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EFFECTS OF SMALL SCALE IRRIGATION ON HOUSEHOLD INCOME AND ITS IMPLICATION FOR LIVELIHOOD SUSTAINABILITY IN THE DROUGHT PRONE CENTRAL RIFT VALLEY OF ETHIOPIA.

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ABSTRACT

Smallholder rainfed agriculture is the mainstay for the majority of the population in Ethiopia. However, its performance is very poor, particularly in drought-prone areas. Hence, small scale irrigation has been introduced to averse the negative effects of climate variability. This research aims to examine the impacts of small scale irrigation on income and its implication on rural livelihood sustainability. Data were collected using a household survey questionnaire and focus group discussions. Descriptive statistics and the Heckman two-step model were used to analyze the data. Participation in irrigation significantly and positively affects the amount of household income. However, the contribution of irrigation on household income has a limited role to support the sustainability of livelihood in the time of chronic drought in which irrigators were in food aid like non-irrigators. Creating market access, credit provision, better extension service, introducing gender-friendly irrigation, and expanding irrigation command area needs policy priority to sustain the economic benefit of irrigation.

Keyword:
Small scale Irrigation, Determinants, Income, Heckman Two-step, Livelihood Sustainability, Central Rift Valley, Ethiopia.

INTRODUCTION

Agriculture is the dominant form of economic activity worldwide and it also provides different ecosystem services. In Sub-Saharan Africa (SSA), agricultural development is the main vehicle to end poverty as the majority of the population depends on agriculture for their livelihood (Shiferaw et al., 2014). However, agriculture by its nature is highly sensitive to climate variations such as insufficient rainfall, rainfall variability, and drought (You, 2008). Drought is a recurring reality in most parts of SSA, where agriculture remains to be a major sector of most economies, and being dominantly rain-fed is highly prone to drought (Gautam, 2006). The negative effects of climate change vary spatially and temporally due to variations in the economic level of development and adaptive capacity of the community to changes and seasonal variability of the climate. Smallholder farmers in developing countries are predominantly affected by the impacts of global climate change due to their high vulnerability as a result of mainly located in the tropics and due to socioeconomic, demographic and policy-related trends limiting their capacity to adapt to change (Intergovernmental Panel on Climate Change (IPCC), 2014; Komba & Muchapondwa, 2012; Mertz, Halsnæs, Olesen, & Rasmussen, 2009). Hellmuth, Osgood, Hess, Moorhead, & Bhojwani (2009) emphasized that the nature of climate variability and unpredictability as the major risk factors that hinder options and limit livelihood development of millions of poor people in SSA. Moreover, according to Scheffran, Marmer, & Sow (2012) drought has caused depletion of assets, environmental degradation, impoverishment, unemployment, and forced migration in Africa during the past five decades. These same authors also noted that the frequency of droughts has increased steadily in East Africa, where Ethiopia is not exceptional. Future climate projection which was undertaken by IPCC (2007) revealed that the area suitable for agriculture, the length of growing seasons, and yield potential are expected to decrease particularly in the margins of arid and semi-arid parts of Africa. Consequently, the changing climate situation can compromise food security and exacerbate malnutrition in the continent.

The rainfall pattern in most regions of Ethiopia is not conducive to crop production because of its erratic nature. Rain occurs only for a few months of the growing season and most of the time short and intense that causes high runoff (Yihun, 2015). Araya & Stroosnijder (2011) also indicated that changes in precipitation results in crop failure in the short run and long-run production decline. Moreover, according to Awulachew (2019) prolonged and recurrent drought occurrence adversely affects the livelihood of the agricultural communities and the Ethiopian economy as a whole. The negative effects of climate variability on the livelihood of people who are dependent on agriculture are diverse, for example, Feleke, Assefa & Zeleke (2019) and Yihun (2015) revealed that high-temperature results in the reduction of agricultural productivity while it creates a conducive situation for weed and pest proliferation. In Ethiopia the drylands occupy 70% of the landmass and 45% of the arable land, but the area has fragile natural resource base and crops suffer from moisture stress and drought even during normal rainfall seasons that result in farm productivity decline and farmers have been sliding into poverty (Awulachew et al., 2005).

