Innovation Lab for Small-Scale Irrigation: Ghana

Technical Report

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Profitability and Economic Feasibility Analysis of Small Scale Irrigation Technologies in Zanlerigu and Bihinaayili, northern Ghana

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Executive summary

- Profitability and economic feasibility of investing in the SSI technologies were analysed based on farm-plot level data on selected SSI technologies piloted in northern Ghana under the Innovation Lab for Small Scale Irrigation (ILSSI). The aim was to identify profitable and economically feasible sets of '*crop type–SSI technology*' combinations that would prove viable in "real world" farm conditions. Four dry season irrigated cash crop (corchorus, onion, amaranths, and cowpea) grown under four SSI technologies (pump-tank-hose technology, watering can technology, and rain/roof water harvesting and drip irrigation technology) were analysed.

- Results from one season of data showed that rainwater-harvesting using poly tank storage and a drip system is not economically feasible at the current yield level and market prices of irrigated cash crops in northern Ghana. SSI technology options using river water or shallow wells with motorized pumps or watering cans are profitable. However, the watering can is relatively more profitable than motorized pumps, because fuel costs and upfront investment in pumps constrain high profitability. The 'pump-tank-hose' technology (water is lifted with motorized pumps, stored in poly tanks, and distributed to fields with a hose) appears to be economically inefficient.

- Results have policy implications. Smallholder farmers are credit-constrained in northern Ghana. Targeted assistance, such as affordable and appropriate credit schemes could mitigate the constraint and enable more smallholders, including at lower income levels, to participate in market-oriented production.

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1.0. Introduction

The Ministry of Food and Agriculture (MoFA) of Ghana promotes small-scale irrigation (SSI) as a climate variability adaptation measure, given the decline in total rainfall and increasing intermittent dry spells during the rainy season cropping period (MOFA, 2014). SSI is one of the three principal irrigation systems recognized in national irrigation development policy[1] in Ghana. According to the policy, SSI is practised by individuals who cultivate an area of up to about 0.5 ha or more, using simple structures and equipment such as buckets, motorised pumps, hoses, watering cans, etc. for water lifting, conveyance and application; water sources include small reservoirs, shallow groundwater, rivers and wastewater. In short, SSI is an irrigation system practiced on small plots using a level of technology that an individual farmer can effectively control, operate and maintain.

SSI continues to expand despite low government support, and limited input from technical or extension services. SSI employs 45 times more people and covers 20 times more land area than large-scale public irrigation schemes. As at 2010, an estimated 185,000 ha was under SSI, benefiting 500,000 smallholder farmers (Namara et al., 2010; Giordano et al. 2012; Namara et al., 2014). Evans et al. (2012) and FAO (2012) projected that use of motorized pumps could benefit up to 730,000 households and irrigate 584,000 ha in Ghana. Projections for suggests that use of small reservoirs could benefit about 163,000 households and irrigate 163,000 ha. In the northern regions, SSI water application is mainly watering cans, handheld hose, and diesel or petrol motorized pumps, although drip and sprinkler irrigation are increasing (Drechsel et al. 2006; 2007). Potential exists in shallow groundwater using various water lifting, conveyance and application technologies (Barry et al. 2010; Namara et al. 2014), as well as improved utilization of multi-purpose small reservoirs.

The rate of adoption of SSI is likely to increase. The demand is growing for vegetables and fruits with increases in income and changing diets of the growing middle-income consumers in urban areas, providing a business opportunity for small-scale irrigators. Different out-grower models are also feasible for more small-scale irrigators to become involved in market-oriented production. However, sustainable adoption and scaling of various SSI technologies depend on the biophysical conditions and economic feasibility along various value chains. At present, little evidence is available on socio-economic and technical factors that could promote or impede sustainable intensification utilizing SSI in northern Ghana. Understanding these factors can enable appropriate support to improve the scaling pathway for SSI. This includes identification of ways to improve:

- water use and management for farmers adopting SSI technologies,
- informed investment decisions by farmers and other actors in value chains that utilize SSI,
- financial returns that improve livelihoods and food security for smallholder farmers, and
- economic, health/nutrition and other benefits at various scales.

This report seeks to contribute to filling the gap in knowledge, particularly about potential returns to farmers and improving investment decision-making. Using primary farm-plot level data on selected SSI technologies piloted in three communities and secondary data from relevant sources, this report presents findings on the profitability and economic feasibility of investing in the SSI technologies in the study areas. The aim is to identify profitable and economically feasible '*crop type–SSI technology*' combinations that would prove viable in "real world" farm conditions in the study area.

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[1] www.mofa.gov.gh/site/wp.../07/GHANA-IRRIGATION-DEVELOPMENT-POLICY1.pdf. The other two irrigation categories comprise of *formal irrigation* (one that is reliant on some form of permanent irrigation infrastructure funded by the public sector and *large scale commercial* irrigation system.

2.0. Brief background

The Innovation Lab for Small Scale Irrigation (ILSSI)[2] is an action-oriented, farmer-centred research project supported by the Feed the Future (FtF) program through USAID. ILSSI aims to investigate and understand the technical and socio-economic factors, constraints and opportunities of SSI towards achieving sustainability and efficiency in resource utilization (water, land and other resources) and enhance the livelihoods of smallholder farmers. Figure 1 shows the location of ILSSI field interventions sites, which are located within the Feed the Future and the SADA[3] zone. Table 1 summarizes the SSI technologies, communities and crop types ILSSI is piloting in farmers' fields. This report focuses on one dry season across three interventions in two sites, Zanlerigu and Bihinayiili.

