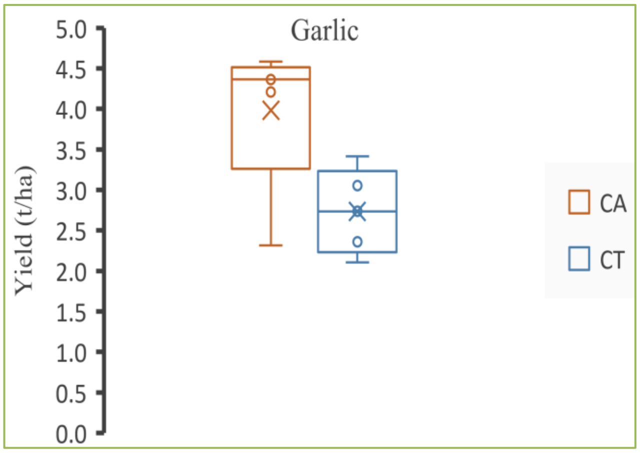
Table 2: Yield of Napier, legume yield and total biomass yield when Napier was grown alone and intercropped with Pigeonpea, Desmodium and Sesbania

Treatment	**N**	**Napier yield**	**Legume yield**	**Total biomass yield**
		kg/ha		
Napier sole	16	2 565		2 565
Napier + Pigeonpea	5	4 328	987	5 315
Napier + Desmodium	2	3 930	1 093	5 022
Napier + Sesbania	3	2 101	2 068	4 169
P < F		0.12	0.38	0.04

NCA&T

During this reporting period in Dangishita, farmers grew garlic for a fourth cropping cycle. Significantly higher yield was observed for garlic ($\alpha = 0.01$) under mulch Conservation Agriculture (CA) system (~46% increase) than farmers practice non-mulch conventional tillage (CT) system (See Figure 3 below). Similarly, we have observed a significant irrigation water use reduction ($\alpha = 0.01$) under CA than CT for garlic (~44% reduction). In Robit, farmers did not plant vegetables during fourth cropping cycle. This was because of shortage of irrigation water and preference of farmers to plant "Khat" plant.

MS students measuring soil moisture on our sites in Ethiopia observed higher soil moisture under CA compared with CT though reduced irrigation water was applied to CA. CA reduces time for labor in particular for tillage, irrigation and weeding.



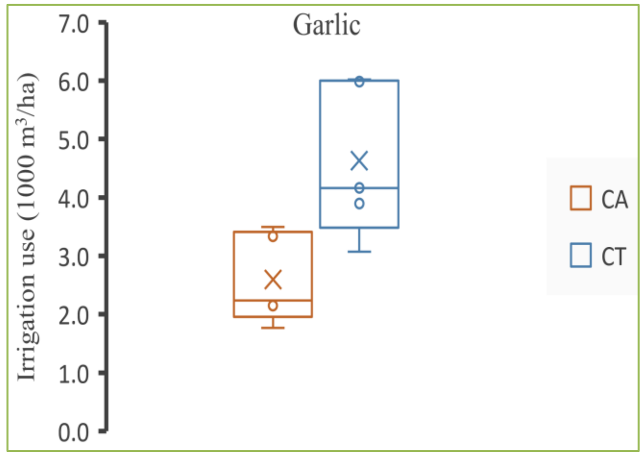


Figure 1: Garlic yield (a) and irrigation water use (b) in Dangishita, Ethiopia

Ghana

IWMI

In Ghana, dry season irrigated vegetable farming continued in Bihinaayili and Zanlerigu for the final season as did the biophysical and socio-economic data collection. Further the data collection and the literature review on the private sector and irrigation supply chain was completed. Also in this quarter, an assessment of the agronomic performance (e.g., water productivity) of water lifting and application technologies in Bihinaayili and Zanlerigu in Ghana sites was undertaken, draft manuscript being prepared with current season data.

ILRI

Surveys on potential for irrigated fodder for producers, sellers and buyers were completed in the 1st (late dry season, May 2017), 2nd (Wet season, August/September 2017) and 3rd (early dry season, November 2017 – January 2018) quarters. Survey data entry and 4th (late dry season 2018) quarter survey is on-going. Feed samples of fodder sold at the markets in both project districts have been collected for the first, second and third quarters, air dried and to be processed for laboratory analysis. Feed samples of fodder at the markets at both districts for the last quarter is on-going. The preliminary findings from the fodder markest are informative, see Table 3, where traditional sales units (bundles, bowls, basins) and prices of encountered feeds are listed. Ghanian Cedi (GHC) prices have also been converted into US cents using a currency conversion of of 0.23 US cents per GHC.

