Demand for Supplemental Irrigation via Small-Scale Water Harvesting

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Selected Paper prepared for presentation at the 2020 Agricultural & Applied Economics Association Annual Meeting, Kansas City, MO
July 26-28, 2020

[1] The author wishes to sincerely thank the Borlaug-Leadership Enhancement in Agriculture Program (LEAP) at UC Davis for funding data collection activities for this study. This paper has benefitted from the guidance of Mario J. Miranda. The views and conclusions expressed in this paper are those of the author and do not necessarily reflect the views of the African Development Bank Group. Any errors are the sole responsibility of the author.

Abstract

Agriculture in sub-Saharan Africa (SSA) countries is predominantly rainfed, but SSA could develop greater dependence on supplemental irrigation due to a changing climate with greater rainfall uncertainty and higher frequency of dry spells. Supplemental irrigation through small-scale water harvesting (SSWH) plays a vital role in helping rainfed small-scale farmers overcome the risk of dry spells and promotes greater investment in agriculture. This study employs a contingent valuation approach to estimate the demand for SSWH supplemental irrigation in Ghana. The study finds the mean willingness-to-pay estimates for SSWH supplemental irrigation to be GHC 25.36 (USD 6.67) per acre per season for open canal irrigation system and 24.76 (USD 6.52) per acre per season for pipeline irrigation system. Drought experience, land ownership, access to credit, land ownership are key determinants of the demand for SSWH supplemental irrigation. The findings are particularly important for pricing small-scale irrigation services from rainwater harvesting public water reservoirs. The study recommends that investing in rainwater harvesting in rainfed agriculture should form a cornerstone of any country's strategy for adapting to drought, particularly in developing countries where rainfed agriculture plays an important economic role.

Key Words: small-scale water harvesting; supplemental irrigation; contingent valuation; drought; agriculture

1. Introduction

Weather variability risk, mainly drought, is among the more pronounced agricultural production risks faced by small-scale farmers in sub-Saharan Africa (SSA), owing to the predominance of rainfed rather than irrigated agricultural practices (Shiferaw et al., 2014). Most small-scale farmers in SSA countries depend on rainfed agriculture for their livelihoods, and they are often afflicted by the vagaries of drought risk in the form of regular dry spells during critical periods of crop growth. Indeed, rainfed agriculture provides about 95 per cent of SSA's food and feed (FAO, 2007) and contributes to the livelihood of more than 70 per cent of the population (Hellmuth et al., 2007). Therefore, for millions of poor small-scale farmers, drought poses a major threat that, if not properly addressed, could pull farmers into or keep them in poverty trap. Drought has both direct and indirect impacts on small-scale farmers' livelihood. Drought directly affects their production (crops and livestock), lives, health, assets, and infrastructure. Direct impacts occur when drought destroys small-scale farmers' assets. Therefore, not only do the farmers and their families go hungry, but if they own livestock, they are forced to sell or consume them in order to survive (Dercon and Hoddinott, 2003); then, when the next farming season arrives, they are significantly less able to farm effectively. These impacts can last for years in the form of diminished productive capacity and weakened livelihoods (Sen, 1981). The indirect impacts are no less important. The threat of drought or dry spell makes farmers highly risk averse. They avoid investing in agricultural innovations that could enhance their farms' yield, since these investments may turn into losses in the event of drought. In additional, micro-creditors are not willing to lend to small-scale farmers if drought might result in widespread defaults, even if loans can be paid back easily in most years.

The following measures have been identified among small-scale farmers in SSA to mitigate the risk of drought: careful diversification of crops and livestock, diversification from farm to non-farm activities, a change in crop varieties, temporal adjustments of cropping patterns and planting dates. Although these measures are particularly important to small-scale farmers, they are not enough to mitigate the risk of drought. They focus on reducing the risk of drought by reducing the dependence on agriculture or by reducing its productivity. Insurance, specifically index insurance, offers another opportunity to small-scale farmers to transfer this risk of drought to a less vulnerable third party. However, small-scale farmers are severely cash and credit constrained so that they cannot afford even a fair insurance premium (Binswanger-mkhize, 2012). Because index insurance does not cover the actual loss and the problem of basis risk are other considerable constraints to the low demand for insurance by small-scale farmers (Barnett et al., 2008).

The challenge of how to cope with dry-spells, or frequent short periods of water stress during crop growth, remains largely unsolved. Experimental research shows that supplemental irrigation through small-scale water harvesting (SSWH) can be an effective tool for small-scale farmers to stabilize crop water supply and thereby increase yields and create incentives for increased investment in innovative agricultural technologies (Fox and Rockström, 2003; Oweis and Hachum, 2006). The landscape of many SSA countries combined with high surface runoff and intensive rains make SSWH supplemental irrigation an option for bridging intra-seasonal dry spells. SSWH supplemental irrigation is defined as the application of additional surface runoff harvesting water[2] to otherwise rainfed crops, when rainfall fails to provide essential moisture for normal crop growth, or to improve and stabilize productivity. This simple, but highly effective

[2] Although surface runoff is proved to be the efficient source of water for supplemental irrigation (Oweis et al., 1999), other sources of water including surface water, underground water, and treated industrial waste water can be used for supplemental irrigation systems. The characteristics of SSWH supplemental irrigation include the following: (1) surface runoff stored water is applied to rainfed crops, which is normally produced without irrigation; and (2) it is applied only when rainfall is inadequate, because rainfall is the prime source of water for rainfed crops.

technology allows farmers to plant and manage crops at the optimal time, without being at the mercy of unpredictable rainfall. SSWH supplemental irrigation contributes to small-scale farmers' livelihoods in three ways: (1) it improves yield; (2) it stabilizes production from year to year; and (3) it provides suitable conditions for economic use of higher technology inputs. The critical importance of SSWH supplemental irrigation lies in its capacity to bridge dry spells and thereby reduce risks of drought in rainfed agriculture. The potential of SSWH supplemental irrigation must, therefore, be explored to make better use of the limited resources available to meet future food demand and growing competition for water. SSWH supplemental irrigation has been successfully developed and piloted with small-scale farmers over the past decades. SSWH supplemental irrigation helps to mitigate low food production caused by dry spells, but its adoption and application has not reached significant scale, and indeed is rare among small-scale farmers in SSA countries.

Many field experimental studies have demonstrated the benefit of supplemental irrigation for quality and quantity production, as well as for wealth creation and poverty eradication. Supplemental irrigation is found to be affordable and appropriate for small-scale farmers, who are the cornerstone of food production in many developing countries.

Although rainfall amount is enough to sustain crop growth, its distribution during the crop season is suboptimal in many SSA countries. Crop season climate varies between a heavy rainfall period and a period of severe dry spells. SSWH supplemental irrigation provides multiple benefits: higher and more stable yields, lower risk of crop failure, and significantly higher water productivity (the amount of grain or biomass produced per unit of water) (Nangia, et al., 2018). For example, Fox and Rockström (2003) assessed the effect of SSWH supplemental irrigation on sorghum in Northern Burkina Faso. They found that adding about 60-90 mm supplemental irrigation per hectare during dry-spell induced crop water stress resulted in an average sorghum yield of 712 kg/ha compared to 455 kg/ha without supplemental irrigation. In addition, when supplemental irrigation was combined with fertilizer, the yield of sorghum increased to about 1403 kg/ha. Fox et al. (2005), in an analysis of the benefit of SSWH supplemental irrigation for sorghum and maize in Burkina Faso and Kenya, found net profits of USD 73/ha and USD 390/ha annually for sorghum and maize, respectively, compared with net income losses in traditional systems of USD 165/ha and USD 221/ha in traditional systems, respectively. Somé (1989) carried out multiple tests of SSWH supplemental irrigation on sorghum in the Sahelian and Sudano-Sahelian agro-climatic zones. He found that supplemental irrigation increases yields by 10-85 per cent depending on the agricultural season. Similarly, Dembélé et al. (1999) found that SSWH supplemental irrigation increased yields of upland rice by more than 90 per cent in sandy soil packed with organic material in the Sudanian zone. Therefore, the collection and storage of surface runoff water for supplemental irrigation substantially improved crop yields compared to the status- quo.