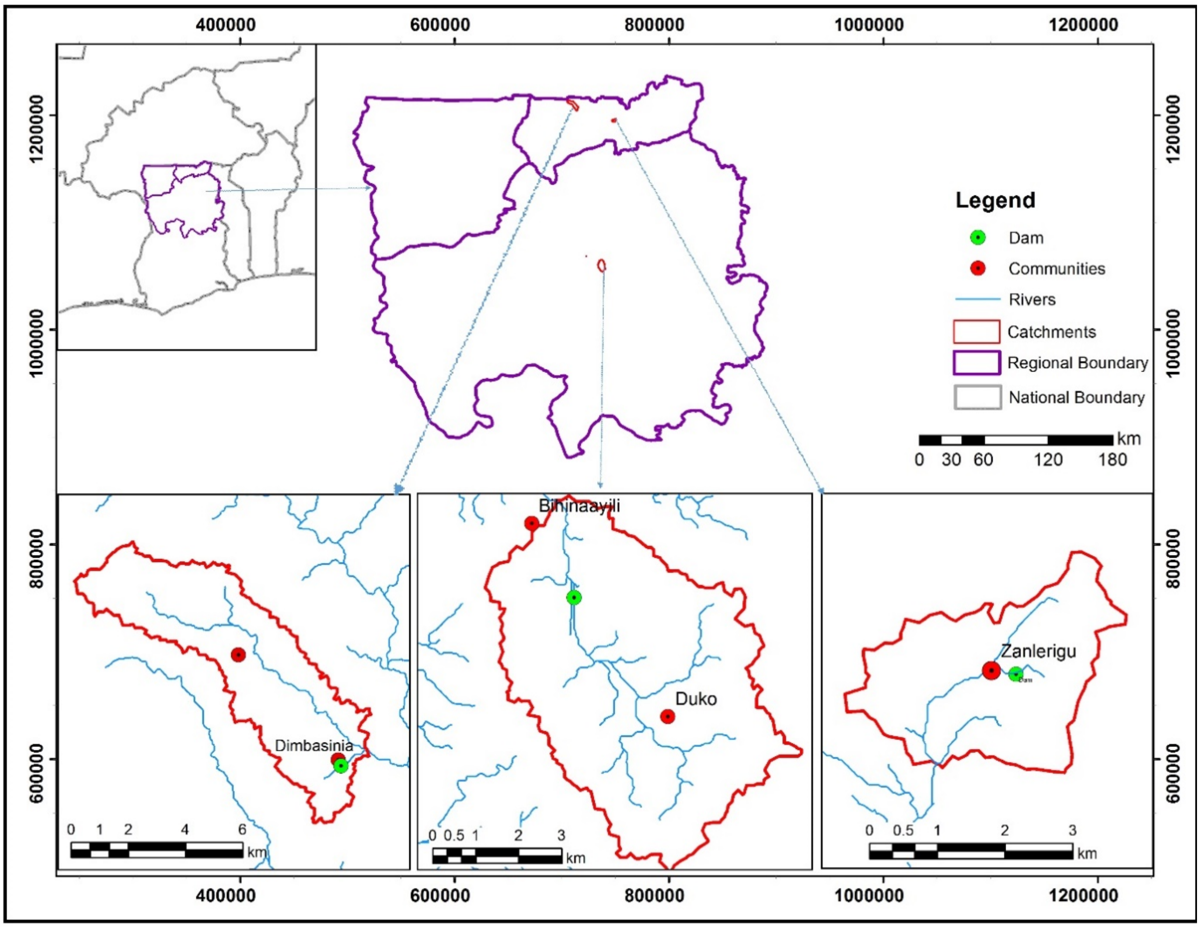

Figure 1: Map of the study communities

Table 1. Communities, water sources and project interventions

Community	Water source	SSI Interventions			Crop type	Number of farmers
		Water lifting	Water storage	Water application		
Bihinaayili	Runoff/ stream	Motorized pump	Overhead tanks	hose	Corchorus	8
		Watering	Canal/	Watering	Corchorus	8

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[2] ilssi.tamu.edu

[3] SADA: Savannah Accelerated Development Authority. The Government of Ghana has mandated SADA to coordinate and facilitate economic development in northern Savannah ecological zone.

		can	trench	can		
Zanlerigu	Shallow wells	Motorized pump	Overhead tanks	hose	Onion & amaranth	8
	Shallow wells	Watering can	Shallow well	Watering can	Onion & amaranth	8
	Rainwater	n/a	Overhead tanks	Drip kits	Cowpea	4
	Rainwater	n/a	Overhead tanks	Hose	Cowpea	1
Dimbasinia	Shallow wells	Motorized pumps	Overhead tanks	iDE Drip system	tomato	8
		Motorized pumps	Overhead tanks	UDS Drip system	Cowpea, Tomato	8

A study by Kadyampakeni et al (2017) on the project sites' climatic and biophysical context provides an overview of the context for agricultural water management interventions. The results show no significant change in rainfall trends, but did identify an annual water deficit and varied dry spells, suggesting the potential for supplemental and dry season irrigation for sustainable intensification. In addition to their use for dry season irrigation, reservoirs and wells can also be used to supplement the intermittent dryspells in each site. Water quality is acceptable for irrigation, though soil variation will impact frequency of watering, e.g. Bihinaayili will require more frequent watering than Zanlerigu. Soil characterization also suggests low organic carbon and total nitrogen across sites, recommending interventions to apply organic matter and nitrogen. The climate, soil and water characterization study has implications for agricultural water management for irrigated vegetable production, in terms of labor and inputs, which could influence costs and yields, particularly over time.