The repeatability of traditional units and their prices were generally good and where unit weights varied strongly this was balanced by pricing, see for example groundnut and cow pea hay where variations in bundle weight per se were much higher than variations in pricing per bundle or per kg fodder (Table 1). The findings from the fodder markets strongly convey two important key messages, though they are somewhat conflicting. On the one hand, there is a high demand for fodder and fodder from crop residues for example cow pea haulms was valued higher than cow pea pods. However, pricing seem to be influenced heavily by perceptions. Though fodder quality traits such as protein, fiber digestibility and metabolizable energy have not been analyzed yet, it is difficult to accept that rice bran should be so inferior to maize bran to justify a five-fold price difference (Table 1). Besides serving as baseline data for exploring irrigated forages-as-cash there exist therefor opportunities for action research to compare scientifically derived least cost diets with prevalent feed quality perceptions at fodder markets.

The ongoing laboratory analysis will show the fodder quality of *Brachiaria ruziziensis* and *Sorghum almum*, the two major forages explored in Ghana, relative to the quality of the fodder presented in Table 1 and a price for *Brachiaria ruziziensis* and *Sorghum almum* can be extrapolated. Ex-ante exercises can then be used to explore the opportunities for planting these irrigated forages as-cash-crops.

Table 3: Fodder traded in Ghanaian fodder markets in Bolgatanga in Upper East Region, traditional sales units uses and prices per traditional sales units and per kg traded fodder. Samples were obtained from three traders each.

Fodder	**Traditional**	**Unit weight**	**Fodder price**	**Fodder price**
		G	GHC/unit	Cent per kg
Maize bran	Bowl	1 112	1.5	31
		1 145	1.5	30
		1 139	1.5	30
Mean		**1 132** [c]	**1.5** [cd]	**30** [d]
Faidherbia albida fruits	Basin	2 130	5.0	54
		1 925	5.0	60
		1 816	5.0	63
Mean		**1 957** [ab]	**5** [a]	**59** [b]
Bambara bean pods	Bowl	825	1.0	28
		881	1.0	26
		830	1.0	28
Mean		**845** [cd]	**1.0** [ed]	**27** [de]
Groundnut haulms	Bundle	2 160	5.0	53
		1 400	3.0	49
		1 500	3.0	46
Mean		**1 687** [b]	**3.7** [b]	**49** [c]
Cowpea haulms	Bundle	565	2.0	81
		330	1.0	70
		567	2.0	81
Mean		**487** [d]	**1.7** [cd]	**77** [d]

Corn mill waste flour	Bowl	2472	2.0	19
		2609	2.0	18
		1775	2.0	26
Mean		**2 285 [d]**	**2.0 [c]**	**21 [e]**
Rice bran	Bowl	1998	0.5	6
		1618	0.5	7
		1779	0.5	6
Mean		**1 798 [b]**	**0.5 e**	**6 [f]**
Cowpea pods	Bowl	736	1.5	47
		697	1.5	50
		862	1.5	40
Mean		**765 [cd]**	**1.5 [cd]**	**46 [c]**

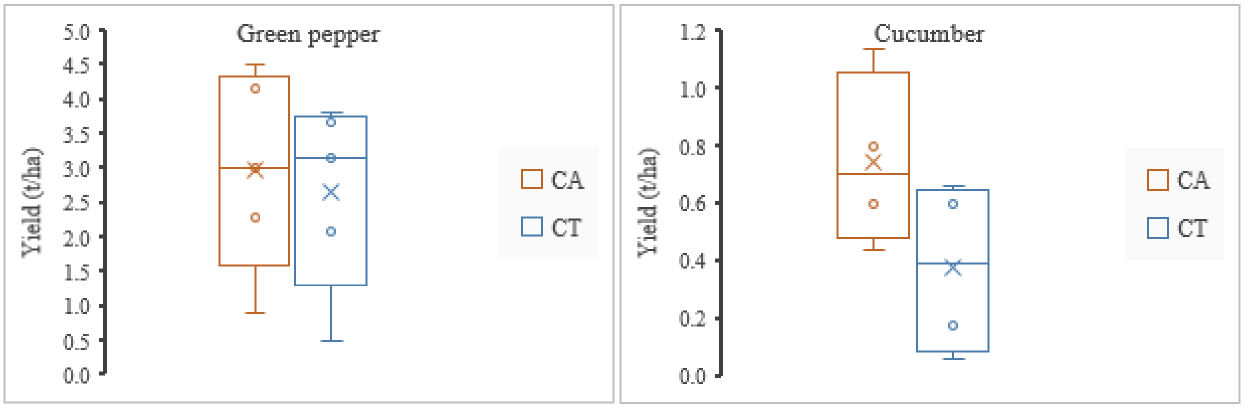
All means were different on a $P < 0.0001$ level

