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Asssesing the effectiveness and impact of agricultural water management interventions: the case of small reservoirs in northern Ghana

Daniel Acheampong[a], Bedru B. Balana[b,*], Fred Nimoh[a], Robert C. Abaidoo[a]

[a] Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[b] International Water Management Institute, West Africa Office, Accra, Ghana

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ABSTRACT

Agricultural water management, particularly management of multi-purpose small reservoirs (SRs) in drier savanna areas of the northern Ghana, is being promoted as a key solution to improve agricultural production, enhance food security and livelihoods of smallholder farm households. However, little empirical evidence exist on how effective these small water infrastructures are in terms of delivering multiple benefits and their impact on the livelihood of smallholder farmers. This study assessed the effectiveness and impact of the small reservoirs on smallholder vegetable farmers in northern Ghana. A participatory rating method using a 5-point Likert-scale was used to assess the effectiveness of SRs in delivering multiple livelihood benefits and an endogenous switching regression model was applied to assess the SRs' impact using a primary data collected from 328 randomly sampled vegetable farmers. Results from the Likert scale analysis show that most of the SRs are either dysfunctional or underutilized and not effective in delivering multiple benefits. Results from the endogenous switching regression model show that there is only about 3% increase in the income of vegetable farmers participating in irrigated vegetable production using SRs against the counterfactual situation but this change is insignificant statistically. The current low level effectiveness and impact of SRs could be enhanced by improving their management, for example, through the provision of incentive mechanisms such as subsidies to the private sector involvement in rehabilitation, management and irrigation service provision and strengthening the capacity of existing water users associations. Furthermore, small reserviors should be recognized not only as water sources for small scale irrigation but also as providers of multiple livelihood benefits to local communities and consequently should attract due attention in public resource allocation in their rehabilitation and management/institutional capacity building.

1. Introduction

Rain-fed agriculture is the dominant form of agricultural production in northern Ghana[1]. Its productivity is severely curtailed by the unimodal rainfall pattern. Food grown during the rainy season is often insufficient to meet year-round household food needs with some households frequently experiencing severe food insecurity for about four to five months annually (Timler et al., 2014). On the other hand, studies show that high potential exists for irrigated agriculture in northern Ghana. Northern Ghana is drained by the Volta River system consisting of the White Volta, Black Volta, Oti, and Darka Rivers. Ghana's total renewable water resources are estimated to be about 53.2 km^3/year. Groundwater is estimated at 26.3 km^3/year (FAO, 2016). In the Volta Basin, water for irrigation is sourced from rivers, groundwater, and stored water in natural and built infrastructure or reservoirs (Johnston and McCartney, 2010; Payen et al., 2012). There are 22 medium and large public irrigation schemes in Ghana covering about 14,700 ha irrigable area of which only about 9000 ha is actually under irrigation. Five out of the 22 schemes (Tono, Vea, Golinga, Bontanga and Libga with storage capacities ranging from 5.9 to 93 Mm^3) are located in northern Ghana. Additionally, there are more than 500 small reservoirs and over 6280 boreholes managed by communities and smallholder farmers (Liebe et al., 2005; Johnston and McCartney, 2010). Water is also stored on-farm in ponds and wetlands (McCartney et al., 2013). Shallow wells are widely used for small scale irrigation (SSI) in several communities in northern Ghana (Molden, 2007; Namara et al., 2011; Payen et al., 2012). Small reservoirs and dugouts are also in high demand because they support multiple

* Corresponding author.
E-mail addresses: sparrow5530@gmail.com (D. Acheampong), b.balana@cgiar.org (B.B. Balana), frediemoh@yahoo.com (F. Nimoh), abaidoorc@yahoo.com (R.C. Abaidoo).

[1] Northern Ghana comprises of the three administrative regions in the north of the country, i.e., Northern, Upper East, and Upper West Regions.

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livelihood benefits including irrigation, livestock production, fisheries and brick fabrication (van de Giesen et al., 2002; Birner, 2008; Namara, 2010).

However, there is seasonality in the availability of some of these water resources because of the variability of the annual rainfall and climatic condition in northern Ghana. Excess rainfall and runoff that is available during the wet season is underutilized, while there is acute water shortage for agricultural use during the dry season. Thus, agricultural water management (AWM) interventions are progressively being suggested and promoted as a first step to enable positive development, alleviating food insecurity and poverty among the smallholder farm households that dominate the agriculture sector in Ghana (Mikhail et al., 2011). AWM is generally perceived as a key step towards improving low yielding smallholder farming systems in sub-Sahara Africa (Barron et al., 2008). Particularly, small scale irrigation using small water infrastructures uch as small reservoirs[2] and shallow wells for water storage and appropriate irrigation technologies are important complements to increase agricultural production and enhance the livelihoods of smallholder farmers.