Central Rift Valley (CRV) of Ethiopia has been facing multiple challenges due to rapid population growth, poverty, and natural resource degradation (Jansen et al., 2007; Pascual-Ferrer, Pérez-Foguet, Codony, Raventós & Candela, 2014). Subsistence rainfed farming is the major livelihood strategy for the majority of the population like most regions in the country. However, such type of agricultural system is very susceptible to water shortage in the CRV due to large variability in rainfall distribution between years and within years together with short rainy seasons (Yihun, 2015). The performance of rainfed agriculture is very poor as a result of the erratic nature of rainfall and recurrent drought in the area (Muluneh, Bewket, Keesstra, & Stroosnijder, 2017). The occurrence of chronic drought is still a prevailing problem in CRV, consequently, it is found is one of the chronically food-insecure areas in Ethiopia where the Productive Safety Net Programme (PSNP) has actively been implemented. Climate risk quantified in terms of drought frequency revealed that all the districts in the CRV experienced drought ranging from 2 to 5 times within 33 years (Gizachew & Shimelis, 2014). Among the worst-hit districts, which experienced the highest frequency of drought (5 times in 33 years), were Adami Tulu Jido Kombolcha (ATJK), Dugda Bora [1], Ziway Dugda, Dodotana-Sire, and Tiyo districts. ATJK and Ziway Dugda districts (study districts) had the highest probability of severe drought occurrence with 46 to 76% severity level in the East Shoa zone of Ethiopia (Gizachew & Shimelis, 2014). Working on climate change adaptation and mitigation mechanisms must be the priority of African governments' sustainable development strategies looking at the past and future projected livelihood challenges of the community associated with drought occurrence and other climate extremes. A study conducted by Feleke et al. (2019) revealed that the sustainability of the livelihood of the community dependent on agriculture is under serious challenge in areas particularly vulnerable to drought. Fischer, Tubiello, Van Velthuize & Wiberg (2007) also emphasized that addressing the challenges of climate change is critically important to attain the goal of sustainable development and ensuring sustainable development is the key to resolve the challenges imposed on development due to climate change and variability. Thus, there is an urgent need for nations to neutralize the potential adverse effects of climate change to avoid welfare losses of the smallholder farmers mainly in SSA (Feleke et al., 2019; Mertz et al., 2009). Turral, Svendsen & Faures (2010) emphasized that irrigation can play a significant role to support the rural economies in the developing world to overcome climate change-induced vulnerabilities of crop failure, famine, poverty, food insecurity, and livelihood hazards. If agriculture is dependent on the rainfed system, there is no agriculture whenever there is no rain, which shows the benefit of irrigation. Irrigation is the prime means of intensification and will remain a keystone of food security policies in the face of climate variability (Awulachew, Merrey, Van Koopen & Kamara, 2010). Amare & Simane (2017) and Tucker & Leulseged (2010) noted that small scale irrigation (SSI) is very promising in developing countries to enhance rural food security, increase resilience, poverty alleviation, and adaptation to climate change. The Ethiopian government has given policy priority to irrigation and water-based development in many of its agricultural development programs to averse the damaging effects of climate variability and drought on the livelihood of the community. Thus, Ethiopia has introduced a national irrigation development strategy to use water and land potential to increase agricultural production (Ministry of Water Resources (MoWR), 2001). Irrigation development has already been identified as an important tool to stimulate economic growth (Ministry of Finance and Economic Development (MoFED), 2006; MoWR, 2002). The country has 12 river basins, abundant rainfall, and groundwater reserves. This provides a good opportunity for the development of irrigation in the country and the government has undertaken various activities to expand irrigation in the country. Based on this policy, concerted efforts have been done to expand irrigation development in the country particularly since 2005/2006 to address the problems of rainfed agriculture and to enable sustainable growth and development (Hagos, Makombe, Namara, & Awulachew, 2009).

Previous studies conducted in the field confirmed that if Ethiopia's water resources are developed cater for irrigation, it would be possible to attain enough agricultural surplus both for domestic consumption and for external markets (Yihun, 2015). The

[1] Currently this district is classified into two as Bora district and Dugda district independently.

country's Agricultural Development Led Industrialization (ADLI) strategy considers irrigation development as a key strategy for sustainable agricultural development. Thus, irrigation development, particularly small scale irrigation schemes (SSIS) is planned to be accelerated (MoFED, 2010). The neglect of SSIS during the imperial and military regime was reversed when the Ethiopian Peoples' Revolutionary Democratic Front (EPRDF) took power in 1991. The EPRDF government has given more attention to the development of SSIS and the improvement of farmer-managed traditional schemes as a priority issue in the water development policy. Thus, CRV of Ethiopia is among the areas in the country where the development of SSI has been promoted through the intervention of the government and non-governmental organizations to overcome drought and rainfall variability induced livelihood challenges of smallholder farmers. Accordingly, most of the districts in the CRV have a long history in practicing SSI on lakes, stream and river diversions, groundwater, dams, and perennial springs (Feleke et al., 2019).

Understanding the impacts of SSI on household (HH) income and its implication on the sustainability of rural livelihood development is critically important from different aspects because simple increase in income may not always contribute to the achievement of the goal of sustainable development. For instance, the result of the study can give valuable information for policymakers and development practitioners to make better policy intervention either to expand new SSIS or upgrade the existing schemes in the area or other parts of the country having similar biophysical and socio-economic conditions with CRV. Furthermore, the finding of the study is very useful to provide essential information to design strategies that can enhance the sustainability of agricultural productivity in irrigated areas, where people are living under the risks of drought. There are some previous researches conducted in this research thematic area such as (Bacha, Namara, Bogale & Tesfaye, 2011; Haji, Aman & Hailu, 2013; Hirko, Ketema & Beyene, 2018; Legesse, Ayele, Tasewu, Alemu, 2018; Ogunniyi, Omonona, Abioye & Olagunju, 2018; Sinyolo, Mudhara & Wale, 2014) and others. The findings of these empirical research works indicated mixed results concerning the impacts of SSI on HH income, asset, poverty, and welfare. Moreover, there are scanty research works that are undertaken in the CRV area though SSI is a vital intervention to enhance HHs' adaptive capacity to drought-induced crop failure and HH economy linking the concepts of sustainable development and livelihood sustainability. Hence, it is plausible to investigate the effects of SSI on HH income in the CRV area. Thus, the objective of this study is to (1) investigate the impacts of SSI on HH income and (2) identify the determinants that affect the amount of HH income, and (3) synthesis the implication of the impacts of SSI on HH income on the sustainability of rural livelihood.

MATERIALS AND METHODS

Study area description

Central Rift Valley of Ethiopia is located between, approximately $7^0$10'N to 8^0 30'N and $38^0$15'E to $39^0$25'E at 150 km south of Addis Ababa. It covers an area of approximately 10,000 km^2. The altitude of the area ranges from 1500 m.a.s.l in the lowest area to around 4000 m.a.s.l in the highest elevation area. The area is characterized by semi-arid and unreliable rainfall pattern with high evapotranspiration. The main rainy season ranges from June to September and the dry season is from October to March with variable and low average monthly precipitation (Pascual-Ferrer et al., 2014). There is local variability of precipitation depending on altitudinal variation; the mean annual rainfall of the area is 900mm. The area is characterized by relatively high temperature February to April is the hottest months having the highest average maximum temperature nearly

30^{0}C. The lowest average minimum temperature recorded in the months of October to December. Agricultural production and its related activities is the major base that sustains the CRV economy; industry and service sectors have low contribution for the economy. The lakes in CRV are globally significant freshwater ecosystems containing important areas of both terrestrial and aquatic biological diversity, and most are becoming degraded as a result of human activities. It is a closed river basin, consists of a chain of four large lakes, streams and wetlands that are spatially and temporally strongly interlinked. The diversity of landscapes and ecosystems comprise unique biodiversity-rich wetlands. The Central Rift Valley is one of the environmentally very vulnerable areas in Ethiopia (Jansen et al., 2007).