SSWH supplemental irrigation contributes equally to water productivity. The water productivity under supplemental irrigation is about 2.5 kg/m^3 compared to 0.3 to 1 kg/m^3 under only rainfed conditions and 0.75 kg/m^3 under full irrigation(ICARDA, 2015). Therefore, SSWH supplemental irrigation is a climate smart solution for drought stress in dry areas.

Despite the underlying contributions of SSWH supplemental irrigation to crop yields improvement, water productivity, and farmers' livelihoods, its application among small-scale farmers is still rare. On the supply side, little has been done to provide irrigation facilities in SSA. The share of area equipped for irrigation, that is, area fitted with technical irrigation facilities, is only about 4 per cent and the average rate of expansion of irrigated area over the past 30 years is only 2.3 per cent in SSA (You et al., 2011). The constraints to the supply of irrigation facilities in SSA include high cost of construction, low involvement of government and other stakeholders, low involvement of farmers and concern about health and environmental consequences. The collection and storage of runoff water for supplemental irrigation may have some negative consequences for the health of the surrounding population. Such studies as Amacher et al., (2004), and Chung (2016) found that dams or reservoirs increase the incidence of diseases such as malaria, which would, therefore, reduce the labor force of households and increase households' health spending. However, much effort is been made to increase the use of irrigation in many SSA countries. In Ghana, for example, the government has initiated a new flagship program called One-Village, One-Dam (1V1D) in the Northern Savannah agro-ecological zone (GoG, 2018), which is the site of this study. The policy consists of constructing of at least one dam per village to provide water for livelihood and the agricultural needs of the village.

There are few studies that have investigated the demand side of SSWH supplemental irrigation in developing countries (Zongo et al., 2015 in Burkina Faso; Alhassan et al., 2013 in Northern Ghana, Kimera et al., 2018 in Uganda). These studies found that high usage fees, lack of land ownership, high land leasing price, lack of extension services and low household are keys constraints that undermine the adoption of supplemental irrigation in SSA. However, these studies employed the open-ended willingness to pay (WTP) elicitation framework. According to this framework, respondents are asked whether they are willing to adopt SSWH supplemental irrigation in their plots during the wet season and to indicate their willingness to pay. The framework has been shown to suffer from incentive compatibility problems in which respondents can influence potential outcomes by revealing value other than their true WTP.

This study employs an experimental design to elicit the WTP for SSWH supplemental irrigation in Northern Ghana using both open canal and pipeline technologies. The study uses the single bounded dichotomous choice method and controls for hypothetical bias in the WTP, which previous studies did not account for. The study also considers heterogeneity among farmers, especially the distance between farmers' fields and the nearest river using GPS co-ordinates, to adjust for WTP.

The rest of the paper is presented in three sections. The next section provides details on the materials and methods of the study, including the experimental design, study area, model, and descriptive statistics. The third section presents and discusses the results. The fourth section concludes.

2. Materials and Methods

2.1. Experimental Design

Many approaches have been used to value non-market goods in the field of water resource economics, including stated preference methods (discrete choice experiment, contingent valuation), residual imputation, production function, and revealed preference methods based on market prices (Griffin, 2006; Young, 2005). Both discrete choice experiment and contingent valuation methods appear to be the most recognized and widely used method (Cameron & Huppert, 1989; Ready et al., 1996). However, the argument of which valuation methodology to use should be based on whether the overall objective is the valuation of the policy package in its entirety or the valuation of each of the policy's distinct outputs (Heynes et al., 2011; Oviedo & Caparrós, 2014). The objective of this study is to assess farmers willingness to pay for the whole package of open canal and pipeline irrigation systems and not attributes of each of the irrigation systems. In this context, Contingent Valuation Method (CVM) appears to be the suitable model to use. The CVM assess individuals' demand for a non-market good or service and requires individuals to state their preferences via a WTP framework (Hanley et al., 2001; Venkatachalam, 2004). CVM is employed in this study in order to measure the value of SSWH supplemental irrigation. Despite its wide use, the CVM has some limitations. It suffers from (i) elicitation format or question framing (open ended, closed ended, dichotomous choice, or payment card), which affects the WTP estimates differently (Arrow et al., 1993; Scarpa and Bateman, 2000); (ii) hypothetical bias due to the hypothetical nature of the question, which inflates stated WTP relative to actual WTP (Carson et al., 2001; Loomis, 2014); (iii) strategic bias, as respondents may misrepresent their preferences in order to influence the decision-making process (Whittington et al., 1990; Whittington et al., 1991; Carlsson, 2010; Meginnis, 2018).

Following the recommendations of Arrow et al. (1993)[3], which lead to maximizing the reliability of the CVM estimates, and the contemporary guidance for stated preference studies provided by Johnston et al. (2017), this study employed single-bounded dichotomous choice questions. For each question, field researchers explain the concept of SSWH supplemental irrigation as follows:

> Supplemental irrigation through surface runoff small-scale water harvesting supplemental irrigation is defined as the application of additional surface runoff water harvested (in a reservoir or pond) to otherwise rainfed crops when rainfall fails to provide essential moisture for normal plant growth. This is done to improve and stabilize productivity. Upon subscription to SSWH supplemental irrigation, your field would be connected to the SSWH reservoir or pond using either open canal or pipeline. However, the decision to release water to your field during the agricultural season is conditional upon rainfall shortages in the area and would be determined by the reservoir or pond authority[4]. You can also call the reservoir or pond authority anytime you feel your field lacks water during the agricultural season.

The explanation was translated into the local language and field researchers conducted visual demonstrated to farmers using pictures of open canal and pipeline, ground drawings as well as relate to existing open canal and pipeline irrigation infrastructures in the communities or nearby communities. After explaining how SSWH supplemental irrigation is applied, the farmer was asked whether he or she understood. If not, the concept was explained again until the farmer fully understood. The farmer was then asked to answer 'yes' or 'no' to the following question: would you be willing to subscribe to the service for a seasonal subscription fee per acre? The subscription fee would be paid at the beginning of the season to the dam or reservoir authority. It could then be paid in multiple installments, but the farmer had to pay the subscription fee in full before the start of the agricultural season.

This study designed contingent valuation questions in the form of hypothetical referenda in which respondents were told how much they would have to pay for each product before being asked to respond with a simple 'yes' or 'no'. This is done, first, to mirror the real-world market, in which a price is given, and the consumer chooses whether to purchase it at the stated price. Second, it avoids bias induced by asking the follow-up WTP questions as with double-bounded dichotomous choice questions (Arrow et al., 1993; Chantarat et al., 2009; Haab and McConnell, 2002). The difficulty of the double-bounded dichotomous

[3] Arrow et al. (1993) studied the applications of the CVM and provided insightful recommendations to maximize the reliability of CVM estimates. Those relevant to our study are: (i) use of a representative sample; (2) phrasing CVM questions in the form of hypothetical referenda in which respondents are told how much they would have to pay for each product before asking them to provide a simple yes or no answer; and (iii) reminding respondents of their actual budget constraint.