Northern Ghana is endowed with a number of multi-purpose small reservoirs (SRs). Many of the existing SRs were established since the independence of Ghana (1960's) by various donor agencies and the Government of Ghana to provide water for irrigation to promote dry season farming among smallholders. Good water storage infrastructure combined with SSI technologies can allow farmers to practice dry season farming and supplementary irrigation during dry spells in the rainy season, thereby avoiding crop failure and allowing higher yields compared with sole reliance on rainfall (Evans et al., 2012; FAO, 2012). Balana et al. (2016) found that dry season irrigation as the major benefit derived from small reservoirs. Small reservoirs, over the last three decades, have been increasingly seen as a way to develop small-scale irrigation (Venot and Krishnan, 2011). Besides their use for irrigation, SRs also provide multiple livelihood benefits such as livestock watering, construction, fishing and domestic uses. Small reservoirs are typically owned and managed communally through water users' associations (WUAs), though in some cases individuals own and manage the reservoirs (Namara et al., 2011; Namara et al., 2014).

However, the multiple benefits communities derive from the SRs, in recent times, are said to be declining posing negative consequences on the livelihoods of the smallholder farmers. The Northern Rural Growth Programme (NRGP)[3] funded by African Development Bank (AfDB), which started in 2007, and the Ghana Social Opportunity Project (GSOP)[4] supported by the World Bank, which commenced operations in 2010, have both recently invested in rehabilitation of small reservoirs for water storage and irrigation through gravity-based water flow to improve agricultural production and provide other multiple livelihoods benefits to farmers.

However, little is known about the effectiveness and livelihood impacts of small reservoirs in northern Ghana. To the best of our knowledge, two key knowledge gaps exist with regard to our understanding of the SRs in northern Ghana: (1) how effective these water bodies are in terms of delivering multiple livelihood benefits, and (2) how important the SRs are to the livelihoods of smallholders farmers in the area? Using primary data collected from randomly smapled smallholder farmers located around selected multi-purpose small reservoirs in the Upper East region of Ghana and applying a five-point Likert-scale analysis and the endogenous switching regression model; this paper assessed the effectiveness of SRs in delivery of multiple benefits and their impacts on the livelihoods of smallholder vegetable farmers in Upper East region of Ghana.

2. Methodological approach

2.1. The study area

The Upper East Region is located in the north-eastern corner of Ghana between longitude 00° and 10° West and latitudes 10° 30″N and 11° N. The land is relatively flat with a few hills to the east and southeast. The total land area is about 8842 km^2, which translates into 2.7% of the total land area of the country. Initial field visits (for site selection and characterization) was conducted in Upper East region to help identify the SRs and understand their delivery of multiple livelihood benefits to the various communities in the region. Based on the information gathered during the field work, the study was conducted in purposively selected communities in four districts in Upper East Region (Fig. 1a, b and Table 1). The selection of communities was based on the availability of multi-purpose small water bodies (reservoirs). The field studies also helped to identify and establish key local contacts (local government units and farmers) to facilitate the actual fieldwork.

Based on information gathered during the site selection and field characterization, reconnaissance surveys were conducted to help gather information for the preparation of final field instruments. The reconnaissance survey helped us in the identification and listing of various stakeholders, particularly Water Users Associations (WUAs) – farmers' groups using SRs for crop production and other uses such as domestic and livestock drinking –and local and government institutions facilitating the management of the SRs. WUAs are being actively promoted in the northern regions of Ghana. Table 2 shows the distribution of active farmer groups in irrigated agriculture in the three northern regions of Ghana. As a result of rehabilitation of several small reservoirs and dugouts since 2007 by various agencies (e.g. Ghana Social Opportunities Project (GSOP) which rehabilitated 56; Northern Rural Growth Programme (NRGP) which rehabilitated 42; and the World Food Programme (WFP) which rehabilitated 12), dormant WUAs have been revived (MOFA, 2014).

Crops produced under rain-fed are mostly grains such as maize, rice, millet, sorghum, groundnut and soybean whereas irrigated crops are mainly vegetables including tomato, onion, pepper, okra and leafy vegetables. Competition to land for irrigated and rain-fed crops is minimal. Farmers use the irrigable areas to cultivate cereals in the rainy season (rain-fed) and vegetables in the dry season (irrigated). In some areas in the region, e.g., Kamega and Binaba communities, the irrigable area is used solely for rice production during the rainy season. This enables them to do supplementary irrigation of rice during periods of dry spells. Land preparation for dry season production starts immediately after harvesting the wet season crops to take advantage of residual soil moisture.