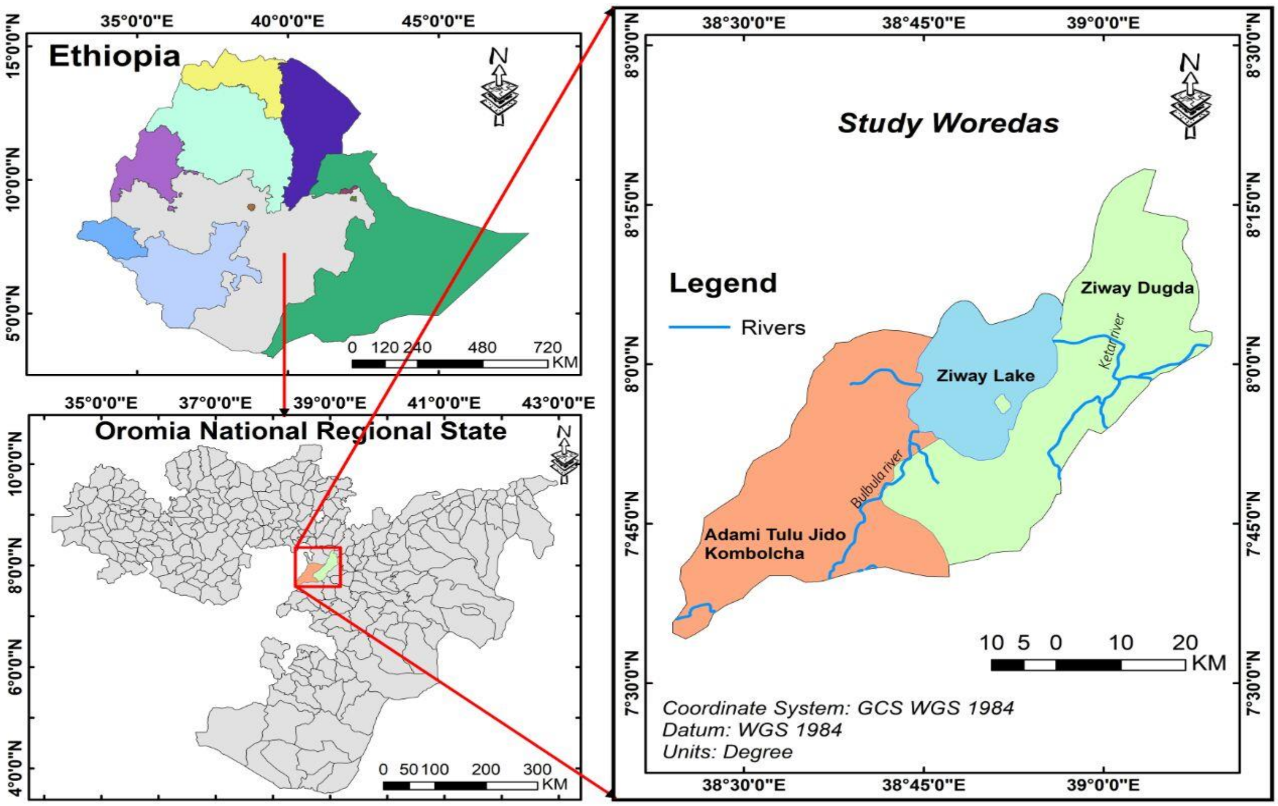

Figure 1. Study area map

Data sources and methods of data collection

The primary data were collected by using HH survey questionnaire, focus group discussion (FGD) and transect walk. The HH survey data were collected during May to June, 2017 for a period of two months by trained data collectors. The survey was collected using Afan Oromo[2] and Amharic[3] languages based on the household head (HHH) language skills. Field data was collected considering the immediate past cropping season of 2016/2017 by helping the farmers to recall their agricultural activities and income generated from different sources in that cropping season. We prepared semi-structured HH survey questionnaire to collect the quantitative data. The HHH were interviewed to fill the survey questionnaire. The contents of the questionnaire include questions on farmers' personal and plot level attributes (age, education, gender, family size, livestock holding, land size owned, off-farm work, and amount of income from different sources). To evaluate impact of small scale

[2] Language used by the study community

[3] Ethiopian official working language

irrigation on annual gross income of the HH, all sources of income such as agricultural (cropping from irrigated and rainfed farming and livestock) incomes and non-agricultural (off-farm and other) incomes were included. Questions were also included on farmers' access to supportive institutions (credit and contact with extension agents). The major plot level characteristics (soil fertility, accessibility of water sources, and distance from the plot to district market, use of inputs and agricultural outputs) were included in the questionnaire.

FGDs were conducted with groups of farmers who are irrigation user and non-user, eight to ten farmers were participated in the FGD by including both male-headed HHs (MHHH), female-headed HHs (FHHH) and HHHs composed of different age groups. We used the qualitative data to verify the results of quantitative data and to get some deeper insights in our investigation. The content of the questionnaire include questions on how irrigation affected their HH income compared to non-irrigation user HHs, the role of irrigation to cope the problem of drought in their area, the factors that affect the amount of HHs' income and other related questions. Audio recorder was used to record the FGDs. Finally, the data were transcribed and translated into English language and used in the discussion of the results of the study collected using HH survey.