Also in this reporting period Irrigation of six (6) fenced farmer plots continued at Bihinayili from January to date in order to determine the regenerating capacity of fodder grasses *brachiaria ruziziensis* and *Sorghum almum* during the dry season. Sprouting took about eight days for both brachiaria and sorghum. Regeneration was slow for both species with sorghum doing better than brachiaria. There wasn't enough water at Zanlerigu to irrigate and there wasn't enough biomass generated to cut for the fodder market for the dry season. Regenerated biomass from the previous season for both grass species is lower than the non-regenerated. Collection of biomass and dry matter data for the regenerated fodder is ongoing.

NCA&T

In continuing studies on conservation agriculture, farmers grew green pepper and cucumber for the second cropping cycle Green pepper yields were combined with the green pepper yield from first cycle. The harvest from cucumber was very small due to disease and lack of frequent follow up by farmers. The average green pepper and cucumber yields were significantly higher (α= 0.01) under CA than CT; about 18% and 97% increase respectively. (see Figure 4 below).

Further, the team in Ghana changed the sites for the third cropping cycle because the previous farmers were not interested in the scientific aspect of the work. The team also modified the plot size (300 square meter for each farmer, 15 farmers total) Farmers preferred the CA system; however, finding the material for mulch was observed as a challenge.



- Figure 4: Green pepper (a) and cucumber yields (b)

Tanzania

IWMI

In response to the constraints on data collection (low capacity in data collection methods, complex templates), ILSSI has developed an open access, online tool that enables detailed data collection for small scale irrigation trials. The tools capture geo-spatial information of the plot, general field conditions, labor, crop performance, amount irrigated and soul moisture. It additionally captures inputs used during the production cycle (fertilizer, seed type). The tool is adaptive for various modes of water lifting (rope and washer, motorized pump, solar) and application methods (bucket, furrow, drip). Respectively assessments on the feasibility of pocket garden for improving water use efficiency and household nutrition were completed in January 2018 while the assessment on the feasibility of small motorized pumps for dry season irrigation were completed in March 2018. Results are being analyzed.

Further Data collection is continuing in Tanzania for the hydrological and water resources assessment, measuring run off for the current rainy season (March – May 2018), this includes:

- Times series of water levels in sites in both the downstream and upstream areas as well as meteorological data for the period up to March have been compiled ready and updated in the existing database
- Water quality data for the sites within the study are were collected and are in the laboratory for analysis
- Cross-sections for a river stretch between the upstream and downstream sites of Rudewa watershed were measured and analysed for flood risk analyses
- Land use and land cover data analyses have been updated
- Draft paper manuscript for mapping of surface water irrigation potential for the Rudewa watershed has been prepared by the national partner.
- Social economic survey has been conducted and data is being analyzed

ILRI

During this reporting period Four Napier cultivars – ILRI 16835, ILRI 16937, Ouma and Kakamega 2 (KK2) cultivars were evaluated under pump irrigation technology and rainfed conditions (control) during the dry period of July to October 2017. In Mawemairo village, Napier cultivars under the irrigation technology were cut three times at intervals of 6 weeks (Figure 3). Cultivars under rainfed conditions could only be cut twice at intervals of 8 weeks. Overall the Napier hybrids ILRI 16835 and ILRI 16837 under irrigation gave DM yields of 12 t/ha. The Napier varieties Ouma and KK2 were superior giving dry matter (DM) yield of 15-18 t/ha. The superiority of Napier varieties over Napier hybrids were maintained under rain-fed conditions where Napier hybrids ILRI 16835 and ILRI 16837 yielded DM 5 t/ha (Figure 2) while varieties Ouma and KK2 yielded DM of 6-8 t/ha (Figure 4). In Gichameda village, farmers selected and tested Napier cultivars Ouma and ILRI 16835. Ouma and ILRI 16835 gave DM yield of 14 and 22 t/ha respectively under pump irrigation technology while the DM yields for Ouma and ILRI 16835 under rain-fed conditions were 5 and 4 t/ha. These findings suggest that the relative performance of Napier hybrids versus Napier varieties is highly location specific