2.2. Sampling and data collection

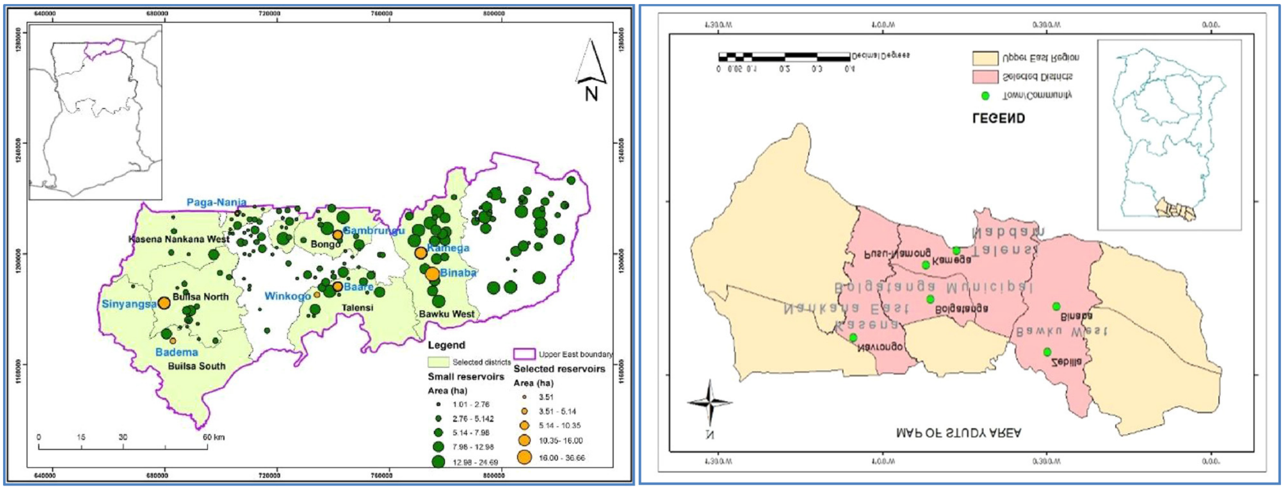
Based on the list of farmers provided during the reconnaissance surveys,[5] a simple random sampling technique was used to select 328

[2] Small reservoirs are artificially-created aquatic ecosystem. The World Commission on Dams defines small reservoirs as "a structure that has a height less than 15 meters and a storage capacity that ranges from fifty thousand to 1 million m^3. However, defining small reservoirs by volume, height, and irrigated area, type of infrastructure or mode of management is site and situation specific and is often not easily comparable. For example, most reservoirs in Burkina Faso are large but very shallow with seasonal variations so storage capacity is not taken into account in the same way as for reservoirs in other locations. There are more than 500 small reservoirs with irrigation potential in northern Ghana.

[3] Details of NRGP activities can be seen here: http://mofa.gov.gh/site/?page_id=713. (Accessed 0n 2 June 2018).

[4] Details of GSOP activities can be seen here: http://projects.worldbank.org/P115247/ghana—social-opportunities-project?lang=en. (Accessed on 2 June 2018).

[5] This includes visits to study sites, interviews with key informants, consultation with agricultural extension workers, discussion with community



a

b

Fig. 1. (a) Distribution of SRs in the Upper East Region. (b) Map of the study districts in the Upper East Region.

Table 1
Selected Communities and SRs in Upper East Region, Ghana.

Municipal/District	Community	Name of SRs
Bawku West	- Googo	- Googo
	- Kamega	- Nagbere
	- Binaba	- Binaba I and Binaba II
Kassena-Nankana	- Samboro	- Samboro
	- Kajelo	- Kunwor
		- Dambudonga and Benatwere
Bolgatanga	- Bolgatanga	- Estate Dam/Tindonsolgo
		- Dorongo
		- Sumbrungu
Talensi	- Winkongo	- Winkongo
	- Pusu-Namongo	- Pusu Namongo

Table 2
Smallholder farmer groups in irrigated agriculture in northern Ghana (2014).
Source: MOFA (2014).

Region	Number of groups	Number of farmers	Major crops	Water sources
Northern	52	1674	Leafy vegetables, Pepper, Cucumber	Small reservoirs, Rivers
Upper East	119	19815	Onion, pepper, Okra, Strawberry, Butternut squash	Small reservoirs, Rivers
Upper West	65	4666	Leafy vegetables, Chilies, Butternut squash	Small reservoirs, Rivers

smallholder vegetable farmers comprising of 159 irrigators using water from SRs and 169 non-irrigators from the study communities. Focus group discussions and interaction with key local farmers, community leaders, executive committee members of WUAs as well as extension officers were conducted to gather contextual data. A total of 15 focus group discussions (FGDs), each comprising of 8–12 participants (men group, women groups, and mixed men and women groups), were held to understand community views on the uses, access rules and management challenges of small reservoirs in the area. This also helped to develop quantitative survey questionnaire. Face-to-face survey of the sample households were administered by well-trained enumerators recruited from the local area and who have previous field work experience and conversant of the local language.

2.3. Empirical analysis

This study applies a five-point 'Likert-scale analysis' to assess the effectiveness of SRs in delivering multiple livelihood benefits to local communities and 'endogenous switching regression model' to assess the impact of the SRs on farmers' income in the study area. As highlighted in the previous section, SRs were established to provide multiple livelihood benefits to local communities such as irrigation, water for livestock, and domestic use. In order to assess how effective the SRs were in terms of delivering the expected multiple benefits; a participatory ranking approach was implemented using the 5-point Likert scale (1 = not effective; 2 = slightly effective; 3 = moderately effective; 4 = very effective; 5 = extremely effective) evaluated with the selected community members in all study communities.

As the small reservoirs investigated in this study are owned by the community and reservoirs water is generally accessible to individual farmers (this was confirmed by community members during FGDs), for the purpose this study we assumed that an individual farmer (who is a member of the community) can have an option to practice irrigated vegetable production using water from a small reservoir or opt for a non-irrigated practice. A farmer's decision to engage in irrigated vegetable production can be conceptualized as a two-step decision: firstly, a decision to grow vegetable crops and secondly to irrigate his/her vegetables. A number of factors, such as farmer characteristics, access to land and/or credit, and livestock ownership may affect the decisions and could lead to endogeneity and self-selection problems. If this is not accounted for it may not depict the estimation of the true impact of small reservoirs. The endogenous switching regression therefore helps to jointly take into account the decision to engage in vegetables farming and irrigate the vegetables in a single framework. Again, it allows the implementation of counterfactual experiments in estimating what the impact of SRs could have been, had non-irrigators participated in the technology or if participants had not participated in the technology.