Sampling technique

Both probability and non-probability sample selection techniques were used to select the sample respondent for the collection of primary data. We used probability multistage stratified sample selection techniques to select the target sample HHs for the study. The districts in the CRV of Ethiopia were categorized as lowland and highland districts. Among the districts in the lowland areas of the rift valley floor ATJK and Ziway Dugda districts were purposely selected because of their long time experience in SSI practices and the occurrences of recurrent drought. These two districts are characterized with arid and semi-arid type of climatic classification, which makes SSI agriculture priority area of development consideration to support the livelihood of smallholder farmers. The HHs in the two districts were considered as the survey population of the study. The *kebeles* in each district were listed and stratified as irrigation user and non-user. Then, using simple random sampling technique representative *kebeles* were selected based on proportion to size from both irrigation users and non-irrigation users from each district. Accordingly, Bochessa, Dodicha and Gulba Aluto were selected as sample *Kebeles* from ATJK district and Shelad Gutu and Arata Chufa *Kebeles* were selected from Ziway Dugda district. The list of the HH heads (HHHs) were collected from these selected *kebele* offices and used as a sampling frame. The sample HHHs were selected using systematic probability sampling technique from each strata based on proportion to the size of farm HHs in the respective *kebeles*. We used HHHs as a unit of analysis.

We determined the sample size of the study based on Kothari (2004). Using this formula at 95% confidence level with standard variate (z) value of 1.96, sample proportion (p) value of 0.5 and a 5% of level of precision(e) are assumed. The calculated sample size of the study is 384, and a contingency of 15% is added to accommodate non-responses and incomplete questionnaires. Thus, data were collected using HH (HH) survey questionnaire from a total sample of 442 HHs. Among these 442 collected questionnaires, 11 questionnaires found being incomplete and not properly addressed as it was designed. Therefore, these 11 questionnaires were excluded from the study and finally the data collected from 431 HH heads were used in the analysis of the data.

$$n = \frac{z^2 . p . q . \mathcal{N}}{e^2(\mathcal{N} - 1) + z^2 . p . q}$$

n is sample population

N is total population

p is sample proportion and q= 1- p

e is level of precision (acceptable sampling error)

z^2 is the value of the standard variant with the given confidence level.

We have also used non-probability sampling technique to select sample respondents for focus group discussion. Purposive sampling was used to select the cases to be included in the sample based on judgmental basis on the possession of the particular characteristics such as in terms of HHHs' age, sex composition, irrigation user and non-users. Convenience sampling technique was used to select sample HHH for FGD until a saturation point is reached.

CONCEPTUAL FRAMEWORK AND VARIABLES

The conceptual framework of the study was developed based on farmer-first and sustainable livelihoods principle (Chambers, 1987; DFID, 2000). It also incorporates important elements from the theory of farm-household behavior under market imperfections (De Janvry, Fafchamps & Sadoulet, 1991), the economics of rural organization (Hoff, Braverman & Stiglitz, 1993) and the role of economic policies and institutions (Heath and Binswanger, 1996). The contemporary global and local problems mainly related with climate change which has been manifested through rising temperature, increasing erratic rainfall, more frequent and chronic droughts and floods resulted in the prevalence of poverty, food insecurity and unsustainable livelihood systems among the rainfed dependent smallholder farmers in SSA where Ethiopia is not exceptional. The impact of climate change and variability is high among such farming communities because the change has been disproportionately increasing the vulnerability of their livelihood systems. In Ethiopia, the Climate Resilient Green Economy (CRGE) indicated that climate change has the potential to negatively affect the country's economic progress and could even exacerbate social, economic and environmental problems. Ethiopia's dependency on climate sensitive rainfed subsistence agricultural production has entangled the advancement of the livelihood of smallholder farming communities particularly in arid and semi-arid areas. Thus, the Ethiopian government has been introducing different strategies and mechanisms to averse the negative effects of those contemporary global and local climate change induced livelihood risks (Figure 2). Government interventions through policy advocacies and investments on SSIS have been given priority in areas where chronic drought occurrence is a serious problem like in the case of the study districts to overcome the livelihood challenges of HHs who are dependent on rainfed agricultural system.

Consequently such government intervention in SSI expansion results in increased irrigable area, reduced rainfall risk and avert the adverse effects of drought. This situation further affects HHs' decision to participate in SSI considering its positive outcomes. On the other hand, smallholder farmers' level of access to the five livelihood assets (Figure 2) has tremendous role in affecting farmers' decision to participate in SSI and consequently determine the benefits that can be obtained from investing in irrigation. HHs' participation in irrigation expected to result in increasing production, market oriented production, and crop diversity including high yield varieties as can be seen from the findings of some previous researches (Hirko et al., 2018; Sinyolo et al., 2014). Such situation results in increasing HH income because selling agricultural products is the main source of income for smallholder farmers. In such circumstances HHs can get the best opportunity to invest in increasing the five livelihood assets in one hand and can be able to enhance the sustainability of their livelihood development.

