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

Memenatu Salefu, in her field of soybeans, Tamale. Photo: Thor Windham-Wright/IWMI

Feed the Future Innovation Laboratory for Small Scale Irrigation (ILSSI) Research Results Discussion Brief

Key research findings

- Water quality and soil types in Ghana are suitable for irrigation in the basins assessed by ILSSI.
- Irrigation scheduling tools increased water productivity and yields.
- Small scale irrigation (SSI) is profitable when using motor pump water lifting for the production of high value vegetables (e.g. onion and corchorus). Inter-planting onion with leafy greens such as amaranthus increases profitability.
- SSI is not always associated with women's empowerment so requires careful targeting. In some places, the economic and social incentives related to irrigation may deepen differences and reduce benefits to women and children. In other places, the incentives may be present to enhance the opportunities and benefit women.
- Labor is a major cost in irrigated production. Labor is more costly than technologies over time, but the upfront costs of technologies and fuel constrain investment.
- Solar pumps offer a feasible alternative to save labor and fuel costs but rural finance options are needed.
- Conservation agriculture practices reduce water use and improve yields while also helping to mitigate some of the risks of irrigated production.

Recommendations

- Increase access to finance products and information
- Reduce labor requirements through technology and tools
- Apply solutions with youth entrepreneurs as entrepreneurs in service provision
- Adapt technologies and sites to women farmers' preferences
- Expand role of private sector actors in technology supply chain and finance provision
- Match technology packages suitable to context
- Improve governance mechanisms

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Introduction

The *Feed the Future Innovation Laboratory for Small Scale Irrigation*, initiated in 2013, has been a focal point of the USAID investment strategy to provide improved efficient methods of supplying water to small holder farmers. The project worked to create research-based evidence that would contribute to increased food production, improved nutrition, accelerated economic development and protection of the environment. The project involved stakeholder-driven field studies to evaluate small scale irrigation (SSI) interventions, and household surveys to assess the impact of SSI on nutrition, economic status and women's empowerment. An integrated suite of analytical models, the Integrated Decision Support System (IDSS) was used to evaluate and interpret results from the field studies. Sustainability of the interventions employed through the project has been promoted through continuous dialogue with stakeholders and a strong focus on multifaceted capacity development.

The target beneficiaries were smallholder farmers, though a wide range of stakeholders were engaged by the research team. This included practitioners at local levels, national decision makers, private sector investors in technology, and future development donors. Studies conducted in farmer's fields, household surveys, analysis and capacity development (both at individual and institutional levels) formed the key components of the research process. These enabled investigation of the consequences of small-scale irrigation interventions on production, the environment, economic factors, nutrition and equity. ILSSI also explored opportunities and constraints to scaling up some of the promising technologies, approaches and practices from farm to national levels. In order to achieve the goals ILSSI conducted research and piloted interventions in three countries, Ethiopia, Tanzania and Ghana.

Small scale irrigation (SSI) technologies offer a number of economic and nutritional benefits, while also playing a role in enhancing environmental sustainability. SSI has been shown to improve labor efficiency and can reduce labor time across multiple water uses. SSI has also been shown to improve yields and incomes from them, and to help reduce crop losses, while offering multiple value chain opportunities for farmers and others in farming communities. With regard to nutrition, irrigators have in general been found to perform better than non-irrigators in household food security and dietary diversity analysis. Use of SSI can help support environmental sustainability in that they have been found to improve water and land productivity, offer effective nutrient management opportunities, and provide both on-farm and off-farm water management options.

During the five year research project, the ILSSI team undertook a total of 28 water resources sustainability assessments in 19 basins, including 6 international trans-boudary basins. ILSSI initiated research on 9 new technologies or management practices and in addition, undertook field testing of 8 new technologies, and at least 15 new technologies were made ready for transfer under the project. In general the technologies were found to be feasible, profitable and to have multiple benefits though it was clear that women face more constraints to accessing and using them than men.

In keeping with the strong focus of ILSSI on capacity development, short-terming training was provided to a total of 938 producers, 115 civil servants, 36 private sector actors and 193 members of civil society (907 men and 375 women overall) across the three countries. Training ranged from practices and tools for on-farm water management and fodder production for farmers, to use of data collection and analysis using the IDSS. Furthermore, as part of ILSSI's commitment to enhancing research capacity in each country, a total of 26 graduate and 10 undergraduate students across the three countries received degree-related training and support, including research design, data collection, field research methods, publication preparation mentoring, and assistance to participate in national and global scientific conferences.