[4] The reservoir authority, a team formed of community leader and members of famer based organization and designated by the water user association of the village, under the supervision of the Ghana Irrigation Development Authority, makes the decision on whether to release water based on the precipitation recorded by the rain gauge located at the dam or reservoir area. However, farmers could also call upon the reservoir authority in case the rain gauge failed to record properly. To explain this to the farmers, the research team used different case illustrations (water released when farmers do not need it and water not release when farmers need water owing to rain gauge failure). In addition, it was explained to farmers that, in most cases, water would be released when they faced a dry spell.

model is that strategic behavior seems to be evident in the responses to the follow-up questions. One consistent finding with double-bounded dichotomous models is that the mean WTP for the sample is smaller when the second question is introduced. This is explained by the proclivity of the initial 'yes' respondents to answer 'no' to the second question, regardless of the amount. The consequence is that the aggregate proportion of 'yes' to a given bid is lower and the double-bounded responses yield a smaller mean WTP. The respondent who initially answers 'yes' may feel he or she is being exploited when asked to pay an even higher amount. The respondent who answers 'no' may feel that the quality of the good may be lowered on the second question. Therefore, the fundamental problem is that the respondent's expectations have changed after the first question. Initially, assuming no untoward strategic behavior, the respondent has no reason to believe that the first question will be followed by a second question, but when the second question is asked, the respondent may wonder whether another will follow, and adjust his or her response strategically (Kanninen 1995; Scarpa et al., 2000). In the extreme, the maximum efficiency gain for estimating mean WTP is obtained by offering a single bid equal to the true mean of WTP to all respondents, but if the true WTP is known, then there is no need to perform a CVM study. Thus, if there is information available on the distribution of the WTP, that information should be used to help design the vector of offered bids. This information may come from focus groups, or pretests. The vector of offered bids could, therefore, have been randomized and offered to respondent using a single-bounded dichotomous model. The seasonal subscription fee per acre was one of seven values which were determined based on the referred fee per acre of GHC 20.00 (USD 5.3 at 2015 average exchange rate of GHC 3.8/USD) obtained from focus groups discussion and from similar services in Ghana, Burkina Faso, Kenya and India (Alhassan et al., 2013; Chandrasekaran et al., 2009; Zongo et al., 2015). The seven bid values used in the study include the referred fee with six additional values, namely 75, 85, 95, 105, 115, 125 per cent of the referred fee (Bids: GHC 15, 17, 19, 20, 21, 23, & 25). One of these bids was randomly assigned to each farmer in the study.

Each farmer was presented with two WTP questions: (i) one for open canal irrigation system; and (ii) one for pipeline irrigation system. The open canal irrigation system is very common in the study area. Each region of the study has at least one big and well-known open canal irrigation scheme. For instance, Bontanga irrigation scheme in Northern region, Tono irrigation scheme in Upper East and Sankana irrigation scheme in Upper West all use open canal to drive water from the reservoir to farmers' fields. During the focus group discussions, farmers mentioned that open canal irrigation, in addition to providing water to their farms, serves as a water source for household usage and livestock, as farmers and their livestock can easily obtain access to the water flowing in the open canal. On the contrary, as the research team explained to farmers, open canal irrigation entails significant water losses owing to seepage, spillways, evaporation, and so on. In piped irrigation, no such losses occur. The pipeline irrigation or piped irrigation conveys and distributes the irrigation water to the farmer' field using PVC pipes, and thus is protected from farming operations, seepage, spillways, and evaporation loss. Both open canal and pipeline systems were demonstrated to farmers by the research team through a short photo visualization. The order of the two tasks was randomized, but each farmer received the same random bid for the two systems.

To what extent do the above-mentioned hypothetical choices correspond to real economic choices? This has been the main controversy of the classic CVM (Morrison and Brown, 2009). Several studies have noted that the classic CVM overestimates real economic choices and the values of products and services, which leads to overvaluation of the goods or services in question. This is known as hypothetical bias (Blumenschein et al., 2008; Neill et al., 1994). There is little reason to suppose that the alternative stated preference method, the choice experiment, could reduce this hypothetical bias more than the CVM could (Arora et al., 2018; Price et al., 2016; Barton and Taron, 2010; Barton and Bergland, 2010; Bateman et al., 2002). The majority of studies that have assessed the discrepancy between hypothetical and real payments have found that hypothetical payment is greater than real payment (Farmer and Lipscomb, 2008; Smith and Mansfield, 1998). Murphy and Stevens (2004) explained that if a good or service provides a positive value to the respondent, and if his or her response to the valuation question may increase the likelihood of the good's provision at little or no cost to him or her, then it may make sense for him or her to report a high value. In novel CVM approaches, two methodological improvements have been introduced to mitigate the hypothetical bias problem. These are (i) cheap talk, introduced by Cummings and Taylor (1999); and (ii) the certainty adjustment bias by Champ et al. (1997).

Cheap talk alerts respondents about the hypothetical nature of the questionnaire and the respondents are then asked to respond to the WTP question as if it were in a real-life situation. Cheap talk also reminds respondents about their budget constraint (Brummett et al., 2007). This study adapted Cummings et al.'s (1999) cheap talk script and repeated it to the respondent anytime the WTP question was asked. The Cummings et al. cheap talk script was adapted as follows:

> Now that I have explained the concept of supplemental irrigation, I will proceed with the questions. Before that, I would like to ask you please to take a moment to think after each question before you answer, and to answer in the way that you would as if I was really providing this SSWH supplemental irrigation service to you at the offered price. Please consider your financial situation and your ability to afford the product at the price given.

Certainty adjustment bias, as the name may suggest, consists of asking a follow-up question after an affirmative response to the payment question about how certain the respondents are in respect of their statements. Two different forms of the certainty adjustment bias have been used depending on the scale. The first form is a 10-point scale, in which 1 is very uncertain and 10 is very certain, and respondents are asked to state their certainty level. This form is then used to assess the degree of certainty in hypothetical WTP responses (Blumenschein et al., 2008; Champ and Bishop, 2001). A caveat of the 10-point scale form relies on the cut-off level (point above which the respondent's 'yes' response is considered as "yes" and below which as 'no'). The cut-off level of certainty varies from one study to another but most studies find that to mitigate hypothetical bias effectively, seven or eight cut-off levels of certainty are needed (Champ and Bishop, 2001; Poe et al., 2002). The second form of certainty adjustment bias consists of a two-point scale certainty: 'probably sure' and 'definitely sure' (Blumenschein et al., 2008). In this form, only 'yes' responses that respondents reported they were 'definitely sure' about were treated as 'yes', while 'yes' responses that respondents reported they were 'probably sure' about were treated as 'no'.

Another cause of hypothetical bias in the CVM is the fact that some respondents may fail to take the WTP questions seriously as the results of the surveys are not binding and do not require respondents' commitment (Arrow et al., 1993; Mohammed, 2012; Murphy et al., 2004). For this reason, the two-point scale certainty question was adopted in this study to isolate the effect of cut-off level certainty calibration in the 10-point scale as follows: How sure are you that you would pay ___GHC to subscribe to SSWH supplemental irrigation? (1. Definitely sure, 2. Probably Sure, 3. Cannot say). In addition, a signed consent was issued to respondents who agreed to take part in the questionnaire. In this way, some level of seriousness of the respondents could be inferred.

2.2. Area of Study

This study took place in the Northern Savannah agro-ecological zone of Ghana (Northern, Upper East, and Upper West regions). The choice of study area was based on its contribution to the entire country's food production and the great threat of drought and dry spells in the zone. The Northern Savannah zone has two-thirds of the country's grassland and is the largest agricultural zone in Ghana.