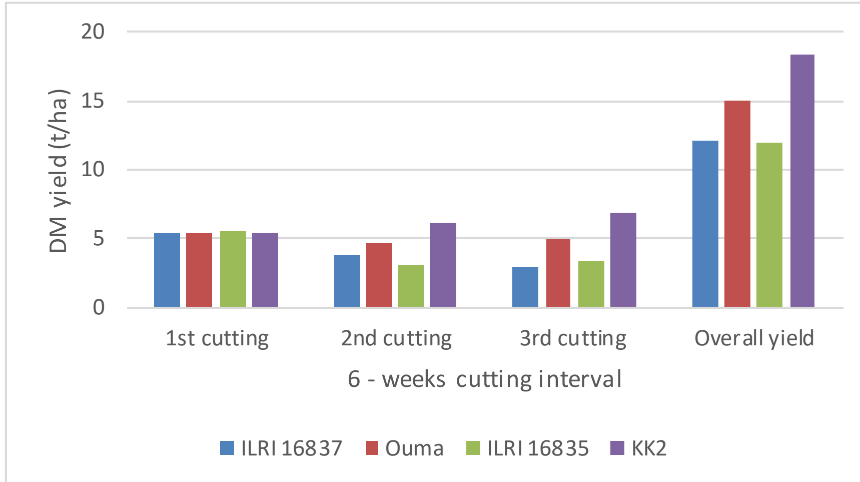


Figure 3: Napier grass yield under pump irrigation technology in Mawemairo village in Babati district

In addition to the evaluation of the Napier Cultivars**,** a participatory farmer evaluation of Napier grass accessions in Mawemairo, Matufa and Gichemeda villages in Babati district was undertaken. The parameters that were evaluated by farmers included greenness as an indicator of feed quality, growth vigor, tallness, disease and pest tolerance and farmers perceived capacity of forage yield. Individual farmers opinions for each criterion, were recorded using a Likert scale of 1 to 4 where 1 = poor, 2= fair, 3 = good, and 4 = very good. Farmers perceived cultivars ILRI 16835 and Ouma to be of higher quality in terms of greenness. Ouma, ILRI 16835 and KK2 were less attacked by diseases and pests. Ouma and KK2 are known to be tolerant to stunt and head smut diseases respectively. Farmers liked all cultivars in terms of yield. The yield advantages of Ouma (Figures 1 to 4), its perceived superior fodder quality and its stunt and head smut tolerance suggest that priority in dissemination should be given to this cultivar.

NCA&T

Continuing conservation agriculture studies during this reporting period, farmers in Mkindo, grew nightshade for the second cropping cycle (09/2016 to 12/2016); less vegetable yield was harvested due to disease. Farmers grew cabbage and nightshade for the third cropping cycle.

Nightshade yield was combined from the second and third cropping cycle for analysis. The average nightshade yield in CA (3.92 t ha^{-1}) was significantly lower ($\alpha = 0.1$) when compared to CT (4.92 t ha^{-1}) (Figure 3a). About 20% decrease in yield was observed in CA mainly because of more pests and animal intrusion in CA plots. No significant yield difference was observed between CA and CT plots for cabbage yield (Figure 4b).