(*footnote continued*)
leaders and committee members of WUAs to familiarize with study area and population, multiple water uses, reservoir management and irrigated crops.

More precisely, vegetable farmers are assumed to make a decision whether to undertake irrigated production using water from the SR or non-irrigated practice. This decision is assumed to be based on the expected total net income from vegetable production. Thus, a farmer will only produce irrigated vegetables if the benefit of doing so is greater than that of the non-irrigated vegetable production practice.

To derive the empirical model, let the expected outcome of a vegetable farmer i for irrigated vegetables (small reservoir as a water source) be T^*_{SWIP} and non-irrigators (rain-fed vegetable grower), T^*_{SWIN}. Vegetable farmers are assumed to engage in irrigated production only if $T^*_{SWIP} > T^*_{SWIN}$. However, both T^*_{SWIP} and T^*_{SWIN} are not observable, while whether a vegetable farmer engage in irrigated production or not is observable.

The first step equation (selection equation) is estimated using the probit regression model as follows:

$$T^*_{ij} = Z_i\alpha + \eta_i\ ; \quad j = \{SWIP, SWIN\}$$
$$T = 1\ if\ \mathrm{T}^*_{i,SWIP} > \ T^*_{i,SWIN}$$
$$T = 0 otherwise. \tag{1}$$

$T_{ij}{}^*$ is a latent variable that captures the expected outcome from a decision to grow irrigated vegetables by the farmer $i;$ vector Z_i represents the variables that affect irrigation decisions including socio-economic and farming characteristics for the farmer $i;$ α is a vector of parameters to be estimated and η_i is the error term with zero mean and variance σ^2_η.

The determinants of vegetable income, depending on whether the framer chooses to practice irrigated production or not, is evaluated in the second step. Two regime equations are estimated in the second step as specified below (Eqs. (2) and (3)):

- Regime equation for irrigators (using SRs as a water source):

$$Y_{i,SWIN} = X_{iN}\beta_{SWIN} + \varepsilon_{iN} \tag{2}$$

- Regime equation for non-irrigators:

$$Y_{i,SWIP} = X_{iP}\beta_{SWIP} + \varepsilon_{iP} \tag{3}$$

Where $Y_{i,SWIN}$ and $Y_{i,SWIP}$ are the net total vegetable incomes for an irrigator and non-irrigator, X_{iN} and X_{iP} are sets of explanatory variables for Eqs. (2) and (3), β_{SWIN} and β_{SWIP} are the parameters to be estimated, ε_{iN} and ε_{iP} are error terms with variances σ^2_N and σ^2_P respectively. Z_i must have at least one more variable that is included in the Eqs. (2) and (3). Thus, engagement in other off-farm business is used as additional instrumental variable in Z_i. The unobservable characteristics of farmers that determine the decision to grow irrigated or non-irrigated vegetables also affect the vegetable income of the famer in each regime. Therefore, the full information maximum likelihood (FIML) estimation was used to simultaneously measure selection and regime equations using the endogenous switching regression model, which takes into account sample self-selection problems. Both the selection and impact equations were estimated jointly using the full information maximum likelihood estimation approach (Lokshin and Sajaia, 2004).

Upon the estimates of β_{SWIN} andβ_{SWIP}, both the conditional and unconditional expectations of vegetable incomes for both irrigators and non-irrigators were calculated. The vegetable incomes in counterfactual situations cannot be observed in this type of study. Thus, their counterfactual value is estimated through β_{SWIN} andβ_{SWIP} considering irrigators using SRs as a treatment group. We need to differentiate the actual vegetable income (observed) and its counterfactual for irrigators in order to calculate the average treatment effect on treated (hereafter ATT). This was done following the approach by Di Falco and Veronesi (2013), where the ATT is calculated as in the Eqs. (4)–(6):

- Expected vegetable income of an irrigator (observed) using the SR as water source is:

$$E(Y_{i,SWIP}|I = 1) = X_{iP}\beta_{SWIP} + \sigma_{\eta p}\lambda_{SWIP} \tag{4}$$

- Expected vegetable income of an irrigator had he/she not practiced irrigation (counterfactual) is:

$$E(Y_{i,SWIP}|I = 1) = X_{iN}\beta_{SWIP} + \sigma_{\eta N}\lambda_{SWIP} \tag{5}$$

Where λ is the inverse Mills ratio. Using Eqs. (4) and (5) yields ATT as follows:

$$ATT = E(Y_{i,SWIP}|I = 1) - E(Y_{i,SWIN}|I = 1) \tag{6}$$

3. Insights from focus group discussions

According to the community, land in the irrigated areas around small reservoirs was allocated based on a number of criteria. Those whose land the small reservoirs were constructed were the first ones to get plots of land. Those who provided labour during the construction of the reservoirs were then accorded second priority. The third category comprised those who wish to be irrigators and who were accommodated when a vacant plot becomes available. Overall, there exists established criteria for access to land and it is generally fair. However, gender is still a major issue in land allocation in the study area as land is generally inherited through the male line (patriarchy). According to some community members "A young male child might even own land ahead of an adult female" (*pers. comm.*, a woman in Binaba community)