Water sources: ILSSI assessed the potential of a variety of site relevant water resources to sustainably meet productive water needs, as standalone sources, in combination to enhance sustainability, or because groundwater alone would be inadequate. Shallow groundwater was a focus in Ethiopia and Ghana.

Water lifting technologies: ILSSI research examined the use of motorized pumps in all three countries, solar pumps in Ethiopia and Ghana, and both rope and washer and pulleys in Ethiopia. Water lifting technologies alone provide benefits, but also carry risks, such as over or under application of scarce water and suboptimal yields and quality.

Water application: the benefits, constraints and impacts of both drip systems and furrow irrigation systems were examined in all three countries.

To mitigate some of the risks of SSI, and as part of efforts towards ensuring improved sustainability of the interventions, ILSSI tested irrigation scheduling tools and trialled conservation agriculture (CA) with farmers. The results indicate that combining water lifting technologies with tools to enhance on-farm management can greatly increase the benefits of SSI for smallholders. Farmers recognized some of the benefits on farm, while other benefits are seen at watershed level. A number of unique data sets were also produced through ILSSI including ones on: gender and nutrition at the intra-household level, on-farm water management, and hydrological data (including shallow groundwater).

Three pilot locations in the Feed the Future Zone in Ethiopia were included in the research:

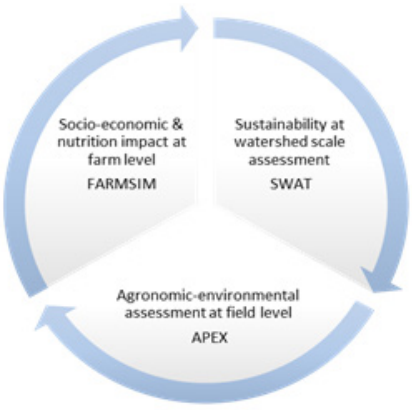
- Bihinaayili village, in Savelugu, Northern region.
- Zanlerigu village, in Nabdam district, in the Upper East.
- Dimbasinia village, in Kassena Nankana East district, also in the Upper East region.

Analysis of the potential and the consequences of SSI

The *Integrated Decision Support System* (IDSS) enables assessment of the consequences of small scale irrigation interventions on production, environmental and economic outcomes, based on data collected from the field.

IDSS is a suite of models including SWAT, FARMSIM and APEX, each of which examines a different set of key aspects. Analysis using IDSS was conducted to help scope existing SSI and to understand its varied impact on agricultural production, environmental sustainability, and both economic and nutritional outcomes.

Analysis of gaps and constraints helped to identify factors that limit the adoption of SSI and to suggest mitigation options. The potential for expanding SSI in a given location was then studied through up-scaling analysis.



IDSS analysis capability
Source: Project team

Estimated small scale irrigation adoption potential in Ghana

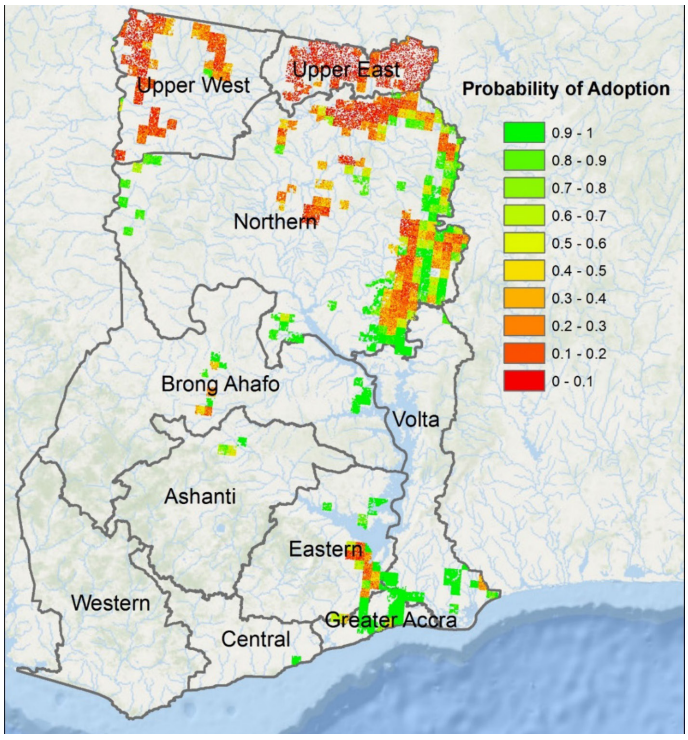


Figure A: Adoption probability of small-scale irrigation in Ghana
Source: Dile et al., 2018. Upscaling of small-scale irrigation in Ghana