3.0. Economic analysis of dry season SSI technologies in N. Ghana

3.1. Methodology

This report uses Gross Margin Analysis (GMA) and Cost-Benefit Analysis (CBA) to assess the profitability/economic feasibility of the selected SSI technologies. GMA is a useful economic tool to assess the profitability of specific interventions to farmers. It is a decision-making framework that can be used to compare changes in costs and benefits that will result from implementing an intervention, for example, adoption of a new irrigation technology or changing an enterprise or modifying a production process. It evaluates the annual profitability of a farm enterprise by examining the total variable costs and revenues of the enterprise. We used a GMA method to assess the profitability of the technology for the ILSSI irrigation field interventions that do not require significant initial capital investment, such as accessing water from shallow wells and rivers and using watering can for water application. We used CBA to assess the economic feasibility of the technologies over a given time period for the ILSSI irrigation trials that involve upfront investment in terms of water storage facility and pumping machines (fuel-powered motorized pumps).

Cost-benefit analysis (CBA) is an applied economic tool often used to guide resource allocations or investment or policy decisions. It is a technique that is used to estimate and sum up the present values of future flows of benefits and costs associated to resource allocation decisions or technology choice or policy alternatives to establish the worthiness of undertaking the stipulated alternative and inform the economic efficiency to the decision maker. In situations where benefits and costs of an action spread over time, decisions are based on comparing the present values of benefit and cost flows. Various decision criteria can be used in CBA. However, the net present value (NPV) and internal rate of return (IRR) are the most common ones. Further decision criteria such as benefit-cost ratio (B/C) and payback period (PP) can also be used.

NPV is defined as the difference between the sum total of the present value of benefit streams and that of cost streams over the life of the project. Equation 1 presents the mathematical expression of the NPV computation. Projects with positive NPV are accepted while projects with negative NPV are rejected.

$$NPV = \frac{\sum_{t=0}^{T} B_t}{(1+d)^t} - \frac{\sum_{t=0}^{T} C_t}{(1+d)^t} = \sum_{t=0}^{T}\left[(B_t - C_t)(1+d)^{-t}\right] \text{--------------} (1)$$

B_t = value of benefit streams in period ‘t’ (i.e., cash flow benefits at each period)

C_t = value of cost streams in period ‘t’ (i.e., cash flow of costs at each period)

d = discount rate

t = time periods (usually in years) ((t = 1, 2, … T) where *‘T’* is the life span of the project.

The IRR is defined as the discount rate that need to be applied to generate a NPV value of zero. In a business world, IRR computes the break-even rate of return showing the discount rate, below which an investment results in a positive NPV. Using the IRR criterion, accept a project if its IRR exceeds the cost of capital (i.e., the return from the capital if invested elsewhere) and reject if the IRR is less than the cost of capital.

Benefit-Cost Ratio (B/C) is the ratio of the present value of the benefits to the present value of the costs. If this ratio is greater than one, the project is recommended. This is an equivalent condition to the NPV criteria where if the discounted present value of the benefits exceeds the discounted present value of the costs then the project is worthwhile. On the other hand, the payback Period (PP) is a technique used for assessing an investment by the length of time it would take to repay it. By focusing on projects which offer a quick payback, payback period helps decision makers avoid giving too much weight to risky, long-term projections. PP has two major shortcomings: (i) it ignores the value of any benefit flows once the initial investment has been repaid; and (ii) it fails to take into account the time value of money (no discounting).

The data used in the economic analysis came from three sources: (i) data collected by the University of Development Studies (UDS) over a period of one dry season with two cropping cycles in 2016-17; (ii) data on farm inputs and outputs collected by IWMI researchers through direct interviews of farmers in the field in March 2017; (iii) data obtained from secondary sources, such as MoFA and local market information, e.g., seasonal price data in the nearest market centers to the production sites. Tables A.1 and A.2 in appendix-A present summaries of the major agricultural activities, crop calendar, and estimates of costs, yields and prices for Bihinaayili and Zanlerigu intervention sites based on interviews of farmers. The UDS data and data from secondary sources are compiled in separate excel files and available on request.

3.2. Results/Analysis

3.2.1 Bihinaayili site (Northern Region, Ghana)

Crop type: **Corchorus** (*Corchorus olitorius*); locally called 'Ayoyo'.

Irrigation technologies/agricultural water management regimes evaluated:

- **Tank-pump-hose** (Water source: River/spillover water from Ligba irrigation dam)
- **Watering can** (Water source: River/spillover water from Ligba dam)

Number of experimental farmers: **16 farmers** (7 female and 9 male farmers) are involved in the field interventions at this site. Each male farmer manages a 132 m^2 plot of land divided into 8 beds of about 16.5 m^2 area; -each woman farmer manages 6 beds of the same size.