Water User Associations (WUAs) were important for irrigation management in the communities surveyed. The rules governing WUAs were largely developed during the establishment of the irrigation schemes. From discussions in all communities where FGDs were conducted, all WUAs are recognized by the District Assemblies and are regulated as Farmer Based Organizations (FBOs) under the Department of Cooperatives, which provides registration certificates. Committee membership of the WUAs is male-dominated in many communities. Gender balancing in access, decision-making, and participation needs to be enhanced in order to improve the performance of the WUAs. In all the communities surveyed, members claimed that the WUAs were effectively implementing their byelaws and water is equitably allocated. Despite these claims, however, there were instances in various communities such as Kamega, Binaba and Winkogo where the downstream farmers did not harvest crops due to lack of water for the tail end farmers.

A levy is charged per plot holder ranging from 1 to 10 Ghana Cedi per season. The amounts collected were said to be important for minor maintenance work. Through the WUAs, the farmers are mobilized to provide labour for canal repairs or boundary fence repairs. In some cases, those who could not provide labour without a reasonable excuse are fined and the cash receipt goes into the WUA fund. However, the amount collected through water levy and fines are so little that it cannot cover major rehabilitation and maintenance works. That was the main reason for the interventions of GSOP, NRGP, and others programmes and NGOs.

4. Results and discussions

4.1. Socioeconomic characteristics of respondents

Results related to the socioeconomic characteristics of the respondents are presented in Table 3. Majority of the respondents were men (68%); this may be due to the rigorous nature of farming thereby serving as deterrent for most females. (Balana, 2016) reported a similar finding in relation to gender and irrigated farming in northern Ghana. He looked at small reservoirs with built-in canal infrastructure and those without canals. Though small reservoirs are more accessible for women farmers compared to large scale irrigation schemes, yet small reservoirs without canals require heavy labour to lift water and limits women's engagement in irrigated production. About 55% of the respondents were within the age category of 20–40 years, and about half (49%) had no formal education, indicating a low level of education

Table 3
Socioeconomic characteristics of the respondents.
Source: Field survey, 2016.

Variable	Categories	Frequency	Percentage
Gender	Male	223	68.0
	Female	105	32.0
Age (years)	Below 20	6	1.8
	20-40	180	54.9
	41-60	103	31.4
	Above 60**Mean (SD)**	39**41.2(14.7)**	11.9
Educational background	None	160	48.8
	Non-formal	2	0.6
	Basic	103	31.4
	Secondary	50	15.2
	Tertiary	13	4.0
Marital Status	Married	278	84.8
	Single	37	11.3
	Divorced/ separated	13	3.9
Household size (No. of persons)	Below 5	68	20.7
	5-10	214	65.2
	11-15	32	9.8
	Above 15	14	4.3
Religion	Christianity	18	5.5
	Islamic	241	73.5
	Traditionalist	63	19.2
	Atheist	6	1.8
Farming experience (years)	Below 10	153	46.6
	10-20	122	37.2
	21-30	31	9.5
	Above 30	22	6.7
Farmer-Based Organization (FBO) Membership	Yes	17	5.2
	No	311	84.8
WUA Membership	Yes	159	48.5
	No	169	51.5
Primary occupation	Farming	313	95.4
	Non-farming	15	4.6
Extension contact	Yes	164	50.0
	No	164	50.0
Veterinary contact	Yes	73	22.3
	No	255	77.7
Ownership of farmland	Yes	287	87.5
	No	41	12.5
Farm size (acres)	Below 5	279	85.1
	5-10	45	13.7
	Above 10**Mean (SD)**	5**2.5(3.5)**	1.2
Access to credit	Yes	23	7.0
	No	305	93.0

among the respondents. Most of them were married (85%) with household size ranging from 5 to 10 persons. A typical smallholder vegetable farmer has been cultivating vegetables for about 2 years. More than half (51.5%) of the smallholder vegetable farmers sampled for the study were not members to any water user associations (WUA) who might have opted not to practice irrigated production. Farming was found to be the major occupation of the respondents and they cultivated an average of 2.5 acres per farmer. Majority of the smallholder vegetable farmers operate on land owned by the family or access land through the local chiefs who acts as the custodian of community land.

Table 4 presents the types of vegetable cultivated by the respondents. Although smallholder vegetable farmers cultivate a range of crops, the most cultivated vegetables were pepper (68.3%) followed by tomato (58.2%), okra (45.7%) and onion (33.8%). A few, however, cultivated eggplant (8.2%) and cabbage (2.7%). It can therefore be inferred that pepper, tomato, okra and onion are mostly cultivated by smallholder vegetable farmers in the Upper East Region. The use of the SRs for vegetable production serves an important example of the provisioning ecosystem services (GreenFacts, 2001).

Table 4
Types of vegetable cultivated by survey respondents.
Source: Field survey, 2016.