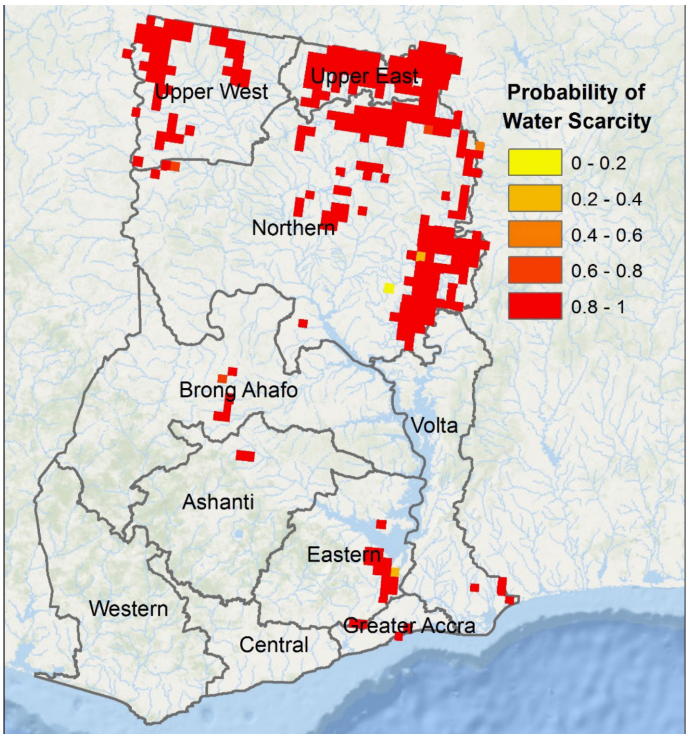


Figure B: Risk of water scarcity induced by small-scale irrigation development in Ghana
Source: Dile et al., 2018. Upscaling of small-scale irrigation in Ghana

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Sites in Ghana with adoption potential for small-scale irrigation identified through a Monte Carlo simulation and associated estimates for adoption probability are shown in Figure A. The estimated national total of small scale irrigation development potential in Ghana is 211,000 hectares. Northern region has the largest identified small scale irrigation development potential (115 thousand hectares) 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 (27,000 hectares), Upper East region (20,000 hectares), Eastern and Brong Ahafo region (16,000 hectares respectively). Figure B shows the estimated probability of water scarcity, induced by irrigation development. This analysis allowed for an allocation of 30% of renewable water resources being reserved for environmental purposes with no over-withdrawal allowed. Appropriate institutional arrangements need to be made hand-in-hand with irrigation development to ensure availability and sustainability of a wide range of water resource ecosystem services.

Improving irrigation scheduling

Research results show that irrigation scheduling tools may be key to enhancing SSI sustainability. In particular, irrigation scheduling tools were found to increase yields and profitability, improve water use efficiency and productivity, and to improve fertilizer efficiency (in some cases). They were also found to promote water sharing. Labor is a major SSI production cost, although it differs across crop types and technologies. It is important to note therefore that irrigation scheduling tools were shown to reduce SSI labor requirements. This may also be an important consideration in their adoption by women farmers. The improvements in water use efficiency offered by these tools are particularly important where water is scarce, as it is in two of the intervention sites in Ghana.

In Ghana, consistent with the other two study countries, irrigation scheduling tools increased water productivity, though the amount varied by farmer. Water savings through improved irrigation scheduling averaged at each site, 9% to 22% to 14%. Water productivity improved by 58.6% overall and the improvement was 96% in the site with ample water and a tendency for over-watering. Irrigation scheduling also had a positive effect on yields. Women face a number of constraints to accessing irrigation scheduling tools. They would benefit from a greater focus on information and training.

Benefits of Conservation Agriculture

Conservation agriculture (CA) aims to improve sustainability of agricultural production by offering benefits such as improved water resource efficiency and reduced labor costs. Conservation agriculture techniques such as mulching, biologically diverse crops in rotation and low tillage approaches, sometimes combined with the use of drip irrigation, were trialled by ILSSI. These methods can have multiple benefits including some that support climate resilience. There are also some constraints to the use of, benefits derived from, and opportunities to scale up the use of, CA.

Overall ILSSI found that CA enhances SSI benefits, for instance when used in commercial home gardens, even under temperature stress conditions. In Yemu, Ghana, significantly higher vegetable yields were observed under CA for sweet potato (57% increase), green pepper and compared to conventional tillage practices. In some, but not all, cases CA was also found to reduce labor costs. Additionally, ILSSI found that irrigation water use was significantly reduced across all vegetable types, by as much as 14-46% depending on the site. CA was also found to improve both soil quality and soil moisture content.