The Northern Savannah zone of Ghana is characterized by uni-modal rainfall of short duration, a high incidence of droughts and excessive evapotranspiration allowing only 4-5 months of farming and leaving 7-8 months of extended dry season. Agriculture in the zone is predominantly rainfed with less than 0.4 per cent of the agricultural land irrigated. As a result, droughts often severely impact small-scale farmers' livelihoods in the area (Laube et al., 2008). The effects of drought on food production in the area are greater than anywhere else in the country (EPA, 2007; MoFA, 2007). Rainfall variability in the zone is exacerbated by climate change, resulting in a rise in the frequency of dry spells during the agricultural season (Hesselberg and Yaro, 2006). However, adaptation policies with regard to drought in this region have been insufficient (EPA, 2012; Yaro, 2013).

The major sources of water for irrigation in the rural Northern Savannah zone of Ghana are surface water and rainwater harvesting. These are also major sources of drinking water in this zone, as the coverage of public piped potable water supply is very low (Safe Water Network, 2017).

This study's novel contribution is that it estimates farmers' WTP for supplemental irrigation services, which could be useful to policy makers in the design of irrigation program, desperately needed in SSA. The WTP results could contribute to the implementation of the government of Ghana's new flagship program, the 1V1D, in the Northern Savannah zone. The program is to construct one dam in each village to provide water for the livelihoods and agricultural needs of the village. The construction phase of the dams started in 2016 (GoG, 2018). Each dam would have the capacity and irrigation facilities to allow for at least supplemental irrigation in the wet season and, in some cases, full irrigation in the dry season. The dam would source its water mainly from runoff during the wet season. Farmers would have to subscribe for a fee to help pay for the operating and maintenance costs of the dam. The government would oversee the construction of the reservoirs and the operation and maintenance will be done by the reservoir authority (a team form of community leaders and members of farmer-based organization) with the supervision of the Ghana Irrigation Development Authority.

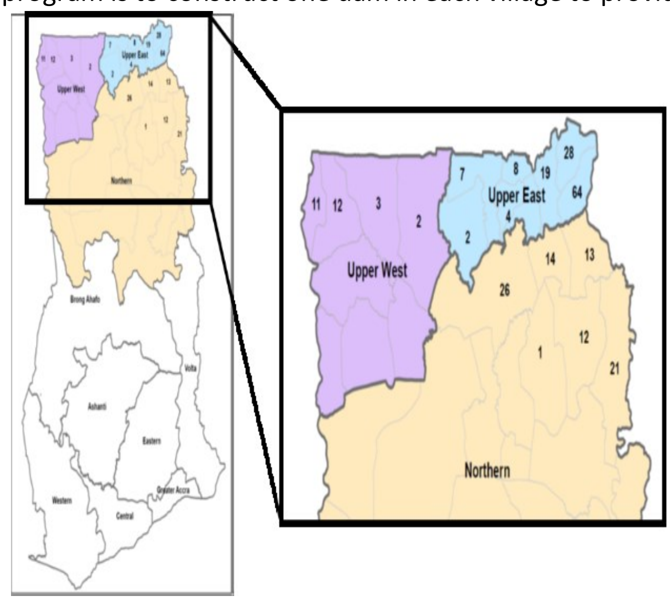

Figure 1. Map of the study area.

The map of the study area presented in Figure 1 indicates the number of farmers groups involved in the experiment per district and region.

2.3. Sampling

The SSWH supplemental irrigation experiment was conducted as part of an ongoing 3-year randomized control trial (RCT) impact evaluation study funded by the US Agency for International Development. The RCT consisted at randomly assigned farmers on one of the following three groups: (i) microinsured, in which farmers were offered production loans coupled with index insurance and payouts were made to borrowers (farmers); (ii) mesoinsured, in which farmers were offered production loans coupled with index insurance and payouts were made to the lenders for the express purpose of repaying the loan; and (iii) control, in which farmers were offered loans without index insurance. The study aims to investigate how insured loans[5] impacts access to credit and agricultural technology adoption among small-scale farmers, including, fertilizer, and high yield seed varieties.

The study team visited the study area in November 2014 for a pilot test of the survey instrument and to establish direct working relationships with key partners, Rural and Community Banks (RCBs) and the Ghana Agricultural Insurance Pool (GAIP). In addition, the team held about 10 focus group discussions with several farmers. During the pilot test, a preliminary sample of 791 farmer groups (both existing and potential borrowers), was obtained from the 14 RCBs. Each farmer group listed in the sample contained information on total number of group members, gender breakdown, community location, loan size, main crops farmed, acreage planted, and loan status in the previous year. To ensure that the study targeted the farmer groups of greatest interest to us, we applied the following three criteria to select our final sample. (i) Farmer groups should belong to districts with low rainfall areas (between 800 and 1100 mm annually), since the impact of insured loans is more likely to be evident when rainfall is low; (ii) Farmers groups should have 7–15 members to account for budget constraints and logistics of maintaining smoother fieldwork; and (iii) the highest loan that farmers should have taken out was less than 10,000 GHC, so as to maintain a focus on the most low-income groups. This process resulted in a sample of 279 farmer groups, representing about 2500 farmers.

For the RCT baseline survey, six farmers were randomly selected from each of the 279 farmer groups using a uniform distribution with the intent to interview the first three farmers and the second three farmers as a back-up in case the first three farmers were unavailable for the interview. A total of 781 farmers were interviewed, and 777 farmers responded adequately. During the baseline survey, conducted in March 2015 during the preparation of the agricultural season, an experimental field survey was undertaken to elicit small-scale farmers' WTP for SSWH supplemental irrigation. Table 1 presents the composition of the sample size by region and gender.

Table 1. Sample size by region and gender.

Region	Male	Female	Total
Northern region	156	142	298
Upper West region	64	20	84
Upper East region	182	213	395
Total	402	375	777

2.4. Model

A contingent valuation methodology was employed to assess the WTP for SSWH supplemental irrigation in Northern Ghana. The single-bounded dichotomous choices method was used. In a single-bounded dichotomous choice setting, respondents were asked to respond 'yes' if they were willing to pay a single randomly assigned bid to increase their status quo utility to the proposed change of utility due to the application of SSWH supplemental irrigation, or to respond 'no' otherwise. In general, in a WTP approach, the proposed change corresponds to an amelioration or improvement of the status quo. Also,

[5] The insured loan is a loan with an insurance policy designed to cover the risk of drought. In the case of drought, the farmer would be compensated with a cash payout made directly to the farmer (microinsured) or to the farmer's bank for the repayment of all or part of the farmer's loan (mesoinsured). The amount of the insurance payout would be determined by rainfall measured at a local rainfall station. These rainfall data are collected regularly by the Ghana Meteorologically Agency.

respondents were asked to respond to two types of irrigation system (open canal and pipeline). Thus, the following random-effects probit model adaptable to the clustered type of irrigation system was used to estimate the mean WTP and the determinants of the WTP for SSWH supplemental irrigation.

$$WTP_{ti} = \alpha + \beta Bid_i + \delta X_i + \gamma EN_i + \varphi TI_{ti} + \mu_i + \varepsilon_{ti}$$

WTP_{ti} is the binary response to the WTP question for farmer i for the type of irrigation system t ($t = 1$ for open canals irrigation system, and $t = 2$ for pipeline irrigation system). Bid_i is the proposed price[6] of the SSWH supplemental irrigation system to farmer i .