Type of vegetable	Frequency	Percentage
Tomato	191	58.2
Onion	111	33.8
Pepper	224	68.3
Eggplant	27	8.2
Okra	150	45.7
Cabbage	9	2.7

4.2. Benefits and effectiveness of SRs

The study found that the majority (more than 70%) of the respondents, particularly members of the WUAs, derive multiple livelihood benefits provided by the SRs, particularly water for irrigation, livestock drinking, domestic use and for construction (Table 5). In all the communities; dry season irrigation, livestock watering, and fishing / aquaculture were identified as the major livelihood benefits derived from the SRs. Many of the focus groups also identified additional issues and distinct perspectives on the livelihood benefits such as availability of water for domestic use and for building and plastering houses. Some focus groups (esp. male participants) identified additional benefits such as swimming/bathing and the presence of green vegetation around the reservoir which serve as feed for livestock in the dry season.

With regard to assessing the extent to which the SRs provide the various benefits identified by the community, i.e., to assess the performance of the small reservoirs against the delivery of the key benefits identified; more than 90% of the study communities stated the supply of water by the SRs for livestock watering as 'very effective'. Kajelo was the only community which rated the availability of the reservoir for livestock watering below the 'very effective' scale; because in Kjelo the reservoir dries up in years of inadequate rainfall and siltation due to poor maintenance. The capacity of the SRs to support fishing/aquaculture received low rating in all communities except the male group in Binaba and the mixed-group in Pusu-Namongo where it was rated as 'very good'. In Pusu-Namongo, a project called 'RESULTS[6]' funded by the Canadian government restocked the reservoir in early 2015 with fingerlings and provided feed to the farmers. The harvest was good, and this encouraged the farmers to actively participate in the aquaculture project. In Binaba, though the reservoir has not been restocked since its construction, communities believe they get enough fish at least for home consumption.

The capacity of the reservoir to provide water for domestic use also received high ratings in many communities. Though the main purpose of the small reservoirs is to provide water for livestock and dry season crop production, the performance ratings provided by the various study communities were not very encouraging. This is mainly due to the siltation of the reservoirs, reducing its capacity to store enough water for irrigation and fragmentation of land due to population growth. The detailed ratings of the key benefits from SRs are indicated in Table 6.

4.3. Impacts of SRs on income of smallholder vegetable farmers

Table 7 presents the differences in farm and household characteristics of irrigators using SRs and non-irrigators, with their respective t-values to test for significance of differences. The t-values suggest that some significant differences exist between smallholder vegetable

[6] Resilient and Sustainable Livelihoods Transformation (RESULT) Project, funded by Canadian Feed the Children (CFTC) and implemented in northern Ghana. It is a 6 year (2012–2018), $19 million project that is being implemented by CFTC in partnership with the Association of Church-Based Development Projects (ACDEP). http://acdep.org/site/index.php/programmes-projects/agriculture/result-project-new.

Table 5
Locally identified benefits from SRs by gender group in selected communities.

Type of benefit	SR communities										
	Kamenga		Binaba		Winkongo		Kajelo	Samboro		Pusu- Namongo	
	M	F	M	F	M	F	MF	F	M	F	MF
Dry season irrigation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Livestock watering	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water for building/ plastering houses	✓	✓	✓			✓	✓	✓	✓	✓	✓
Fishing / aquaculture	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fruits from trees around reservoir							✓	✓		✓	
Cold weather due to water and trees around reservoir					✓	✓	✓				
Domestic use	✓	✓	✓	✓	✓	✓		✓		✓	✓
Swimming and bathing			✓						✓		✓
Green area around dam (fodder)	✓		✓		✓		✓				
Reduction in migration				✓	✓			✓	✓		✓
Selling reservoir water for income									✓		

Note: M = men group; F = female group; MF = mixed male and female group.

Table 6
Rating of the effectiveness of SRs in delivery of multiple benefits in selected study sites in upper East Region, Ghana.

	SR communities										
Type pf benefits	Kamenga		Binaba		Winkongo		Kajelo		Samboro		PusuNamongo
	M	F	M	F	M	F	M	F	M	F	MF
Dry season irrigation	4	5	4	5	4	4	2	3	4	3	4
Livestock watering	5	5	5	5	5	5	3	4	5	5	5
Building of houses	5	5	5	n.a.	n.a.	3	3	3	4	5	n.a.
Fishing/aquaculture	2	2	3	5	3	2	2		3	2	5
Fruits	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2	2	n.a.	5	n.a.
Cool weather	n.a.	n.a.	n.a.	n.a.	2	n.a.	2	n.a.	n.a.	n.a.	5
Domestic use	5	5	5	5	4	5	4	3		4	5
Swimming & bathing	n.a.	2	n.a.	n.a.	n.a.	n.a.	n.a.	3	n.a.	3	n.a.
Greenery around dam (fodder)	n.a.	3	n.a	5	n.a.	n.a.	n.a.	n.a.	a,a.	n.a.	n.a.
Reduction in migration	n.a.	n.a.	n.a.	3	5	n.a.	n.a.	2	1	n.a.	3
Selling water for income	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1	n.a.	n.a.