Timeframe: **Two cropping cycles** of one dry-season corchorus production (each for 3 months). Cropping cycle-1 covers November-January; cycle-2 covers February-April (2016-2017 season).

3.2.1.1 Cochorus Production (pump-tank-hose technology)

Production of corchorus using pumps for water lifting with tanks and hoses is economically feasible, according to the CBA (see Table 2). All the key decision criteria used in the analysis (i.e., NPV, IRR, PP, and B/C) show economic feasibility. For instance, the NPV of GHS 9467[4] and IRR of 47% (which is more than twice the discount rate indicate economic feasibility of this technology in corchorus production. However, Ghana's high interest rates for borrowers means that the IRR is not high enough to guarantee against a potential fall in NPV, should the market interest rate increase, say above 35%, which is not uncommon in local money markets (esp. among local, informal moneylenders). The high cost of borrowing could discourage investment by farmers in the technology, if relying on credit.

In addition, the tanks and hoses added costs to this technology approach. Pumping water to the tank and then applying to the crops using a hose adds significant labor time for farmers, as well as increasing the capital costs. ILSSI 'packaged' the pumps, tanks and hoses to optimize water use, but interviews with farmers and site observations reveal that the site has relatively continuous and stable access to adequate water from the nearby Libga dam. Therefore, farmers had little incentive to reduce water use and higher incentive to reduce labor costs; farmers abandoned the tanks and hoses in the trial sites to apply water directly to plots using the pumps.

In addition to the above issues, it appears that motorized pumps are underutilized in this experimental design. Currently four farmers share a motor pump to irrigate a combined land area of just under 0.1 ha. In a study of business potential of SSI to market-oriented irrigation service provision, de Fraiture and Clayton (2012) assumed one motor pump of this specification can serve 2 ha of land. Thus, in extrapolating the ILSSI farmers plot data into a hectare equivalent, we assumed the existing two motorized pumps shared by eight farmers can irrigate additional plots (up to a hectare, i.e. one pump serves 0.5 ha). From researcher observation, it does appear that farmers are using the pumps to irrigate larger areas than the project plots on which this economic analysis was based, and also that farmers may be providing pumping services to other farmers working in the same area. This additional income was not included in this economic feasibility, because it was outside the experimental area, but suggests that profitability is higher than reported here.

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[4] The exchange rate of Ghana Cedi to U.S. Dollar during the month of May 2017 ranged from 4.33 to 4.48.

Table 2. Bihinaayili – CBA of corchorus production using motorized pumps

		Years				
	Cost items (ha)	1	2	3	4	5
1	Cost of motor pumps (1unit @GHC2000; a total of 2 motorized pumps shared by 8 farmers)	4000	0	0	0	0
2	Water storage tanks (2 units per farmer @GHC150; and hose @GHC 75 per famer). Both replaced after 3 years of use.	1800	0	0	1800	0
3	Labor cost (excluding irrigation labor)	7462	7462	7462	7462	7462
4	Agricultural Inputs cost	7576	7576	7576	7576	7576
5	Irrigation - labor cost	4921	4921	4921	4921	4921
6	Irrigation- fuel and machine maintenance	6533	6533	6533	6533	6533
	Interest payment @10% soft agricultural loan rate per year	3229	3229	3229	3229	3229
7	Other cost (fencing etc.)	0	0	0	0	0
8	**Total annual cost**	35521	29721	29721	31521	29721
	Value of harvest (ha)					
9	Total annual crop value	45327	45327	45327	45327	45327
10	**Net annual cash flow**	9806	15606	15606	13806	15606
	Data series for IRR computation	-32292	25412	15606	13806	15606
	Decision Parameters					
11	NPV= GHC 40, 790; NPV in USD= 9467/ha	Discount Rate= 20% (based on Bank on Ghana current base rate)				
12	IRR= 47%					
13	Pay back period= 2.5years					
14	B/C Ratio = 1.45					

It appears that irrigation labour costs more than the cost of motor pumps. This may be partly due to the 'double-pumping' labour requirement of this technology; firstly pumping water to the tank and then to the crops using hoses. However, if utilized to full capacity, the motor pump cost in relation to revenue would decline further, given that one motor pump could potentially serve a larger area.

3.2.1.2 Cochorus production (watering can)

Corchorus production is highly profitability using watering cans, according to calculated gross margin. Production of corchorus using watering can does not require substantial capital investment.. Comparing the undiscounted per ha annual net cash flows of pump-tank-hose technology, about GHS 15, 606 (Table 2) and the annual gross margin of GHS 19,249 (Table 3), the latter shows a clear advantage financially over the former. The fuel cost for pumping explains the lower relative profitability of motorized-pump irrigation technology compared to watering can. Thus, given the current fuel prices in Ghana, SSI technologies that are less dependent on fuel can appear to be more profitable.