X_i is the vector of exogenous farmer i characteristics, which is comprised of: *Farmers experiences with climate*, measured here by two proxies: (i) climate condition in the last agricultural season (1=good rainfall, 0=otherwise), which recalls whether farmers had good rainfall or not in precedent agricultural season; and (ii) climate condition in the last five agricultural season, which measures the number of time farmers had experienced good rainfall in the past 5 agricultural seasons. This variable is likely to increase the demand for SSWH supplemental irrigation. Studies, including Chantarat et al. (2009), Hill et al. (2013), Kazianga and Udry (2006), and Sarris et al. (2006), found that respondents who experienced recent adverse weather conditions had high demand for drought mitigation strategies, including insurance and irrigation. *Risk and time preference,* whereby WTP for SSWH supplemental irrigation is likely to increase with risk aversion and decrease with the discount rate (Chantarat et al., 2009). Risk preference and the discount rate were elicited via a list of lottery questions. For risk preference elicitation, respondents were asked to respond to three lottery questions. The first lottery question is: '*Which of the following choices would you prefer? (i) A fixed amount of money GHC 30; or (ii) a coin toss whereby head earns you GHC 100, and tails earns you GHC 0.'* For the second and third questions, the fixed amount changed to GHC 40 and GHC 50, respectively. The risk preference coefficient was then generated following Harrison (2008). The risk coefficients were categorized into two groups: risk averse, and risk loving. Similarly, six lottery questions were asked to farmers to elicit their time preference. The first time preference question is '*Which of the following choices would you prefer? (i) Receive 15 GHC tomorrow; or (ii) receive 16 GHC in 3 months*'. *Risk perception* is measured by asking farmers the likelihood that they would be a drought in the next 5 years and farmers were to choose: 1. very likely, 2. likely, 3. unlikely, 4. very unlikely. *Distance to nearest river* measures the distance between the farmer field and the nearest river. During the baseline survey, farmer GPS locations were recorded and used to estimate the distance between their locations and the nearest river. Figure 2 presents the distance between the farmers' location and nearest river in five categories (0-1, 1-2, 2-3, 3-4 and >4 km). This study tested the hypothesis that farmers who were closer to the river would be less likely to subscribe for irrigation. *Farmers' house structure*, another indicator of wealth considered in this study, takes the value 1 if the household is built with mud, 2 if concrete, and 3 if bricks. Since house structure is a proxy for wealth status it may

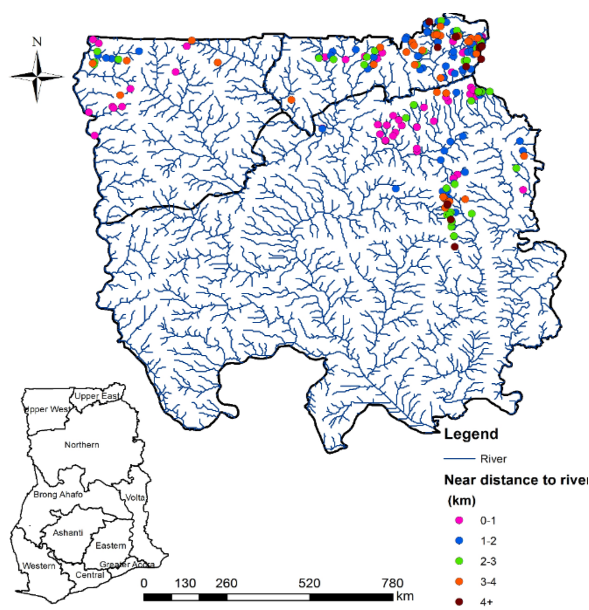

Figure 2. Distance to the nearest river.

[6] Same random bid was proposed for both open canals and pipeline irrigation systems.

have positive as well as negative influence on the farmers' willingness to pay for SSWH supplemental irrigation. *Extension service access*, measured by the number of times a farmer has been visited by an extension service officer, is likely to increase demand for SSWH supplemental irrigation. Extension service access increases the farmers' knowledge about modern and productive practices and, therefore, is likely to increase the demand for SSWH supplemental irrigation. *Distance to market*, measured in hours of walking (main mode of transportation in rural areas where this study took place) from the household to the nearby input and output market, is considered as another proxy for extension service. *Household dependency ratio*, measured by the ratio of inactive household members (household members between 0-14 and 65 plus of age) and active household members (households' members between 15 to 65 years of age), has an ambiguous effect on the demand for supplemental irrigation. Large household size may be a source of labor for the household and thus, may contribute positively to increase household income and the demand for supplemental irrigation, large household size may also deplete household income, especially when the dependency ratio is greater than 1. Many studies have shown that households with high dependency ratio invest less in farming (Mosley and Verschoor, 2005; Nielsen et al., 2013; Yesuf and Bluffstone, 2009). *Credit,* measured here by the amount of credit received by the farmer, is likely to increase the demand for SSWH supplemental irrigation. However, the worry with credit is that in most circumstances, credit is cashless. In fact, 80 per cent of credit received by farmers in this study is cashless. The other household characteristics include age, gender, support received during negative economic shocks, number of plots, remittance, livestock endowment, land ownership, education (refer to appendix 1 for the definition and sign of these variables).

EN_i is the vector of farmer i characteristics that are endogenous in nature, and we estimate our models with and without them to assess the stability of the estimates and the potential importance of these endogenous variables. These variables include agricultural income, savings, and share of land allocated to rice crop. Agricultural income, and savings represent farmers' financial resources necessary to afford SSWH supplemental irrigation but could also reflect the ability of farmers to cope with the risk of drought. Farmers who are wealthy can easily smooth their consumption or can afford to own small-scale private irrigation technologies or other alternative drought mitigation technologies such as insurance. Farmers WTP may also be informed by their desires to increase their incomes as well as to grow more water demanding crop such as rice.

TI_{ti} is the type of irrigation system t for farmer i. ϵ_{ti} is an independent residual distribution $\mathcal{N}(0, \sigma^2)$. Here, μ_i represents a coefficient for the random cluster effect. $\beta, \gamma, \delta, \varphi$ are vectors of parameters representing mean marginal effects.

2.5. Descriptive Statistic

Table 2 presents the summary statistic of farmers in the sample. Farmers on average are 46 years old and 83 per cent of them have no formal education. Male respondents comprise 52 per cent of the sample. Farmers' households are composed of predominantly dependent members. The average households size is about 11 members with a dependency ratio of 1.4. In other words, every employed member of the household is in charge of more than one dependent member. On average about six members of the household participate in agricultural labour. Households on average earn GHC 1,334.00 (USD 351.05) from agriculture compared to the average total income of GHC 2,889.00 (USD 760.26) per year. Households typically obtain about 60 per cent of their income from agriculture (compared to less than 6 per cent from remittances). Nearly all (96 per cent) farmers rely on only rainfall for crop production. The majority of farmers' households (97 per cent) own at least one unit of livestock. The average livestock endowment measured in Tropical Livestock Units (TLU) is 3.43. Landholdings in Ghana are typically small. Small farms predominate throughout the country, although they tend to be larger on average in the savannah zones, with land distribution more skewed when closer to the coast. The average landholding in the sample is 6.2 acres (with more than 62 per cent holding less than 5 acres), which is considerably higher than the national average of 5.6 acres (Chamberlin, 2008). Extension service officers visit farmers about twice a season. The average walking time to the market is 1 hour. On average, 49 per cent of farmers experienced drought the previous cropping season and about 47 per cent and 91 per cent had experienced drought at least thrice and twice, respectively, in the previous five cropping seasons. On average, 53 per cent of farmers believed there would be a drought in the next cropping season. Farmers could call upon two to three people (household member, friend, or neighbor) for help in years of drought.

Table 2. Descriptive statistic.