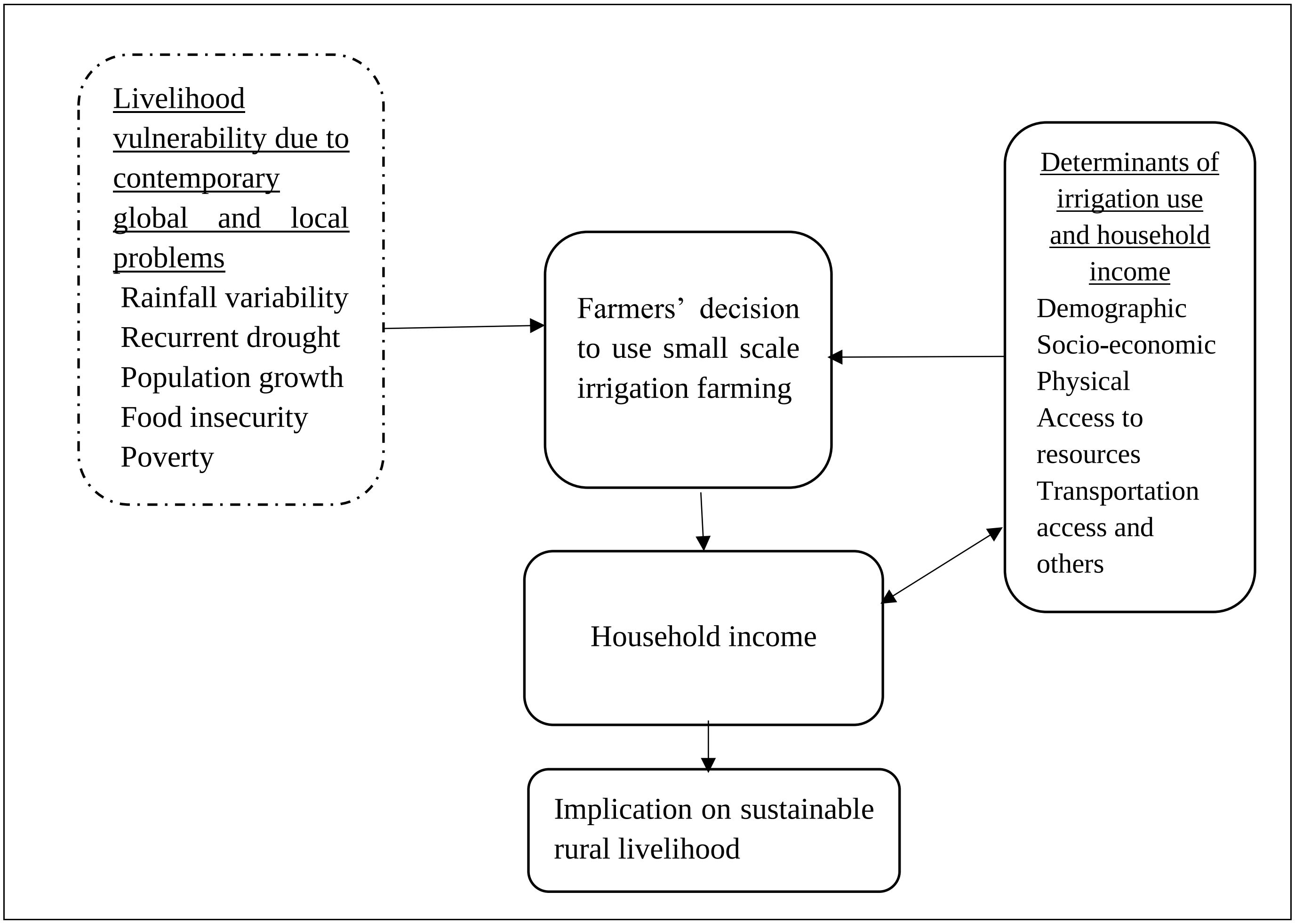

Figure 2. Conceptual framework of the study (Source: Authors own construction)

In the conceptual framework the arrows that point two-ways indicates that there is an interaction between the concepts in both ways. The unidirectional arrow shows the effect is only from one to the other but not the reverse. HHs' level of access to livelihood assets affects the amount of income and the amount of income also determines farmers' access to the livelihood assets now and in the future. Therefore, the interaction is interdependent. Furthermore, the role of any agricultural technology has to be evaluated from the view of its contribution for the sustainability of the livelihood of the users and sustainable development at a broader level. HH income is among the key factors that can affect the sustainability of the livelihood of the communities in many ways. If the income of the HH is good, he/she is able to invest into different production enhancing agricultural technologies, can diversify livelihood strategies and could invest on environmental conservation and rehabilitation strategies. All these could contribute to sustainability of livelihood systems and sustainable development of an area in the long-run. Furthermore, the two-way interaction between the sustainability of livelihoods and averting the risks of rainfall variability and drought is strong because sustainable livelihood strategies are key way-outs to withstand unexpected rainfall variability and drought induced crop failure, food insecurity, poverty and other livelihood challenges. The sustainability issue of livelihoods categorized into two groups such as environmental and socio-economic sustainability (Chambers & Conway, 1992). Environmental sustainability refers to the internal capacity of livelihoods to withstand outside pressures. According to most of the conventional thinking sustainability refers to preservation or enhancement of the productive resource base, particularly for future generations. Socio-economic sustainability refers to whether a human unit (individual, household or family) cannot only gain but maintain an adequate and decent livelihood in terms of equity.

> *A livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term* (Chambers & Conway, 1992).

This study examined the effects of SSI on HH income and its implication on the sustainability of rural livelihood development. It also analyzed the factors that determine the amount of HH income.

Table 1. Definition of dependent and independent variables on determinants of HH gross income

Dependent Variable	**Definition and measurement**				
HH annual income	HH gross annual income (a total of all forms of income measured in Ethiopian Birr (ETB, the unit of currency)				
Independent variables	Definition and measurement	Variable type	Hypothesized relationship	Identified relationships in the previous studies	
				Positive	Negative
AGE	Age of the HHH (in years)	Continuous	Positive		
AGESQ	Age of the HHH square(in years)	Continuous	Negative		
FAMSIZAD	Family size in adult equivalent (in number)	Continuous	Indeterminate		(Sinyolo et al., 2014; Tesfaye, Bogale, Namara, & Bacha, 2008)
FAMSIZADSQ	Family size in adult equivalent square (in number)		Positive	(Sinyolo et al., 2014; Tesfaye et al., 2008)	
DEPRAT	Dependency ratio(in number)	Continuous	Negative		
TCULAND	Total cultivated land (hectar)	Continuous	Positive	(Ayele, Nicholson, Collick, Tilahun & Steenhuis, 2013; Legesse et al., 2018)	
TLU	Total livestock holding of the HH in TLU)	Continuous	Negative	(Bacha et al., 2011; Haji et al., 2013)	
EDUC	Educational level of the HHH (in years)	Continuous	Positive	(Ayele et al., 2013)	
PARTIRR	Participation in irrigation (irrigation user=0, otherwise=1)	Dummy	Positive	(Gebremariam & Ghosal, 2016; Ogunniyi et al., 2018)	
DISMARK	Distance from farm plot to the district market(in walking hours)	Continuous	Negative		(Mengistie & Kidane, 2016)