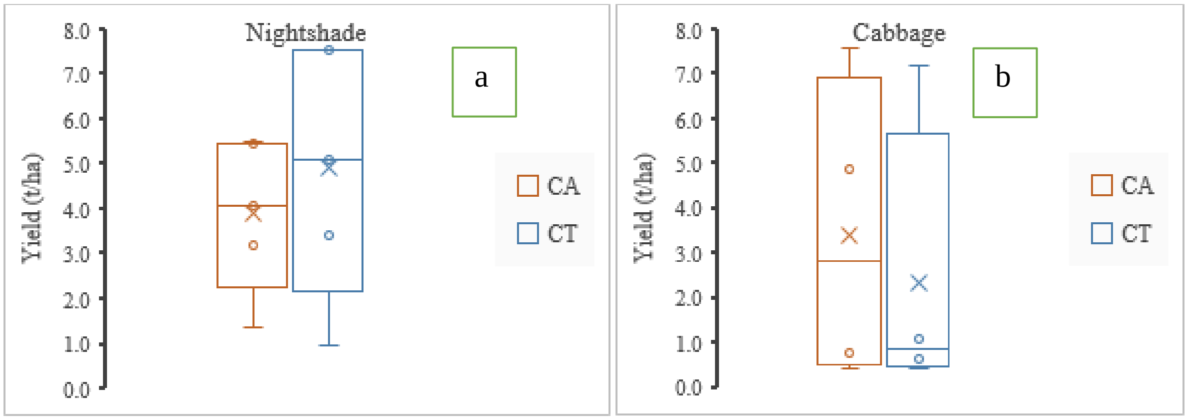


Figure 4: Nightshade (a) and cucumber yields (b) for the second & third cropping cycle

Household Surveys

In the first half of year 5, IFPRI implemented the endline household survey in Ghana. With that, all six survey rounds planned under ILSSI have been completed. The IFPRI team also spent time on cleaning the endline household survey data for Ethiopia and Tanzania. The IFPRI team also made substantial progress on a first paper for northern Ghana irrigation-nutrition linkages over the reporting period. Moreover, the group 1) resubmitted the first irrigation-nutrition paper, following comments; 2) submitted the qualitative gender-irrigation study with IWMI to a journal; and 3) published a second ILSSI policy note on irrigation, also with IWMI. A series of results from the household surveys were presented at an AGRILINKS webinar on October 31 with the title "Can small-scale irrigation empower women? Insights from the Feed the Future Innovation Lab for Small-Scale Irrigation" and again during the ILSSI final symposium in January 2018.

Key messages from the AGRILINKS seminar that focused on irrigation-gender linkages include:

1) *Reaching women with SSI makes a difference*: SSI diffusion approaches and technologies can be designed to better meet women's preferences and fit their needs
2) *..But REACH is not sufficient:* To avoid increasing inequalities, investigate constraints within the household preventing women from benefiting from irrigation
3) *Women can be empowered through SSI*: SSI has potential to reduce both men and women's workload and increase income if conditions are right
4) *Leverage opportunity for time savings via SSI*: By meeting multiple needs and reducing labor intensity of technologies, SSI can reduce women's time burden

5) *Provide access to information on technology, credit and markets*: Concerted effort is required to ensure that information, credit, etc. reach women
6) *Collect sex-disaggregated data on SSI*: SSI adoption almost always affects gender roles and relations. Investigate and monitor to understand program impact

Additional key messages on irrigation-gender linkages can be derived from the final ILSSI symposium and the ILSSI policy note 2 to address gendered constraints in the adoption of small-scale irrigation, specific steps can be taken along the three phases of technology adoption: 1) Awareness of the technology; 2) Testing the technology; and 3) continued adoption (i.e. use and decision to keep).

IDSS Analysis

The Integrated Decision Support System (IDSS) is a suite of proven, interactive and spatially explicit agroecosystem models: The Soil and Water Assessment Tool (SWAT); the Agricultural Policy/Environment eXtender (APEX); and the Farm Income and Nutrition Simulator (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. **The results of field and analytical studies reported here provides an integrated ILSSI result across components of the project**.

Approach: The effect of Conservation Agriculture (CA) together with different irrigation management practices was studied to understand the impact on onion production, household income, and nutrition in the Dangesheta watershed, Ethiopia. The study explores water use efficiency of the different scenarios and impact on environmental sustainability at the watershed scale.

The biophysical analysis considered field collected data from 51 field plots (i.e. 10 m by 10 m) of small-holder farmers in the Dangesheta watershed. Farmers, who participated in the field research, cultivated Red Bombay Onion variety (*Allium cepa* L.) in the dry season from December 2016 to March 2017 using irrigation from shallow wells. The field experiments were designed into three trails such as 1) CA, a method where the farm plots were covered with a mulch throughout the crop growing period and irrigation based on crop water requirement, 2) Conventional Tillage (CT) with irrigation based on crop water requirement, and 3) Conservation Agriculture (CA) with irrigation based on farmers irrigation practice (CA-FTP). The socio-economic analysis were comprised of four scenarios comprising. A baseline with current farming conditions (non-intervention farmers) and three alternative scenarios. Two rainfed crops (maize and teff) and one irrigated vegetable crop (onion) were analyzed at the farm household. The baseline scenario considers no or minimal irrigation based on the information for the existing irrigation practice from the household surveys while the alternative scenarios consider the irrigation of onions during the dry season using the pulley system to minimize the investment costs.