Variables	Obs	Mean	Std. Dev.
Age (year)	777	45.80	12.73
Gender (1=male, 0=female)	777	0.52	0.50
Level of education	777		
No education		0.83	0.38
Primary education		0.05	0.21
Middle education		0.06	0.24
High education/University		0.06	0.26
Access Irrigation (0=no, 1=yes)	777	0.045	0.21
Household size (#)	777	10.71	6.65
Married (1=married, 0=other)	777	0.87	0.34
Distance to nearest River (meter)	777	1937	1272
Dependency ratio	777	1.39	2.73
Total income (GHC100)	777	23.89	15.30
Agricultural income (GHC100)	777	13.34	8.86
Remittance (GHC100)	777	1.24	2.23
Saving (GHC100)	777	0.79	0.41
Loan received (GHC100)	777	2.18	2.72
Livestock endowment (TLU)	777	3.43	3.47
Distance nearest market (hour)	777	1.05	0.77
Extension service visit (#)	777	1.81	1.64
Climate condition last season (1=good rain, 0=otherwise)	777	0.51	0.50
Climate condition last 5 agric seasons (#)	777	2.48	0.82
Drought perception (next 5 agric seasons)	777	2.70	0.94
Help if drought (#)	777	2.40	2.39
Risk preferences (0= risk loving, 1= risk averse)	777	0.67	0.47
Time preference	777	0.06	0.05
House structure	777		
Mud		0.80	0.40
Concrete		0.03	0.16
Brick		0.17	038
Share of land allocated to Rice	777	0.11	0.17
Land ownership (1=yes, 0=no)	777	0.48	0.50
Land cultivation size (acreage)	777	6.21	5.74

3. Results and Discussions

3.1. Factors Affecting Demand for Supplemental Irrigation

There are a number of factors that explain farmers' WTP for SSWH supplemental irrigation as summarised in Table 2. Figures 3 and 4 present the probability of 'yes' responses of farmers associated with each bid value. The probability of 'yes' responses dicrease with the increase of the bid values. And the probability of 'yes' responses is higher when the certainty scale adjustment (CSA) is not taken into consideration.

Table 3 presents the covariate marginal effect results of a random- effects probit model estimation of the determinants of the demand for SSWH supplemental irrigation. Columns 2, 3, and 4 of table 3 present the estimates of the random-effect probit model with no covariates, with only exogenous covariates and with endogenous covariates, respectively. The Results of the open canal and pipeline choice tasks modeled separately via a probit model are presented in appendix 2. Since the CSA is preferred ex-ante, this study reports only the results of the CSA models.

As demand theory predicts, the WTP price (bid value) is negatively correlated with demand for SSWH supplemental irrigation at a statistically significant level of 1 per cent in all specifications. Specifically, every GHC 1 increase in the bid value is associated with a reduction of the demand for SSWH supplemental irrigation of about 0.03, 0.04, 0.04 percentage point for the models with no covariates, with only exogenous covariates and with endogenous covariates, respectively. The likelihood ratio (LR) test of the difference between the model with only exogenous covariates and the model with endogenous covariates results on a test statistic of 21.52, and the associated p-value is very low (0.0002). The results of the LR-test show that adding endogenous variables (agriculture income, saving and land allocated to rice) results in a statistically significant improvement in model fit. The interpretation below is therefore based on the model with endogenous covariates.

Agricultural income has a positive and statistically significant effect (at 1 per cent level) on farmers' demand for SSWH supplemental irrigation. In addition, farmers' WTP increases with land ownership, the amount of loan received as well as the better structure of their housing. This demonstrates the overwhelming wealth effect on the demand or adoption of technology as shown in previous studies (Carter et al., 2013, Feder et al., 1985, Duflo et al., 2011). The two proxies for farmers experiences with climate are negative and statistically significant at 1 and 5 per cent levels. This shows that farmers who previously experienced good rainfall are less likely to adopt supplemental irrigation compared to farmers who experience dry spells or drought. Therefore, dry spell or drought experience increases the WTP for supplemental irrigation for both open canal and pipeline.

Because rice crops have high water demand, it is expected that farmers with large land share allocated to rice would be more likely to subscribe for supplemental irrigation. Farmers who mostly cultivate rice or have a large share of their land allocated to rice are very vulnerable to the risk of dry spells, as rice production requires much more water than do other crops, such as maize. As anticipated, a positive correlation is found between the variable for the share of land allocated to rice and demand for SSWH supplemental irrigation; its coefficient is however not statistically significant. As the investment in supplemental irrigation is likely to enhance farm productivity beyond the agricultural season, farmers who own the land are more likely to adopt supplemental irrigation than are those who rent, as the estimation result confirms. We found that land ownership effect on WTP for SSWH supplemental irrigation is positive and statistically significant at 5 per cent level. This is similar to the literature on the effect of farm certificate on farm investment (Bezabih et al., 2014).

Table 3. Factors affecting the demand for supplemental irrigation (marginal effects)

VARIABLES	Bid	Without endogenous variables	With endogenous variables
Bid	-0.033***	-0.039***	-0.037***
	(0.004)	(0.004)	(0.004)
Age (year)		0.001	0.001
		(0.001)	(0.001)
Gender (1=male, 0=female)		-0.002	-0.009
		(0.020)	(0.024)
Level of Education			
Primary Education		0.015	0.004
		(0.043)	(0.044)
Middle Education		0.022	0.027
		(0.037)	(0.047)
High Education/University		0.023	0.016
		(0.042)	(0.056)
Dependency Ratio		0.003	0.003
		(0.003)	(0.006)
Remittance (GHC 100)		0.005	0.003
		(0.005)	(0.006)
Livestock Endowment (TLU)		0.004	0.001
		(0.003)	(0.004)
Distance to Nearest Market (hour)		0.015	0.017
		(0.012)	(0.014)
Climate condition last season (1=good rain, 0=otherwise)		-0.055***	-0.062***
		(0.020)	(0.023)
Climate condition last 5 agric seasons (#)		-0.026**	-0.029**
		(0.010)	(0.013)
Drought Perception (next 5 agric season)		-0.009	-0.011
		(0.009)	(0.011)
Risk Preference (1=risk averse, 0=risk loving)		-0.034*	-0.046*
		(0.019)	(0.024)
Time Preference		-0.057	-0.069
		(0.161)	(0.185)
Help if Drought		-0.002	-0.004
		(0.003)	(0.004)
House Structure			
Concrete		0.163***	0.171***
		(0.018)	(0.028)
Bricks		0.046**	0.064**
		(0.022)	(0.027)
Land Ownership (1=yes, 0=no)		0.069***	0.058**
		(0.021)	(0.024)
Loan Received (GHC 100)		0.013***	0.012***
		(0.004)	(0.005)
Distance to Nearest River (km)		-0.011	-0.008
		(0.007)	(0.009)
Extension Service Visit (#)		0.006	0.005
		(0.006)	(0.007)
Agricultural Income (GHC 100)			0.006***
			(0.001)
Saving (GHC 100)			-0.003
			(0.003)
Share of Land Allocated to Rice			0.063
			(0.059)
Type of Irrigation System 1=canal, 2=pipeline)	-0.007	-0.006	-0.008
	(0.004)	(0.006)	(0.009)
Order of WTP Question ((1=if canal 1st, 0= if pipeline 1st)	-0.001	-0.006	-0.006
	(0.018)	(0.018)	(0.021)
Observations	1,554	1,554	1,554

The effect of risk preference on the demand for SSWH supplemental irrigation is negative and statistically significant at 10 per cent level. This shows that risk averse farmers are less likely to invest in SSWH supplemental irrigation. Although we anticipated a positive effect, the observed results can be explained by the fact that risk averse farmers prefer to keep their investment in agriculture to the minimum to diverse from the downside risk that may arrive from pest, lack of market, etc.