SEX	Sex of the HHH (male=0, otherwise=1)	Dummy	Negative	(Mare & Girmay, 2016)
CREDIT	Credit service (0=Yes, otherwise=1)	Dummy	Positive	
EXTENSION	Extension service (Yes=0, otherwise=1)	Dummy	Positive	
TRAINING	Participation on farming related training (yes=1, otherwise=0)	Dummy	Positive	

Methods of data analysis

Data were analyzed using both descriptive and econometrics techniques. The descriptive analysis was performed using frequencies, mean, t-test and Chi-square analysis. The qualitative data, which were collected using FGD were coded in Nvivo software, organized and reduced into themes, interpreted and presented concurrently with the quantitative data in the presentation and discussion section. Econometrics estimation were used in the analysis of the determinants of farmers' decision to participate in SSI and impacts of SSIS on HH income. The quantitative data were analyzed using STATA version 14 and SPSS version 24 software. The data were checked for the problem of multicollinearity using variance inflation factor and Pearson correlation coefficient. Appropriate recoding was done for detected multicollinearity among the variables.

Econometrics model specification

Heckman two-step procedure was used to evaluate the impact of irrigation on the income of HHs from other possible factors that affect the income. Other researches applied Heckman sample selection model (Abdissa, Tesema & Yirga, 2017; Asayehegn, 2012; Bacha et al., 2011; Tesfaye et al., 2008)**.** The effect of the program may be under or overestimated if program participants are more or less able due to certain unobservable characteristics unless the selection bias is controlled. Therefore, in the first step using binary probit model the inverse mills ratio or the selectivity bias was determined based on maximum likelihood estimation (MLE). If the inverse mills ratio is significant it will be included as one explanatory variable in the second model that is the Ordinarly least square (OLS) model to determine the effect of irrigation on the income of farm HHs. The Heckman two-step model estimation was done by using binary probit(MLE) in the first step and OLS was used in the second step.

$$\mathcal{D}_i = \sum_{k=1}^{k} \gamma_k \mathcal{Z}_{ik} + \mathcal{U}_i \qquad (1)$$

$Let\ \mathcal{Z}_{ik}\ be\ a\ group\ of\ k\ variables\ which\ represnt\ the\ characterstics\ of\ a\ household\ i\ which\ influnce\ the\ probability\ of\ participation\ in\ irrigation\ agriculture\ measured\ by\ a\ latenet\ variable\ \mathcal{D}_i\ and\ \gamma_k\ are\ the\ coefficients\ which\ reflect\ the\ effect\ of\ these\ variables\ onthe\ probability\ of\ being\ an\ irrigation\ farmer.$

$$\mathcal{Y}_i = \sum_{n=1}^{n} \beta_n \mathcal{X}_{in} + \mathcal{E}_i\ , observed\ \ only\ if\ D_i > 0 \qquad (2)$$

$Let\ \mathcal{X}_{in}\ is\ the\ group\ of\ variables\ which\ represent\ household\ i\ which\ determines\ the\ households'amount\ of\ income(\mathcal{Y}_i)and\ \beta_n\ are\ the\ coefficients\ which\ reflect\ the\ effect\ of\ these\ variables\ on\ households'amount\ of\ income.$

$\mathcal{U}_i\ and\ \mathcal{E}_i\ are\ the\ disturbances\ follow\ a\ bivariant\ normal\ distribution\ with\ a\ zero\ mean\ and\ variance\ \sigma_u\ and\ \sigma_\varepsilon\ respectively, and\ covariance\ \sigma_{\varepsilon u}.$

$\mathcal{D}_i\ is\ a\ dichotomous\ variable\ which\ takes\ the\ value\ of\ 1 = irrigator\ and\ 0 = otherwise. The\ estimator\ is\ based\ on\ the\ conditional\ expectation\ of\ the\ observed\ variable\ household\ income\ (\ \mathcal{Y}_i\ ).$

$$E(\mathcal{Y}_i/\mathcal{D}_i > 0) = \mathcal{X}\beta + \sigma_{\varepsilon u}\sigma_\varepsilon\lambda(-\gamma\mathcal{Z}) \qquad (3)$$

$$\lambda \text{ is the inverse Mills ratio defined as } \lambda(-\gamma\mathcal{Z}) = \phi(-\gamma\mathcal{Z}/\big(1-\varphi(-\gamma\mathcal{Z})\big);\ \beta \text{ and } \gamma$$
$$\text{are the vectors of parameters which measure the effect of variables } \mathcal{X} \text{ and } \mathcal{Z}$$
$$\phi \text{ and } \varphi \text{ are the functions of density and distribution of a normal respectively.}$$

The expression of conditional expectation shows that $\mathcal{Y}_i$ equals $\mathcal{X}\beta$ only when the errors $\mathcal{U}_i$ and $\mathcal{E}_i$ are not correlated, $\sigma_{\varepsilon u}$= 0; otherwise, the expectation of $\mathcal{Y}_i$ is affected by the variable of equation 1. Thus, from equation 3:

$$\mathcal{Y}_i/\mathcal{D}_i > 0 = E(\mathcal{Y}_i/\mathcal{D}_i > 0) + \mathcal{V}_i = \mathcal{X}\beta + \sigma_{\varepsilon u}\sigma_\varepsilon\lambda(-\gamma\mathcal{Z}) + \mathcal{V}_i \qquad (4)$$

$\mathcal{V}_i$ is the distributed error term.

RESULTS AND DISCUSSIONS

Socio-economic characteristics of respondents

The current study revealed that irrigation user HHs have higher gross income and farm income than non-irrigation users at P< 0.01 and P<0.05 level of significance respectively as can be seen from the t-test statistics in Table 2. Irrigation user farmers found to have better income because SSI provides opportunity for farmers to produce market oriented vegetables, crops and fruits twice or thrice a year. Consequently, it enables farmers to get better farm income from the sale of such agricultural products. Using the farm income, the HH could invest into other income generating activities like livestock rearing and they could also invest more on input on the rainfed and irrigation plots to get better production. In the FGDs held with farmers, the participants noted that irrigation increases farmers' adaptive capacity to unexpected rainfall interruptions and associated harvest lose, which can have potential effects on the economy of the farm HHs. Abebe (2017) reported similar finding in the study conducted at Arba Minch Zuria Woreda, Southern Ethiopia.