Findings: Watershed level analysis at the Dangesheta watershed showed that the average annual surface runoff was between 195 mm to 300 mm while the average annual groundwater recharge ranged from 285 mm to 456 mm. The significant amount of shallow groundwater recharge at the watershed scale suggests that small-scale irrigation (SSI) may be possible using shallow groundwater to cultivate vegetables during the dry season.

The field data indicated that CA-CWR practice had a higher yield compared to other practices. The CA-CWR had a 35% and 83% higher yield compared to CT-CWR and CA-FTP practices, respectively (Figure x1). Water productivity under the CA-CWR practice increased significantly due to mulch application. However, crop yields were lower when mulch was used with traditional farmers irrigation practice. This indicates that mulch application should be integrated with an effective irrigation management system for sustainable crop production.

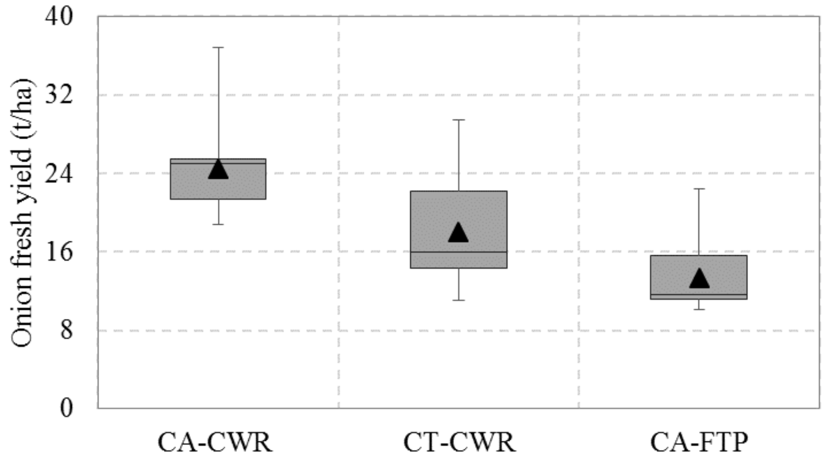


Figure 5: Onion yield for three management practices in Dangeshta: CA-CWR = Conservation Agriculture with mulch and irrigation based on; CT-CWR = Conventional Agriculture with irrigation based on crop water requirment; and CA-FTP = Conservation Agriculture with irrigation based on Farmers Traditional Practice.

The economic analysis used several indicators a positive economic return was obtained for all the scenarios over the five-year planning horizon and forecasting period (Table 4). However, superior results were obtained with the conservation agriculture with irrigation based on crop water requirement (CA-CWR) scenario.

Table 4. Economic impact of three alternative farming systems in Dangishta kebele

	Baseline	Alt.1(CA-CWR)	Alt.2(CT-CWR)	Alt.3 (CA-FTP)
Averages values in Birr /family in year 5				
Net present value	75,438	104,307	92,274	91,777
Avg. net profit	3,958	11,173	7,863	8,333
Increase in profit: Alt./Baseline		**2.8**	**2.0**	**2.1**
Benefit-Cost Ratio: Alt/Baseline		**6.4**	**4.0**	**5.4**
Internal Rate of Return: Alt/Baseline		**1.8**	**1.1**	**1.5**

The nutrition analysis showed that in Dangishta kebele the quantities of crops and livestock products consumed by families in both the baseline and alternative scenarios met minimum daily requirements for calories, proteins, iron, and vitamin A; however, families did not fulfill their calcium and fat requirements.

The analysis was also conducted at the national level in Ghana to assess the biophysical as well as socio-economic potential of small-scale irrigation. Potential suitable land for small scale irrigation was estimated using multicritrea evaluation in GIS using physical land features (land use, soil, and slope), climate characteristics, and access to market. The SWAT model was also developed to estimate the water resources potential, irrigation water requirement, crop production and soil loss at a 10 km by 10 km grid for Ghana. The best available data, e.g. 250 m resolution AFSIS soil, disaggregated land use data based on the Spatial Production Allocation Model (SPAM), climate and household survey crop information, was used for the upscaling analysis. The SWAT analysis considered cultivation of vegetable crop and fodder during the dry season. Agent Based Model (ABM), which takes output data from SWAT model, potential land suitability map and household survey data, was also developed to estimate on the socio-economic development potential of small-scale irrigation across Ghana and geographic locations where such development is most likely to occur.