The nearest distance to river variable is negatively correlated with the demand for SSWH supplemental irrigation, but the effect is not statistically significant. Also, there is no statistically significant difference between the two types of irrigation systems.

Farmers' education level, which could provide some indication of cognitive ability to understand the mechanics of SSWH supplemental irrigation, is shown to have positive but no significant effect on the decision to opt for SSWH supplemental irrigation.

The observations are percentage. *** p<0.01, ** p<0.05, * p<0.1. The standard errors are estimated using delta method. Log L= -455.13 for the model without endogenous variables, and -441.70 for the model with endogenous variables. The panel-level variance (sigma_u) is 5.95 (std. err. 0.50) for the model without endogenous variables, and 4.47(0.26) for the model with endogenous variables.

To control for ordering bias, the study randomly assigns the WTP questions for open canal and pipeline to respondents and included a WTP questions order variable in the regression model. The control order question is negative, but not statistically significant. So, the order of the WTP questions did not affect the behavior of famers.

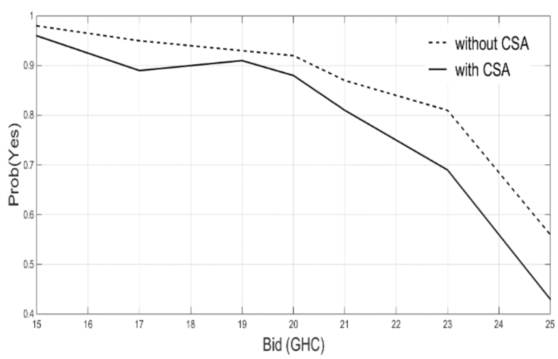

Figure 3. Probability of 'yes' response to hypothetical bid (canal).

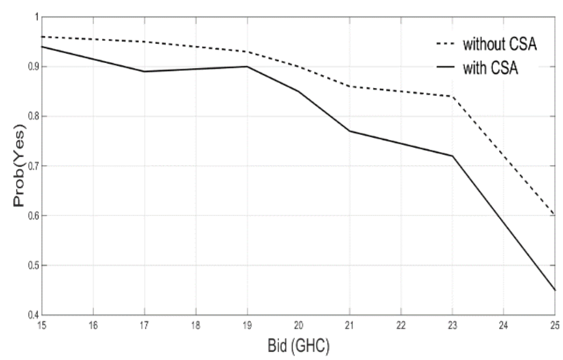

Figure 4. Probability of 'yes' responses to hypothetical bid (pipeline).

3.2. WTP for SSWH Supplemental Irrigation Estimates

The results of sample mean and total WTP for SSWH supplemental irrigation in the model with CSA are presented in Table 4, while the distributions of individual WTP estimates for both open canal and pipeline are presented in Figures 5 and 6. The mean WTP for SSWH supplemental irrigation using open canal is GHC 25.25 (USD6.64) per acre per season without covariates and GHC 25.36 (USD 6.67) per acre per season with covariates. Similarly, the mean WTP for SSWH supplemental irrigation using pipeline is GHC 25.55 (USD 6.72) per acre per season without covariates and 24.76 (USD 6.52) per acre per season with covariates. The total WTP for SSWH supplemental irrigation using open canal with covariates is GHC 19,705 (USD 5.186) and exceeds that of pipeline by GHC 466 (USD 123).

Table 4. Mean and Total WTP for SSWH supplemental irrigation estimates (GHC).

	Mean WTP with no covariate	Mean WTP with covariates[7]	Total WTP with no covariate	Total WTP with covariate[6]
Open canal	25.25	25.36	19,246	19,705
Pipeline	25.55	24.76	18,695	19,239

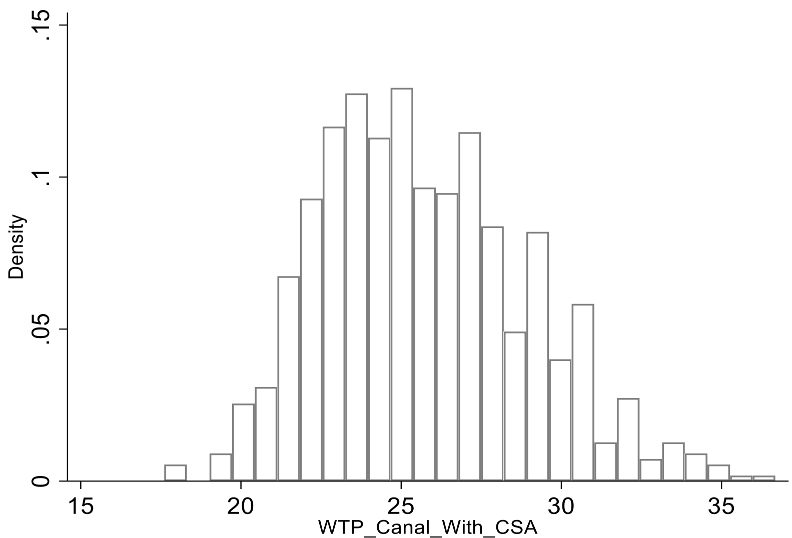

Figure 5. Distribution of Individual WTP Estimates for Open Canal with CSA.

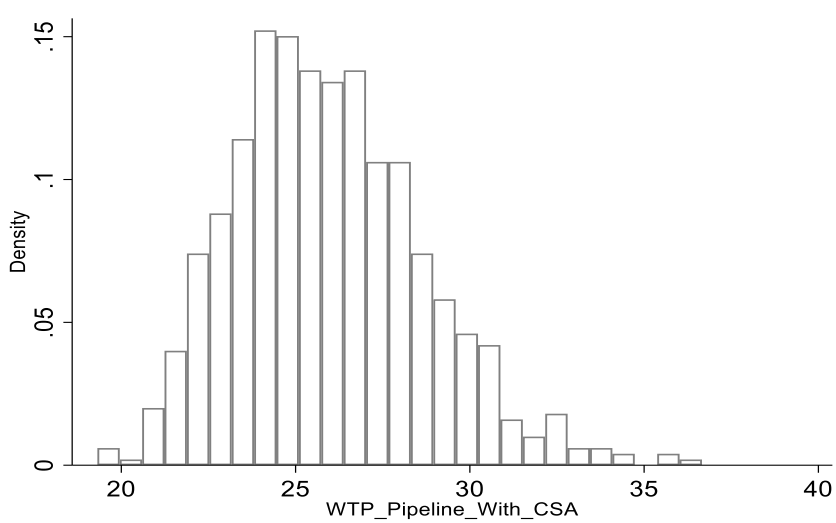

Figure 6. Distribution of WTP Estimates for pipeline with CSA.

[7] Covariates here include endogenous variables.

4. Conclusion

Whilst most agriculture in SSA countries is rainfed, greater dependence on supplemental irrigation could become more important due to a changing climate in which there is greater rainfall uncertainty and higher frequency of droughts. For millions of poor small-scale farmers, drought critically restricts their options, limits development, and pull them into a poverty trap. SSWH supplemental irrigation as a potential drought risk management tool can help to reinforce farmers' decisions to adopt new productive agricultural technology in drought-prone areas. The objective of this study was to assess the demand for SSWH supplemental irrigation in Northern Ghana.