The constraints on CA identified by ILSSI include potentially limited supplies of mulch or competition for other uses such as animal fodder and pest control challenges. Access to adequate information and extension services relating to CA, and in some cases the fact that CA can actually increase the amount of labor required for production were also identified as constraints to successful CA. For example, in the Ghana sites farmers had to fetch water from nearby ponds in order to fill the drip irrigation water tank. This additional effort required became a disincentive to spend sufficient time on farm plots. These constraints will all need to be addressed if the use of CA is to be scaled effectively.

Scaling irrigated value chains - fodder for livestock

Lack of improved, good quality, fodder was identified as a key constraint to enhancing livestock production systems in Ghana. However, there are opportunities to develop fodder production as a cash crop and so enhance household incomes as well as the quality and productivity of livestock, for example in milk production.

ILSSI found small scale irrigated fodder production to be profitable as a cash crop in Ghana when sold in local fodder markets. Biophysical modeling revealed that although the amount of land available for small scale irrigation in Ghana may

be small, this available land has potential. The highest potential for fodder (vetch) production was found to be located in the south west of Ghana, whereas there is only modest potential in the north. Furthermore, in consideration of water resources the research results indicated that there is sufficient water to meet dry season irrigation water requirements for fodder, or vegetable, cultivation in most parts of the country.

Providing an enabling environment for the successful development of improved fodder will require a number of challenges to be overcome. For example the lack of awareness among farmers of opportunities in irrigated fodder production as a cash crop, lack of information on market prices for fodder and poor linkages to markets. Inadequate availability of quality fodder and forage seed and inadequate fodder storage and conservation techniques are also significant challenges.

Linkages between irrigation and nutrition

Significant differences were found between irrigators and non-irrigators in the areas of household food security, household dietary diversity and women's dietary diversity. Irrigators performed better in measures of food security and dietary quality in all three countries, although the differences in female dietary diversity were not statistically significant in Ethiopia. Econometric results, using data from household surveys in each country, indicate that access to irrigation significantly improves both household income and production diversity. However, although increases in household income were found to lead to higher dietary diversity, increases in household production diversity did not necessarily contribute to increases in dietary diversity. This reveals that irrigation improves nutrition through an income pathway rather than through household consumption of the diversity of food grown.

	Non-irrigators n=264 (Mean)	Irrigators N=568 (Mean)
Household food insecurity access scale: 0-27 (higher = worse)	7.19	**6.40**
Female dietary diversity score: # of categories consumed	3.39	**3.98**
Household dietary diversity: # of food categories consumed	7.19	**7.52**

Figure C: Irrigation-food insecurity-dietary quality
Source: Project research results

Irrigation for greater gender equality

Results from the Women's Empowerment in Agriculture Index (WEAI) show that in general women irrigators are better off than non-irrigators. However, results also revealed that women and men do not have equal access to technologies, information, training, credit or inputs and that women have lower levels of access to technologies, or lose rights over them, to men within the household.

SSI is not always associated with women's empowerment

- GHANA -

Irrigators	Non-irrigators	Contributors to disempowerment
WEAI Score	WEAI Score	
0.82	0.80	• Credit access • Workload • Group membership • Control over use of income

Household survey results showed that small-scale irrigation does not always lead to women's empowerment. As an example, irrigated fodder may have great potential, but women may end up losing out if the crop gets too profitable and is taken over by men in the household. In households where women's labor is perceived to be plentiful, male decision-makers may be less apt to invest in irrigation technologies, which could otherwise reduce women's labor burden.

Levels of empowerment, the roles of women and men, and the contributors to women's disempowerment as well as the distribution of benefits and costs vary across the three study countries. However, women face a number of common constraints to adoption of irrigation technologies. For example, technologies not matching women's needs and preferences (with regard to affordability, maintenance needs, fuel requirements, transportability, and applicability for multiple uses).

Women also lack access to and control over the assets required for adoption (such as land), and lack of access to sufficient information (for example mobility constraints and/or not belonging to groups where information is disseminated). Women often have limited ability to participate in decision-making over use of water resources for irrigation and low control over management of technologies and benefits of adoption by the household. Limited access to credit is also a common constraint.