The land suitability for small scale irrigation analysis showed that slope and rainfall deficits were the most important factors, followed by population density and soil characteristics. The value of suitability ranges between 26% and 94%, where 26% indicates the least suitability and 94% the most (Figure 6). Taking 80% as the suitability threshold, there is about 21,000 km^2 suitable area for small scale irrigation in Ghana.

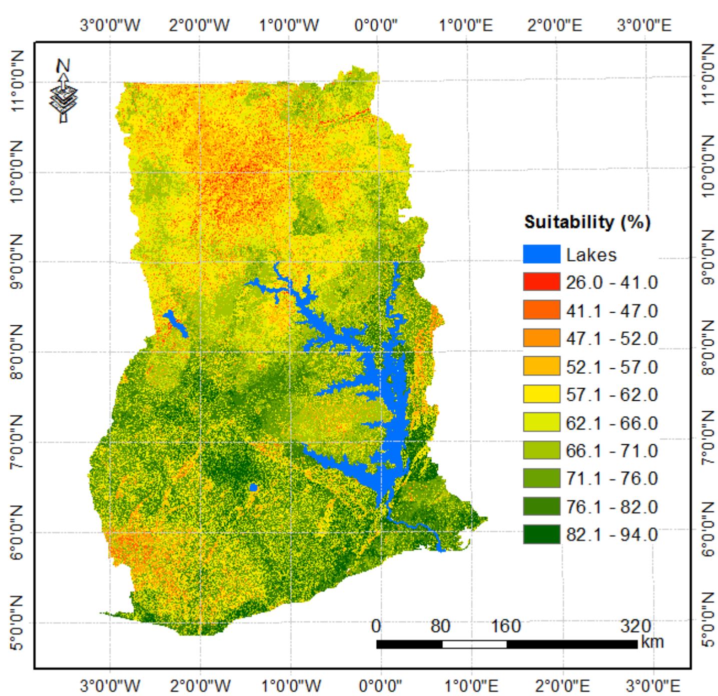


Figure 6. Level of land suitability for irrigation in Ghana; 26% shows the least suitability and 94% shows the highest suitability.

Upscaling analysis for Ghana has shown that the most productive areas for small-scale irrigation during the dry season are in the northeastern part of the country. The southern, southeastern and central part of the country is either grassland, forest land or used for cultivation of perennial crops. Thus, the potential for small scale irrigation was studied only on agricultural land. During optimal agro-ecological conditions, the dry matter tomato yield across Ghana is predicted to range between 0.23 t/ha to 5.11 t/ha (Figure 7a) and the irrigation water requirement ranges between 18 mm to 622 mm (Figure 7b). The available water resources meet the irrigation water requirement in most parts (~68%) of the country except in the northwestern and small pockets in the southwestern parts of the country. The annual available water resources during optimal tomato production condition ranges between 1.86 mm to 943 mm (Figure 7c) while the annual soil loss ranges between 0 t/ha and 78.5 t/ha (Figure 7d)