The study found high demand for SSWH supplemental irrigation with mean WTP estimate of GHC 25.36 (USD 6.67) per acre per season for both open canal irrigation system and 24.76 (USD 6.52) per acre per season for pipeline irrigation system. The analysis of the determinants indicated that drought experience, agricultural income, loan received, and landownership and risk aversion were key drivers of the demand for SSWH supplemental irrigation. This analysis also sheds light on the need to improve the WTP methodology commonly employed in the literature to elicit the demand for supplemental irrigation. The study employed a certainty scale adjustment method to control for hypothetical bias that has a robust effect on the results. Without certainty scale adjustment, farmers tend to overstate their WTP but the certainty scale adjustment provides a more conservative estimate of WTP value.

In light of the increasing pressure on water resources and uncertainty due to climate change, rainfed agriculture will continue to play a dominant role in providing food and sustaining livelihoods, particularly in SSA. Several studies indicate that supplemental irrigation systems are affordable for small-scale farmers. This study found a strong demand for SSWH supplemental irrigation. However, policy frameworks, institutional structures, and human capacity are required for the successful application of supplemental irrigation in rainfed agriculture in SSA. The findings of this study are reassuring for the financial sustainability of the Ghanaian government's flagship program to provide every village of the Northern Savannah zone with its own dam. Farmers' contributions could pay for the operation and maintenance costs of the dams, reducing, therefore, government financing to the construction cost.

Acknowledgements

This work was supported by the U.S. Agency for International Development Borlaug LEAP [grant numbers 60045697]

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Appendix 1: Description of Variables

Variable name	Type of Variable	Definition and measurement
Age	Continuous	Age of the household in years.
Gender	Dummy	Sex of the household 1, male 0 female.
Education	Likert scale	Level of education 0, no education 1, primary education 2, Middle education 3, High education, University.
Dependency ratio	Continuous	Dependency ratio of the household (0-14 plus 65+ over 15-64).
Total Income	Continuous	Income of the household per year in GHC.
Agricultural income	Continuous	Agricultural income of the household per year in GHC.
Remittance	Continuous	Remittances received by the household per year in GHC.
Saving	Continuous	Household formal saving per year in GHC.
Loan received	Continuous	Loan received by the household per year in GHC.
Livestock endowment (TLU)	Continuous	Household livestock endowment, measured in tropical livestock unit (TLU).
Distance to nearest market	Continuous	Distance to the nearest market measure in hours walking.
Distance to nearest river	Dummy	During the baseline survey household's GPS were recorded and those were used to estimate the distance between the household and the nearby river. We believe farmers who are closer to the river will be less likely to subscribe for the supplemental irrigation extension services.
Extension service visit	Continuous	Number of time the extension service officer visited the household in the last agricultural season.
house structure	Discrete	What is your house built with? 1. mud and sticks 2. Concrete 3. Bricks 4. other (specify)
Climate condition last season (1=good rain, 0=otherwise)	Dummy	Natures of last growing season 1= good rainfall, 0=otherwise.
Climate condition last 5 agric seasons (#)	Continuous	Number of good rainfall season in the past 5 seasons.
Risk perception	Likert scale	In your view, what is the likelihood that there will be a drought in the next 5 years (1. very likely, 2. likely, 3. unlikely, 4. very unlikely).
Help if drought	Continuous	Number of person that the household may call upon for help during drought.
Labor	Continuous	Number of household members involved in agriculture
Plots	Continuous	Number of plots owns by the household.
Total land	Continuous	Household total land in acres.
Credit constrained	Dummy	Equals to 1 if individual responses that they haven't applied for (formal/informal) loan/credit since last year and citing reasons related to lack of credit. This equals to zero if they cite no need for credit. It also equals to one if they have applied for any credit but have never gotten one since last year.
Improved maize dummy	Dummy	High yield maize variety equals to 1 if a farmer grew high yield maize last cropping season.
Maize land	Continuous	Total land allocated to maize in acres.
Rice dummy	Dummy	Equals to 1 if the farmers grows rice and 0 if not.
Riceland	Continuous	Total land allocated to rice in acres.
Land ownership	dummy	Dummy variable, 1 if the farmers owns land and 0 otherwise.

Appendix 2: Factors affecting the demand for supplemental irrigation (open canal and pipeline choice tasks estimated separately)

	Open canal			Pipeline		
VARIABLES	Bid	Without end var	With end var	Bid	Without end var	With end var
Bid	-0.042***	-0.041***	-0.040***	0.040***	-0.039***	-0.038***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Age (year)		0.001	0.000		0.001	0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Gender (1=male, 0=female)		-0.003	-0.011		-0.011	-0.015
		(0.027)	(0.027)		(0.028)	(0.028)
Level of Education						
Primary Education		0.035	0.015		-0.003	-0.014
		(0.052)	(0.057)		(0.061)	(0.064)
Middle Education		0.010	0.008		0.048	0.048
		(0.052)	(0.051)		(0.050)	(0.050)
High Education/University		0.030	0.013		0.024	0.017
		(0.067)	(0.063)		(0.065)	(0.064)
Dependency Ratio		0.001	0.002		0.004	0.005
		(0.004)	(0.004)		(0.005)	(0.005)
Remittance (GHC 100)		0.003	0.000		0.006	0.004
		(0.006)	(0.007)		(0.007)	(0.007)
Livestock Endowment (TLU)		0.006	0.004		0.002	0.000
		(0.004)	(0.005)		(0.004)	(0.005)
Distance to Nearest Market (hour)		0.019	0.021		0.013	0.014
		(0.016)	(0.016)		(0.017)	(0.016)
Climate condition last season (1=good rain, 0=otherwise)		-0.070***	-0.069***		-0.063**	-0.065**
		(0.026)	(0.026)		(0.028)	(0.028)
Climate condition last 5 agric season (#)		-0.031**	-0.033**		-0.025	-0.028*
		(0.015)	(0.015)		(0.016)	(0.016)
Drought Perception (next 5 agric season)		-0.018	-0.020		-0.002	-0.003
		(0.013)	(0.013)		(0.014)	(0.014)
Risk Preference (1=risk averse, 0=risk loving)		-0.063**	-0.064**		-0.036	-0.038
		(0.026)	(0.025)		(0.027)	(0.027)
Time Preference		0.243	0.223		-0.183	-0.225
		(0.222)	(0.212)		(0.234)	(0.230)
Help if Drought		-0.002	-0.005		-0.001	-0.004
		(0.005)	(0.004)		(0.005)	(0.005)
House Structure						
Concrete		0.180***	0.178***		0.177***	0.175***
		(0.027)	(0.027)		(0.032)	(0.032)
Bricks		0.103***	0.109***		0.053	0.056
		(0.028)	(0.028)		(0.035)	(0.035)
Land Ownership (1=yes, 0=no)		0.072***	0.054**		0.069**	0.059**
		(0.026)	(0.026)		(0.027)	(0.028)
Loan Received (GHC 100)		0.012***	0.012***		0.012**	0.012**
		(0.005)	(0.005)		(0.005)	(0.005)
Distance to Nearest River (km)		-0.012	-0.010		-0.008	-0.007
		(0.010)	(0.010)		(0.011)	(0.010)
Extension Service Visit (#)		0.011	0.007		0.008	0.006
		(0.008)	(0.008)		(0.008)	(0.008)
Agricultural Income (GHC 100)			0.008***			0.006***
			(0.002)			(0.002)
Saving (GHC 100)			-0.004			-0.004
			(0.004)			(0.004)
Share of Land Allocated to Rice			0.047			0.092
			(0.059)			(0.068)
Order WTP (1=if canal 1st, 0= if pipeline 1st)	0.007	0.001	0.002	-0.015	-0.020	-0.018
	(0.026)	(0.024)	(0.024)	(0.027)	(0.026)	(0.025)
Observations		777	777		777	777

The observations are percentage. *** p<0.01, ** p<0.05, * p<0.1. The standard errors are estimated using delta method.