Table 3. Gross margin analysis of corchorus production using watering can irrigation technology

Crop - Corchorus	
Yield (kg/ha) (4 times harvest)	67451
Price (GHC/kg)	0.60
Gross Revenue (GHC/ha)	***40471***
Cost Items(GHC/ha)	
Labour (excl. cost of irrigation labour)	8457
Cost of agricultural Inputs	5844
Cost of Irrigation labour*	5801
Watering can 16 units @GHC 880 and 8 buckets@GHC 240	1120
Total cost	**21222**
Gross Margin (GHC/ha)	**19249**
Gross Margin (USD/ha)	**4466**

**This includes digging canals to bring the water near to the crop field. Because in Bininaayili site farmers field are located in certain distance from the main drainage course of the nearby Libga dam where they draw irrigation water. Therefore, they dig canals and store water near their farm to apply using watering can.*

The result of this analysis does not suggest manual technologies based on human labor should be promoted, but rather the need for further analysis of labor costs and time burden. For example, women farmers in the ILSSI sites tend to use manual technologies (e.g. watering cans, buckets or calabash), which adds to their workload and time demands, thereby discouraging engagement in irrigated production (Theis et al 2017).

3.2.2 Zanlerigu site (Upper East Region, Ghana)

Crop type: Intercropped **Onion** (*Allium cepa*) and **Amaranth** (*Amaranthus caudatus*), locally called Alefu; **Cowpea** *(Vigna unguiculata)* home garden

Irrigation technologies/agricultural water management regimes evaluated:

- **Tank- pump- hose** (Water source: shallow wells)
- **Water canning** (Water source: Shallow wells)
- **Drip irrigation** (water source: roof/rain water harvesting)

Number of experimental farmers: **16 farmers** (8 female and 8 male farmers) involve in onion-amaranths intercropping system and **4 farmers** in home garden (cowpea) trials.

Timeframe: **One crop for onion and continuous for amaranth,** during the November/December 2016 to April 2017 dry season. In onion-amaranths intercropping system, onion matures in 3-4 months. After harvest of onion in February, the amaranth continues to be cultivated until April (end of dry season).

3.2.2.1 Onion-amaranth intercropping' system (pump-tank-hose technology)

The results show that with a NPV of GHS 39, 023/ha (ca. USD 9054/ha) and IRR of 45%, the onion-amaranths intercropping system is economically feasible (Table 4). The following assumptions underpin the economic feasibility assessment of investment in dry season irrigated onion-amaranth intercropping agricultural production system:

- Eight farmers operate dry season irrigated onion-amaranths intercropping agricultural system on a hectare of land – each operates a plot of 1250 m^2 land area.
- Four farmers jointly own a 5 HP motorized diesel pump (i.e., two motorized pumps for the eight farmers)
- Each farmer owns a water storage tank and hose for water application
- Each farmer utilizes three shallow wells located across the individual farmer's plot
- Four farmers jointly access soft agricultural loans (10% interest rate) from a local Agricultural Development Bank/Microfinance Institution/Development organization used to finance purchase of irrigation equipment and cover other operational costs.

Two interesting comparisons can be made. First, dry season irrigated production of corchorus and the onion-amaranth intercropping system using motorized pumps provide more or less similar level of economic return. So far, corchorus production in the region has not received the same level of attention as onion as a cash crop. The result here shows that corchorus production can be equally or even marginally more profitable than onion production. So, SSI interventions and the corresponding crop choices in northern Ghana should explore a range of options to maximize farmer's benefits instead of focusing only on historical cash crops. Second, the NPV of onion could have fallen significantly (by almost one-third) if onion had been grown as a mono-crop in the Zanlerigu site. Stated otherwise, intercropping onion with amaranth boosted annual cash flows almost by 30%. Interviews with men and women farmers in the area suggested that women farmers proposed the amaranth, because of the higher price and ability to produce continuously; continuous production enabled farmers to cover fuel and other input costs without borrowing. This implies the need to explore innovative inter-cropping options throughout the dry season.

Table 4. Zanlerigu – CBA of onion-amaranths production using motorized pumps

		Years				
	Cost items (ha)	1	2	3	4	5
1	Cost of motor pump (1unit @GHC2000; 4 users share a unit; 2units purchased)	4000	0	0	0	0
2	Water storage tanks (1uint per farmer @GHC150; and hose @GHC75 per famer). Both relplaced after 3 years of use	1800	0	0	1800	0
3	Labour cost (excluding irrigation labour)	5598	5598	5598	5598	5598
4	Agric. Inputs costs	8614	8614	8614	8614	8614
5	Irrigation - labor cost	3550	3550	3550	3550	3550
6	Irrigation- fuel and machine maintenance)	1367	1367	1367	1367	1367
7	Additional cost - Amaranths prodution	1565	1565	1565	1565	1565
8	Interest payment@10% sepcial agric loan rate per year	2649	2649	2649	2649	2649
9	Other cost (fencing etc.)	0	0	0	0	0
10	**Total annual cost**	29143	23343	23343	25143	23343
	Value of crop harvets					
11	Onion-Total harvest value	30089	30089	30089	30089	30089
12	Amaranths-Total harvest value	10531	10531	10531	10531	10531
13	**Tota crop value**	40620	40620	40620	40620	40620
14	**Net annual cash flow**	11476	17276	17276	15476	17276
	Data series for IRR computation	-29143	17276	17276	15476	17276
	Decision Parameters					
15	NPV= GHC 39, 023; NPV in USD=9054/ha	Discount Rate= 20% (based on Bank on Ghana base rate)				
16	IRR= 45%					
17	Pay back period= 1.85 years					
18	B/C Ratio = 1.63					

3.2.2.2. Onion-amaranths intercropping' system (watering can)

On a seasonal basis, use of manual the manual watering can is relatively more profitable than the *pump-tank-hose* technology (GHS 21,205/ha/year vs. GHS 17,276 /ha/year respectively). Table 5 presents the economic profitability of onion-amaranths inter-cropping system using watering can technology in Zanlerigu. This is similar to the finding for corchorus in Bihinayiili. Again, the cost of irrigation equipment (motorized pump, tank and hose) and fuel cost largely explained the lower performance of the pump-tank-hose technology in terms of annual net return compared to the watering can.