Note: M = men group; F = female group; MF = mixed male and female group.
n.a. = not applicable (the group indicate that the community do not derive that particular benefit from the SRs).
1 = poor/not effective; 2 = slightly effective; 3 = moderately effective; 4 = very effective; 5 = extremely effective.

Table 7
Characteristics of SRs Users (irrigators) and non-users (non-irrigators).
Source: Field survey, 2016.

Variable	SRs Users (standard deviation)	Non-SRs Users (standard deviation)	Mean difference (t-values)
Gender	0.70 (0.46)	0.07 (6.48)	0.48 (0.92)*
Age	41.61 (14.63)	40.78 (14.95)	0.83 (0.51)
Education	4.58 (5.27)	4.05 (4.92)	0.54 (0.96)
HH size	7.75 (4.33)	7.18 (5.17)	0.57 (1.07)
Farm experience	12.76 (10.44)	12.38 (9.67)	0.38 (0.34)
FBO Membership	0.08 (0.27)	0.02 (0.15)	0.06 (2.39)***
Extension	0.75 (0.44)	0.27 (0.44)	0.48 (9.93)
Land Ownership	1.13 (0.34)	1.12 (0.32)	0.01 (0.38)
Farm size	2.55 (2.47)	2.51 (4.32)	0.04 (0.09)
Perception on SRs	0.58 (0.49)	0.43 (0.50)	1.59 (2.90)
Engagement in other business	0.18 (0.38)	0.21 (0.420	0.37 (0.83)*
Vegetable income	1369.97 (2430.25)	1328.34 (1754.74)	41.63 (0.97)
Livestock income	935.45 (1528.28)	803.90 (120221)	131.55 (0.67)
Observations	*159*	*169*	

farmers who use SRs to irrigate their vegetables and those who do not. The results show that farmers' engagement in 'other businesses' has a significant effect on their decision to practice irrigated vegetable production or not. Farmers who engaged in 'other businesses' were found to be less likely to undertake dry season irrigated farming.

Table 8 presents results from the estimated endogenous switching regression model. Presented in the second column of Table 8 are the estimates from the selection models, which explain the determinants of the likelihood of the vegetable farmer participating in irrigated farming. The likelihood ratio test statistic for joint independence show that the equations are dependent. Also, the chi-square statistic indicates over-identification in the regression specifications of income is significantly different from zero at 1% level. Therefore, the null hypothesis of the influence of the instruments (credit access, off-farm activity participation and FBO variables) on participation in irrigated practices is rejected.

The (ρ_{PA} = 1. 484) implies self-selection into irrigated farming by the vegetable farmers in the study area. This also implies that participation in irrigation may impact differently on non-irrigators, should they decide to practice irrigated production. The positive sign of the covariance term ρ_{PA} also suggests the existence of negative selection bias and that vegetable farmers whose income are below average are more likely to undertake irrigated production.

It is worth noting that, off-farm work participation and extension visits were considered as possible endogenous variables. The results indicate that the residual of the potential endogenous variable "*off-farmresid*" was statistically significant at 1% level in the irrigator's outcome specification, implying that accounting for possible endogeneity of this variable for users of small water infrastructure for irrigation is inappropriate in the study area. Similarly, the residual of

Table 8
Endogenous switching regression estimates for irrigators and its impact on vegetable farmers' income.
Source: Field survey, 2016.

Variable	Selection	Income	
		Participants	Non-Participants
Constant	−1.197***	3.958***	5.474***
	(0.371)	(1.029)	(0.468)
Age	0.007	0.024***	0.005
	(0.007)	(0.009)	(0.007)
Gender	−0.105	0.861***	1.841***
	(0.173)	(0.247)	(0.196)
Education	0.017	0.120***	0.093***
	(0.017)	(0.022)	(0.022)
Household size	0.010	0.004	0.028*
	(0.015)	(0.021)	(0.016)
Experience	0.011	0.188	0.088
	(0.119)	(0.146)	(0.120)
Extension	1.243***	1.163***	−0.639***
	(0.148)	(0.249)	(0.188)
Land owned	−0.129	−0.201	0.220
	(0.219)	(0.256)	(0.240)
Perception SRs	0.526***	1.124***	−0.232
	(0.148)	(0.254)	(0.213)
Other business	−0.011	15.055***	9.641***
	(0.256)	(1.728)	(1.204)
Extensionresid		−1.746	−3.687***
		(1.238)	(0.858)
Off-farmresid		−17.324***	−10.812***
		(1.967)	(1.351)
Credit access	−0.228		
	(0.429)		
Off-farm activity	−0.099		
	(0.206)		
FBO	−0.168		
	(0.419)		
LR test of independence	15.55***		
Log likelihood	−595.23		
Wald chi-square	158.09***		
Lns0			0.117
			(0.088)
ρ_{NP}			−1.444***
			(0.306)
Lns1		0.183***	
		(0.089)	
ρ_{PA}		1.484***	
		(0.294)	

*, ** and *** indicates significance at 10%, 5% and 1% levels; Values in parenthesis are standard errors.

the potential endogenous variable "*extensionresid*" was statistically significant at 1% level in the non-irrigators outcome specification, suggesting that accounting for possible endogeneity of this variable for non-participants of small water infrastructure is inappropriate in the study area.