In this study irrigation user HHs have statistically significant higher HH size measured both in number and adult equivalent compared to non-users as presented in Table 2. This higher number of family size for irrigation users is related to the fact that irrigation is a labour intensive agricultural practice than rain-fed agriculture. In the FGD farmers reported that irrigators in most cases have hired labour force living regularly with the HH. In the case of total cultivated land holding, irrigation users and non-users have a mean of 0.89 and 0.84 hectares respectively with statistically significant difference at P<0.05. Similarly, irrigators have statistically significant higher number of livestock holding in TLU with a mean of 3.94 than non-irrigators with mean of 2.57 (Table 2). In the study districts where the occurrence of recurrent drought and erratic precipitation are common, farmers consider livestock rearing as an alternative economic activity to sustain their livelihood. This is due to the situation that livestock sector is relatively more resistant to unexpected climate variability compared to crop production. Moreover, in the view of FGD participants the number of livestock holding is an indicator of wealth status in their community. This implies that SSI can create the potential for the users to have more number of livestock as they have better income.

Table 2. Characteristics of respondents (continuous variables)

Variables	Irrigation	Mean	t-value	Sig.
Age	Irrigation User	41.40	1.27	0.204
	Non-users	39.73		
Family size in number	Irrigation User	5.94	4.61	0.000***
	Non-users	4.91		
Family size in adult equivalent	Irrigation User	5.94	4.61	0.008***
	Non-users	4.91		
Dependency ratio	Irrigation User	0.94	-0.67	0.504
	Non-users	1.00		
Education of HHH in years	Irrigation user	6.2	3.06	0.025**
	Non-user	5.5		
Total cultivated land in hectare	Irrigation User	0.89	8.43	0.016***
	Non-users	0.84		
Livestock holding in TLU	Irrigation User	3.94	4.98	0.000***
	Non-users	2.57		
Farm income in ETB	Irrigation User	35197.36	5.10	0.027***
	Non-users	15948.27		
Non-farm income	Irrigation User	10542.98	0.62	0.539
	Non-users	9552.96		
HH gross income	Irrigation User	44965.65	6.69	0.000***
	Non-users	24667.55		
Distance from farm plot to district market in walking hour	Irrigation User	2.733		
	Non-users	2.761	-0.316	0.752

*****, **, and * significance P-values at 0.01, 0.05 and 0.1 respectively**

The Chi-square analysis indicated that sex of the HHH affects HHs' participation in SSI at P<0.05 statistically significant level as shown in Table 3 in which FHHH found to be less participant in irrigation. This could happen due to two reasons, one factor is the dominancy of male being HHHs due to the patriarchal culture of Ethiopia. The second factor is related to some FHHHs preference to lease their irrigable land for other farmers due to the labour intensive nature of irrigation and some inconvenient irrigation practices for women like night time watering. In relation to HHs' practice in using credit service, about 71% and 77% of irrigators and non-irrigators have never used credit service respectively. Farmers participated in the FGD reported the limited provision of credit service in their locality. Moreover, the FGD participants noted that though the farmers working in irrigation agriculture want to take credit to purchase different agricultural inputs, they don't take credit due to the fear of the interest rate. This implies the need to provide appropriate credit services for farm HHs with low or if possible no interest rate through government subside to increase farmers' investment in productivity enhancing technologies like SSI to averse the negative effects of drought on farm HHs livelihood.

Farm HHs' perception on the land being fertile increases their participation in irrigation at P<0.01 level of significance (Table 3). This implies that land fertility enhancing techniques should be promoted in irrigated plots as a package with SSI so as to enhance farmers' investment in SSI to overcome their livelihood challenges associated with drought and erratic rainfall situation in the study districts. The land in irrigating plots commonly cultivated twice a year and in some situations thrice a year. Such cropping practices degrade the natural fertility of the land and productivity declines in the long run. In such situation, some farmers quit working on irrigation sustainably. This has great implication on the need to work on land reclamation and land fertility enhancing mechanisms so as to enable smallholder farmers sustainably work on irrigation to overcome the adverse effects of climate variability induced livelihood challenges. Furthermore, participation in farming related trainings increase farmers' participation in irrigation agriculture. Thus, farming related trainings should be taken as an integral component in the adoption of agricultural technologies including irrigation.

Table 3. Characteristics of respondents (categorical variables)

Variable Definition		**Irrigation user**		**Irrigation non-user**		**Total**		**Chi-square value**	**Sig.**
		Freq.	%	Freq.	%	Freq.	%		
Sex	Male	222	86	133	77	355	82	5.01	0.025**
	Female	37	14	39	23	76	18		
	Total	259	100	172	100	431	100		
Credit service	Yes	75	29	39	23	114	26	0.14	0.148
	No	184	71	133	77	317	74		
	Total	259	100	172	100	431	100		
Extension service	Yes	205	79	140	81	345	80	0.33	0.568
	No	54	21	32	19	86	20		
	Total	259	100	172	100	431	100		
Perception on land fertility	Fertile	152	59	34	20	186	43	63.82	0.000***
	Infertile	107	41	138	80	245	57		
	Total	259	100	172	100	431	100		
Participation in training	Yes	140	54	52	30	192	45	23.74	0.000***
	No	119	46	120	70	239	55		
	Total	259	100	172	100	431	100		

*****, ** and * significance at P-values 0.01, 0.05 and 0.1 respectively**

Results of Heckman two-step model

Determinants of farmers' participation in SSI: Probit regression model results

In the first step of Heckman two-stage model, Probit regression model was estimated to analyze the determinants of farmers' participation in SSI farming as can be seen in Table 4. The overall model is statistically significant (P<0.01). Therefore, the selected observable characteristics explain the probability of irrigation use appropriately. The pseudo R-square shows that about 72.15% of the variation in the participation model can be explained by the included explanatory variables. A positive sign of the coefficients shows increase in the probability of farmers' participation in SSI farming while a negative sign shows decline. The variables age of the HHH, age square, sex of the HHH, family size in adult equivalent, family size in adult equivalent square, cultivated land holding size, livestock holding, distance from farm plot to district market, education level of the HHH, access to irrigation land, and perception about land fertility determine farmers' participation in SSI farming in the study districts (Table 4). Different demographic, socio-economic and institutional factors determine farmers' decision to participate in irrigation farming as can be seen in Table 4.