Table 5. GMA of onion-amaranth inter-cropping watering can irrigation

Onion	**Quantity or Value**
Yield (kg/ha)	12000
Price (GHC/kg)	2.50
Gross Income (GHC/ha)	***30000***
Amaranths	
Yield (bundles/ha)	21073
Price (GHC/bundle)	0.60
Gross Income (GHC/ha)	***12644***
Total gross revenue (GHC/ha)	**42644**
Cost items (GHC/ha)	
Labour (excl. irrigation labour)	6209
Cost of agric. Inputs	9727
Cost of Irrigation labour*	2892
Watering can 16 units@GHC 880 and 8 buckets@GHC 240	1120
Additional cost - Amaranths (weeding & harvesting)	1491
Total cost	**21439**
Gross Margin (GHC/ha)	**21205**
Gross Margin (USD/ha)	**4920**

** This includes labour used for digging shallow storage wells. Each farmers has 3 shallow wells. At the end of the dry season, they dismantle the shallow wells to use the land for main rainy season crops and re-dig at the beginning of each dry season agriculture.*

3.2.2.3 Cowpea production under rain/roof water harvesting and drip irrigation technology

The use of technologies that combine rainwater harvesting with tanks and drip kits is simply too expensive for smallholders or other farmers to manage as a commercial enterprise, according to analysis on cowpea production in Zanlerigu. As indicated in Table 6, the negative NPV GHS 433,959 shows that investing in a hectare of cowpea using roof water harvesting in poly storage tanks and drip irrigation system is not economically feasible. A Benefit Cost Ratio of 0.194 shows that for every GHS 1 that is invested, there is a return of only GHS 0.194; this is a loss of GHS 0.806. The other profitability/economic feasibility indicators reported in Table 6 also show that it will not be economically feasible to invest in dry season irrigated cowpea production using these technologies.

Table 6. CBA of cowpea production: Roof/rain water harvesting, water storage tanks and drip irrigation technology

	Years				
	1	2	2	4	5
Annual Cash flows					
Costs	-681600	-1938	-2035	-2137	-2243
Benefits	42650	44783	47022	49373	51841
Net Cash Flow	-638950	42845	44987	47236	49598
Discount rate	**20%**				
NPV (GHC)	**-433,959**				
IRR	**-36%**				

ILSSI set up test interventions at Zanlerigu of rain/roof water harvesting with water storage tanks to grow irrigated dry season home garden crops to test feasibility of addressing both household food nutrition needs and commercialization of gardens. Farmers chose to grow cowpea.

Figures from FAO indicate that cowpea needs approximately 350-550 mm water, which translates into 4 million litres of water per hectare per the growing cycle of cowpea. However, due to the water efficiency advantage of drip irrigation, the project assumed that a hectare of irrigated dry season cowpea production would be possible using half of the recommended water requirement, i.e. 2 million litres of water[5]. With this assumption, a total number of 200 water storage tanks each with 10,000 litre capacity would be required to supply water for one hectare of land for cowpea production. Also, at the current market price of GHS 3240 per 10,000 litre water storage poly tank, the cost of water storage tanks alone is about GHS 648, 000 with drip kits adding another GHS 33,660/ha. The fixed cost of this technology is about GHS 681,600/ha, at current exchange rates[6] just over USD150, 000/ha. The yield of cowpea varies depending on the variety that is used and other agronomic practices. According to studies, including by the Savannah Agricultural Research Institute (SARI), Ghana cowpea yield varies from 1.5 – 2 tons/ha in northern Ghana under rainfed conditions. However, because of the assumed efficiency of water use under drip, the pod yield of 2.3 tons/ha was used in this analysis generating a revenue of GHS 12, 650 in two-production cycles per season at a price of GHS 2.75/kg. Based on UDS record on harvest of cowpea leaves, farmers can get about 1000 buckets from a hectare. A bucket of cowpea leaves is valued at GHS 15, bringing the revenue for a hectare to about GHS 30,000 per season (in two-cropping cycles). This intervention is not feasible technically or economically.

4. Conclusions and implications

This report provides the examples of profitability and economic feasibility assessment of selected SSI technologies field piloted by ILSSI in northern Ghana. Depending on the specific local biophysical and socio-economic conditions, various technology options can be proposed and implemented to benefit smallholder farmers and ensure the sustainability of technology adoption. Economic analysis of SSI technologies provides key decision support evidence for promoting technology adoption and upscaling.

This report assessed the profitability and economic feasibility of four different dry season irrigated crops under five SSI technologies in two communities/sites based on data collected by the University

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[5] The economic analyses presented here is based on this assumption and on the secondary costs and yield data obtained from various sources.