The coefficient of the extension variable is positive and statistically significant at 1% level, suggesting that vegetable farmers who have access to extension services are more likely to undertake irrigated farming. The findings which concur with that of Abdulai and Huffman (2014) in northern Ghana is not surprising, considering the relevance of agricultural extension in providing vital information on efficient and sustainable agricultural technologies in developing countries. It was found that the decision of a farmer to participate in irrigated vegetable production using water from small reservoirs is highly dependent on one's perception about small reservoirs. This is shown by the highly significant and positive estimate for the perception variable ('*Perception SRs*'). By creating positive and correct mental attitude regarding the importance of the SRs in providing multiple benefits to farmers and the community as a whole, smallholder farmers could be encouraged to explore the benefits through irrigated vegetables and involve in management of SRs. The results in the last two columns of Table 8 show that farmer's age contributes significantly to higher income from vegetable production among irrigators. Gender variable was found to be significantly different from zero for both irrigators and non-irrigators. This suggests that the income effects for vegetable farmers is more for men as compared to women.

Education was found to have a positive impact on the income of both irrigators and non-irrigators. This implies that education contribute significantly to welfare in terms of income of vegetable farmers. Household size was found to have a significantly positive impact on the income of non-irrigator vegetable farmers in the study area. Extension access had positive impact on the income of irrigators. Farmers' perception was found to have a significantly positive impact on the income of irrigated vegetable farmers. This implies that the attitude of vegetable farmers about small water infrastructure indirectly enhances their chances of gaining more income. Furthermore, the ownership of other business besides vegetable farming also was found to contribute significantly to the income of both participating and non-participating vegetable farmers.

4.4. Counterfactual analysis and treatment effects

The results of the average treatment effect on the treated (ATT) from the endogenous switching regression (ESR) estimation showed a positive but insignificant impact irrigators on vegetable farmers' income (Table 9).The causal effects of participating in irrigation using small water infrastructure was found to be GH¢41.63 per hectare, suggesting that use of SRs for irrigation by farmers results in about 3.13% increase in income of vegetable farmers. Irrigator farmers using SRs on average obtain a net income of GH¢1370/ha relative to GH ¢1328/ha for non-irrigators.

The results from the propensity score matching (PSM) technique showed that use of SRs for irrigated vegetable production exerts positive but statistically insignificant impact on vegetable income. Specifically, using small water infrastructure for irrigated vegetable production insignificantly increase vegetable income by ca. 29% from the nearest neighbour matching algorithm, ca. 26% from the kernel-based matching and ca. 3% from the radius matching (Table 10).

5. Conclusion and recommendations

The study has established that in addition to enhanced agricultural productivity, the SRs in the study area provide multiple livelihood benefits such as for livestock drinking, fishing, construction/building, recreation and other domestic use. Effectiveness of the SRs in terms of delivery of the intended multiple benefits is not encouraging in general. Most of the SRs are functioning below the potential capacity, which may be explained by poor management and maintenance of the water storage infrastructure. Prioritization of various benefit items from the SRs by the community members reveal that small-scale irrigation and livestock watering are the most important livelihood benefits community members derive from the SRs.

The counterfactual analysis shows that there is about 3% increase in the income of irrigated vegetable farmers using water from SRs but the increase is not statistically significant. This may be attributed to the

Table 9
Average treatment effect of irrigated vegetable farmers' income: Endogenous switching regression estimation.
Source: Field survey, 2016.

	Mean outcome		ATT	*t*-Value	% change
	Irrigators N = 159	Non-Irrigators N = 169			
Income (GH¢/ha)	1369.97	1328.34	41.63	0.19	3.13

*, ** and *** indicate significance at 10%, 5% and 1% levels.

Table 10
Average treatment effect of small water infrastructure on vegetable farmers' income: Propensity score matching estimation.
Source: Field survey, 2016.

	Mean outcome		ATT	*t*-Value	% change
	Participants	Non-Participants			
Nearest neighbour matching (NNM)					
Income (GH ¢/ha)	1711.97	1328.34	383.63	0.80	28.88
Kernel-based matching (KBM)					
Income (GH ¢/ha)	1679.38	1328.34	351.03	0.95	26.43
Radius					
Income (GH ¢/ha)	1369.97	1328.34	41.63	0.21	3.13

*, ** and *** indicates significance at 10%, 5% and 1% levels.

underperformance of the SRs due to siltation and inadequate water for irrigation. Though the present results show that the impact on household income of irrigated vegetable production using SRs appears to be below the usually claimed 'high impact' in northern Ghana, the impacts of SRs' can be enhanced by improving their management through, for example, the provision of incentive mechanisms such as subsidies to the private sector involvement in rehabilitation, management and irrigation service providers; strengthening the capacity of existing water users associations for effective and efficient management of reservoirs; and recognizing the multiple benefits and the wider socio-economic values of small reservoirs (i.e., ecosystem-based management approach) to attract public resource allocation in the rehabilitation and management of small reservoirs. Building farmers' capacity in good agronomic and irrigation management practices and facilitating their access to improved seeds and other yield enhancing inputs and markets could also allow smallholder irrigators to fully utilize the currently underutilized available small water infrastructure in the region.

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