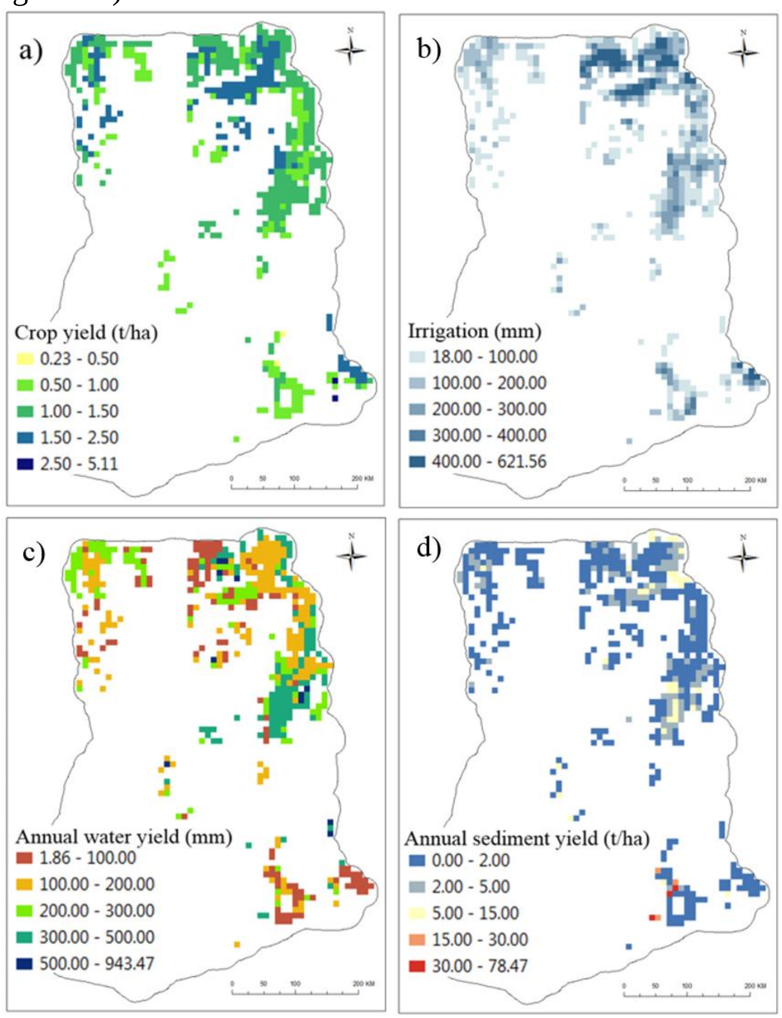


Figure 7. Simulations of biophysical parameters while cultivating tomato during the dry season using irrigation. a) optimal tomato yield, b) irrigation water requirement for the optimal tomato yield, c) annual water yield and d) annual sediment yield.

The estimated national total of small-scale irrigation development potential in Ghana is 2,110 km^2. Northern region is the region with the largest identified small-irrigation development potential (1,150 km^2) and accounts for more than half of the total irrigation development potential in the country. Other regions with significant small-scale irrigation development potential are Upper West region (27,0 km^2), Upper East region (20,0 km^2), Eastern and Brong Ahafo region (16,0 km^2, respectively).

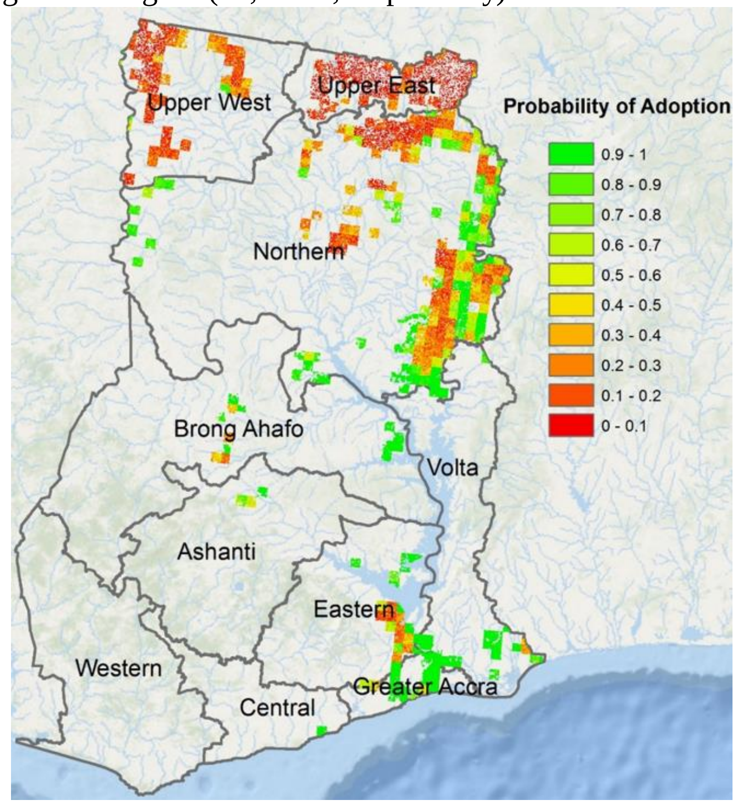


Figure 8. Adoption probability of small-scale irrigation in Ghana

If the potential for small-scale irrigation is fully tapped, the ABM analysis predicts that $285 million USD per year will be generated, benefitting more than 690,000 people in Ghana (Table 5).

Table 5. Adoption potential of small-scale irrigation in Ghana

Region	Expected adoption area (thousand hectares)	Expected profits received by irrigators (million USD/yr)	Expected beneficiary population (thousand people)
Ashanti	5	5	15
Brong Ahafo	16	14	52
Central	1	2	4
Eastern	16	24	54
Greater Accra	3	6	11
Northern	115	133	377
Upper East	20	39	65
Upper West	27	48	89
Volta	7	13	23

Western	0	0	0
Total	211	285	690