[6] Currently, May 2017, the market exchange rate is about GHS4.40 = 1USD,

of Development Studies, project researchers' field observations and interviews with participating farmers, and relevant secondary data. Results show that some crop-technologies were profitable and economically feasible: (a) Cochorus production: use of pump-tank-hose irrigation technology; (b) Cochorus production: use of watering can irrigation technology; (c) Onion-amaranths intercropping' system: use of pump-tank-hose irrigation technology; (d) Onion-amaranths intercropping' system: use of watering can irrigation technology. Comparison of the economic results on watering can and motorized pump technologies showed that watering can was relatively more profitable, though highly labor intensive. The variation in levels of profitability – with motor pump less profitable - is mainly due to the cost of fuel and capital investment required to purchase a pump. However, rainwater-harvesting using poly tank storage and drip required large capital investment that could not be recovered from the current yield level and market price of cowpea. Lower cost technologies would need to be considered to intensify cowpea production.

The economic analysis results suggest three main policy implications. First, rainwater harvesting for dry season irrigation is an expensive technology for irrigation purposes, especially when poly tanks are used for water storage combined with drip equipment. This technology is not financially feasible for upscaling, even with higher value crops. Secondly, the high cost of borrowing in Ghana makes the upfront investment in irrigation technologies very expensive. This is supported by other studies that show smallholder farmers are credit-constrained in northern Ghana (Balana et al. 2016). Targeted assistance is needed to ensure that smallholders at lower levels of economic status can access credit on appropriate terms (Namara et al 2013)[7]; otherwise, poorer farmers, such as women, risk being left out of market-oriented production activities. Third, alternative energy options, notably solar pumps, could be a promising option for smallholder farmers to reduce labor while decreasing reliance on fuel. Studies have shown that agriculture labor costs in Ghana are high, as is the opportunity cost of labor employed in agriculture in absolute terms, particularly as rural households increasingly depend on non-farm activities to boost income (Nin and McBride 2014). The upfront cost of solar pumps is expensive in Ghana compared to fuel pumps, and may deter smallholder farmers from adopting solar-based irrigation technology, unless affordable credit or innovative loan schemes become available.

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[7] The majority of farmers that adopt SSI technologies on their own are usually wealthier. See: R.E. Namara, G. Gebregziabher, M. Giordano, C. De Fraiture (2013). Small pumps and poor farmers in Sub-Saharan Africa: an assessment of current extent of use and poverty outreach. *Water International* 38(6): 827-839.

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Appendix A. Costs and benefits data based on field interviews on SSI technologies in N. Ghana

Table A1. Cost of corchorus production in Bihinaayili site (Northern Region, Ghana)

Activities or inputs	Descriptions	Costs/revenues
Seed	Seed was provided by the ILSSI project for the trial. But farmers reported that it would cost NGC 50 for a 132 m^2 plot.	NGC 50 per 132 m^2 plot.
Nursing	No nursing is required. Corchorus is planted through direct sowing.	N/A
land preparation	This includes land clearing, ploughing, and bounding. According to farmers own recall, land clearing and ploughing with hired labour cost NGC 50 per 132 m2 plot area. For bounding, they use 2-3 man-day own or family labour.	NGC 50 (hired labour) per 132m^2 area (based on farmers' report.
Fencing	No fencing	N/A
Digging shallow wells	No applicable	N/A
Planting	Planting of first cropping cycle in November and 2nd cycle in February. Planting doesn't require lots labour (because it is a direct sowing practice).	N/A
Weeding (4 times)	Farmers reported that they undertake weeding four times in one cropping cycle. They claimed that they pay NGC 5NGC per bed i.e. NGC 40 per 8-beds (male farmers) or 30 NGC per 6-beds (female farmers) for one complete weeding.	NGC 200 per season per farmer, but this appears much higher than the data reported by UDS.
Irrigation cost	Technology: Water canning Labour: Irrigate daily (3 hrs labour time in irrigation) Labour: Digging canals to divert water from the river close to the farm field– 3 man-day labour is required May seem deficit irrigation, because watering can demand lots of labour time, the amount of water applied using watering can may not be sufficing to crop water requirement. Technology: Pump, tank and hose: 4 farmers share a pumping machine Labour and irrigation frequency: Irrigate 2 times per week Fuel cost – 1Gallon/week is enough to irrigate four farmers' plots. The cost of fuel is NGC19/Gallon which is sufficient to pump water to four farmers per week.	Irrigation cost for watering can technology was estimated by converting the labour time using local wage rate. For pump-tank-hose technology, irrigation cost includes labour and fuel costs.
Pump maintenance	This includes repair i.e., replacing parts and servicing the machine.	NGC 27 on servicing and NGC 100 on repair per machine per the two crop cycles for the 4 farmers.
Fertilizer	Apply 3 bowls i.e., ca. 3 kg of fertilizer per 132 m^2 plot this costs NGC30. Fertilizer is applied after every harvest. Thus, in 5 harvests: 5@30= 150 NGC	150 NGC/season/famer (i.e., cost of fertilizer for the 8 beds is NGC150).
Pesticides (chemicals)	Not used that much. If used, just 6NGC for all the 132 m^2 plot area.	
Harvesting	5 times of harvesting per three months cropping cycle.	
Yield	Yield varies by irrigation technology used. Technology: Watering can In one harvest yield is 1.25 bucket per bed (10 buckets per 8 beds i.e., 132 m^2 plot area). Total harvest per farmer in two cropping cycle is 100 buckets/season: i.e., (1.25 bucket @ 8beds @ 5 harvests per crop cycle @ 2 crop cycles) Technology: Pump-tank-hose Yield in one harvest equals 2 buckets per bed (i.e., 16 buckets per 8 beds or 132 m^2 plot area). Total harvest per farmer in two cropping cycle is 160 buckets: i.e., (2 buckets @ 8beds @ 5 harvests per crop cycle @/season (1.25 times @ 2 crop cycles)	100 buckets /farmer in two crop cycles. (1bucket = about 13.85 kg; source: UDS) 160 buckets /farmer in two crop cycles.