ILSSI identified a number of opportunities for the promotion of greater gender equality in irrigation, including:

- Capitalizing on the great potential for participatory, user-centered technology design to better address women's needs and preferences
- Supporting women's greater participation in group decision-making
- Developing new outreach models to ensure information effectively reaches both men and women
- Facilitating access to credit on both the supply and demand sides, providing financial literacy training for women and men and helping them to forming groups to manage and share risk
- Identifying ways to enable women to focus on under-explored crops which may be profitable and to capitalise on the high potential of seed production through approaches that don't increase the risk of women losing profitable and preferred crops to men, such as fodder and leafy greens
- Enabling access to and control over assets and inputs and encouraging joint ownership of productive assets

Understandably women were found to favor labor saving technologies such as mechanized water lifting and solar pumps. Installation of technologies for multiple uses placed near the home, suitable for home gardens, can enable multiple growing seasons. Efforts to ensure women's equal access to irrigation will be crucial to achieving the goals of scaling up irrigation for climate resilience, improved productivity and enhanced food and nutritional security. In some location specific cases, researchers found that women do not want to engage in irrigated farming at the plot level but may instead want to engage at other points in an irrigated value chain, such as in processing or marketing.

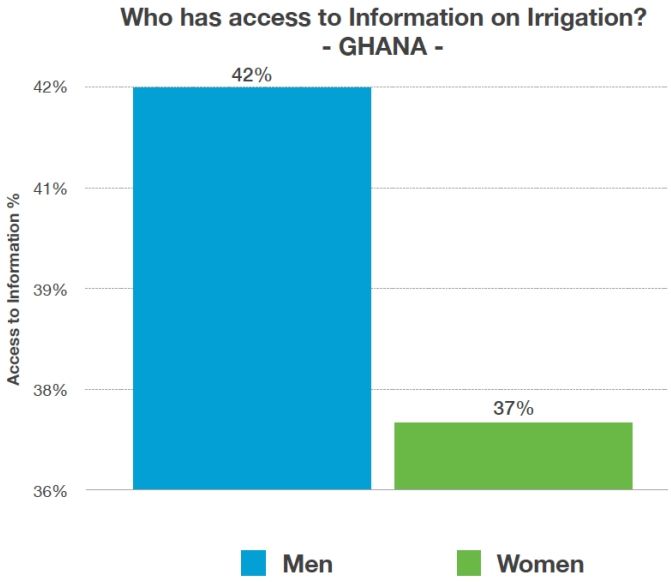

Figure D: Access to information on irrigation
Source: Project research results

Markets and returns on SSI investment

ILSSI results show that investments in SSI technologies and complementary inputs can contribute to poverty reduction in Ghana. ILSSI conducted a profitability and economic feasibility analysis of four SSI technologies in the three study sites in Ghana (Bihinaaylili, Zanlerigu and Dimbasinia).

Small scale irrigators, Ghana
Photo: IWMI

Motorized pumps with tanks and hoses, watering cans, rainwater harvesting and also drip irrigation were analyzed in the cultivation of Corchorus olitorius, onion, amaranthus, cowpea and tomato, all with recommended fertilizer application. Water was sourced from rivers, rainfall or shallow wells for irrigation. Use of mechanized SSI technologies and tools was found to generate higher profits and result in significantly improved nutrition levels compared to no, or minimal, use of irrigation.

Although in all the case studies the diesel pump generated the highest income, cost-benefit analysis showed that the watering can method provided both a high return on investment and a lower risk. The cost of fuel for motor pumps and the capital investment required to purchase them are the key constraints to their use among smallholder irrigators. Rainwater harvesting for dry season irrigation, especially when poly tanks are used for water storage in combination with drip irrigation, was found not to be financially feasible for up-scaling, even with higher value crops. Enabling access to rural finance increases the likelyhood of adoption of SSI. Suitable credit schemes targeting smallholder farmers aimed at increasing their use of SSI will have to be developed in order to enable them to invest in more intensive SSI technologies and their economic benefits.

Project findings to development impact

ILSSI analyzed SSI interventions, and the impact of SSI on nutrition, economics and women's empowerment through household surveys, and the use of the IDSS to plan, evaluate and interpret results from the field studies. The results of the multidisciplinary research revealed a number of important findings to be considered for upscaling SSI and its benefits in Ghana. For example, water quality and soil types in Ghana are suitable for irrigation and irrigation scheduling tools have been shown to increase water productivity and yields.

SSI is profitable when using motor pump water lifting for the production of high value crops and while labor is a major cost in irrigated production, SSI is not always associated with women's empowerment so requires careful targeting. The research also showed that there is a need to build rigorous business cases for SSI, including profitable irrigation business models for men, women and youth, and also to identify ways to enhance private investment in the various aspects related to the use of SSI in Ghana. By taking these insights into account, and acting on them, the goals of increased food production, improved nutrition, accelerated economic development and protection of the environment can be more affectively achieved.

Exploring the benefits of SSI in Ghana
Photo: IWMI

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Further information

This brief has been produced by the ILSSI project: ilssi.tamu.edu

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