Price	High price time: NGC 15 per bucket Low price time: NGC 7 per bucket	High price of NGC 15 per back is reported in first crop cycle and low price in second crop cycle as the supply is high in the second cycle.
Revenue	Using the average price of high and low, revenue can be computed by multiplying price and total quantity of harvest in the two crop cycles for the two irrigation technologies.	**Watering can**: Revenue= 100buckets @ NGC 11= NGC 1100 per farmer per season. **Pump-tank**: Revenue= 160buckets @ NGC 11= NGC 1760 per farmer per season

A.2. Cost of production and crop calendar of onion-amaranths cropping system in Zanlerigu (UE, Ghana)

Activities/inputs	Onion	Amaranths
Seed	Provided by the project	Own produced seed is used.
Nursing	Onion is nursed in September. Nursery takes from 4-6 weeks before transplantation. Family labour is used to undertake nursery activity and no hired labour is involved.	Nov (4 weeks in nursery)
land preparation	October: Land clearing, ploughing and bed preparation – both hired labour and family labour are used. Farmers indicated that they pay about GHS80 for land preparation (clearing, ploughing, bedding of 300-400 m^2 plot) if hired labour is used.	No separate land preparation activity.
Fencing	. Materials: Local materials (sorghum stalks are used). Not direct cash cost (i.e., no purchased inputs) involved in acquiring fencing materials. . Labour: Group labour sharing arrangement. The project farmers work in a group to fence the surroundings of their field. They reported that each farmer works for about 8 days to complete the whole fencing activity.	No separate fencing activity is needed.
Digging shallow wells	October: Hired labour @GHS20 per well – each farmers owns 3 wells. Cost of wells digging per farmer is GHS60.	The same wells are used.
Planting	November (early): family labour, mostly children labour were used. They reported two children work for three days to plant ca. 350 m^2 plot.	Early Dec. (1 month after planting onion
Weeding (3 times)	1st: labour sharing among the 4 farmers & their children (i.e. 8 children and 4 adults) 2nd: same as above 3rd: same as above	No separate weeding until the harvest of onion harvest. But after
Irrigation	. Labour: Family labour (mostly use children), no hired labour involved). .Capital cost: pumping machine and tanks are provided by the project. .Fuel cost: 4 farmers share a pumping machine. One gallon of fuel, costing ca. GHS15 is sufficient for the 4 farmers per week. i.e., 4 Gallons (ca. GHS60 per week) for the first one month. When the irrigation frequency increase (see below) from once per day to twice per day for the last two months growing season of onion, pumping fuel consumption increases 8 gallons per month for the 4 farmer. So the total fuel cost for the four farmers is: 20 gallons@ GHS15= GHS300 per season; i.e GHS75 expenditure on pumping fuel per farmer per 3 months. . Irrigation frequency – month 1: once a day for the first one month after transplanting .Irrigation frequency –months 2 and 3: twice a day for the last two growing season. .Time taken to irrigate: Irrigation activity takes 2 hours per ca.350 m^2 plot by one person.	Until they harvest onion in early February, the same irrigation serves. But after harvest of onion. Amaranths stays in the field for about 2.5 months (i.e., Feb., March and up to mid-April). After mid-April the fields are used for rain-fed crops.
Fertilizer	. Compost application – after two weeks of planting . NPK: 1.5 bags (ca.180 GHS) per about 350m^2 per season.	After onion harvest, they apply only

		manure. No fertilizer cost.
Pesticides (chemicals)	1.5 litres (ca. 15-25 GHS) per 0.03 ha	
Harvesting	Feb (early Feb). Farmers grow onion variety with a maturity period of 3 – 3.5 months.	First harvest early January, then harvesting continues every two weeks until mid-April.
Yield	2 buckets per bed (i.e. per ca.10m^2 area). A bucket is approximately ca. 20 kg. According to the farmers they harvest 1 bag (ca. 60 kg) from 3 beds (i.e., about 30 m^2 area). That means a farmer having 30 beds can harvest about 10 bags of 60 kg each (or a total of 600kg/300m^2). This is equivalent to about 20 ton/ha.	15 bundles per bed per harvest. i.e., a total of 105 bundles per bed per season.
Price	Low price: 20-30 GHS/bucket (i.e., this is approximately 1 – 1.5 GHS/kg. High price: 60-70 GHS/bucket (i.e., this is approximately 3 – 3.5 GHS/kg.	3-5GHS per 15bundles, i.e., 3-5 GHS per bed per one harvest.
Revenue per ha	.Min 600 GHS/300m^2 (at low price) .Max. 1800 GHS/300m^2 (at high price) Per ha revenue: Min. 20,000GHS/ha Per ha revenue: Max. 50,000 -60000 GHS/ha	.1bed= 21-35 GHS/season .30beds=630 to 1050GHS/300m^2 .21,000GHS/ha