Table 4. Determinants of farmers' participation in SSI: Probit regression model

	Coefficients	**Std.Err.**	**P>|z|**
Age	.566	.024	.047**
Age square	-.081	.001	0.009***
Sex	-.603	.290	0.048**
Family size in adult equivalent	.052	.020	0.015**
Family size adult equivalent square	-.654	.237	0.006***
Dependency ratio	-.038	.172	0.825
Extension service	.476	.325	0.144
Credit service	.351	.268	0.190
Cultivated land size	-.446	.142	0.002***
Number livestock	-.458	.046	0.041**
Distance from farm plot to district Market	-.315	.140	0.024**
Educational status	.347	.174	0.046**
Access to irrigation land	3.354	.304	0.000***
Perception on land fertility	.791	.259	0.002***
Participation in farming related training	.274	.234	0.242
_Cons	-2.385	1.521	0.117
Log likelihood = -75.994507			
Number of obs = 411			
LR Chi2(15) =393.70			
Prob > Chi2 = 0.0000			
PseudoR2 = 0.7215			
***, ** and * significance at P-values 0.01, 0.05 and 0.1 respectively			

Determinants of HH income: Heckman second-stage outcome model results

The current study revealed that different factors determine the amount of farm HH income in the study districts as presented in Table 5. The variables sex of the HHH, family size in adult equivalent, family size in adult equivalent square, dependency ratio, cultivated land holding size, distance from farm plot to district market, HHH's educational level, participation in irrigation and lambda (inverse mills ratio) were found statistically significant affecting the amount of HHs' income. Lambda (inverse mills ratio) was found significant ($P<0.01$). This shows the presence of selectivity bias and this has indication on the appropriateness of using the model. Similar findings were reported by (Abdissa et al., 2017; Yihdego, Gebru & Gelaye, 2015). The positive coefficient of lambda indicates that the disturbance terms in the participation and outcome equations are positively correlated. The significant result indicates the presence of unobserved determinants of HHs' participation in SSI than those variables included in the model. These factors most likely have positive relationship with HH participation in SSI. The next paragraphs presents discussion on some of the most important determinants of HH income.

Participation in SSI: Controlling other variables, HHs' participation in SSI has positive and significant effect on their HH income ($P<0.05$) as shown in Table 5. Thus, irrigation user HHs have significantly better annual income than non-irrigation users. This finding is in line with our prior hypothesis and some previous research results (Gebremariam & Ghosal, 2016; Hagos, Jayasinghe, Awulachew, Loulseged & Yilma, 2012; Hirko et al., 2018). This is due to the enabling factors that irrigation provides for the users to cultivate twice or thrice a year than non-users who cultivate once in a year even under the severe risks of crop failure due to frequent occurrence of drought in both districts. Furthermore, irrigators produce cash crops, which contributes for better HH income than non-irrigators. Astatike (2016) also noted that cash crop oriented production of irrigators is a contributing factor for enhanced HH income of irrigators in northern part of Ethiopia. The farmers in the FGDs pointed out that irrigation serves as a relatively better livelihood strategy in their area especially during erratic rainfall condition as it reduces or avoids rainfall variability induced crop failures. However, irrigation user farmers underlined the problem that SSI faced challenges to be a sustainable agricultural system to support their livelihood through providing food and better income during severe drought situation like the 2015/2016 in which they lost their crop in the rainfed and the vegetables in the irrigation farms. The main challenge that hinders the sustainability of irrigation farming during drought occurrence is scarcity of irrigation water as the volume of water reduces or the rivers even dry in such situation. Consequently, irrigators have been under government food aid support like non-irrigation users in both study districts. The FGDs held with irrigators at Dodicha *Kebele* indicated the situation in their words "if there were no government support in food aid last year, you may not find us alive here" (Irrigators FGD, Dodicha *Kebele*). Furthermore, the FGD participants elaborated that small irrigable landholding is the other challenge that hinders the sustainability of SSI in supporting agricultural productivity, food and HH income when there is severe drought and no production in rainfed fields.

The result of our research is similar with the findings of Awulachew (2019 who reported that even the monthly changes in weather condition constitute significant effects on agricultural production let alone seasonal changes in weather condition. This implies that to enhance the adaptive capacity of smallholder irrigators under severe drought situation drought resistant crops should be planted and provision of sustainable sources of irrigation water has to be designed with proper climate variability and drought occurrence forecasting. Furthermore, well performing extension packages are also important so as to give the necessary training and advisory services for irrigators to enhance their benefit from irrigation especially during drought situations in which the productivity of raifed agriculture is highly constrained. Amare & Simane (2017) identified SSI as one of the adaptation mechanism to climate change. However, the authors further recommended that farmers should diversify their livelihood from being dependent on farming activities to off-farm and/or non-farming income generating activities. Mengistie & Kidane (2016) also indicated the problem of irrigation water shortage due to continuous drought and dry spells causing the volume of rivers to decline among the irrigators in North Wolllo, Ethiopia. Furthermore, future researches are necessary on how to design SSI to be a sustainable source of agricultural production, income and livelihood strategy in the drought prone arid and semi-arid areas like the study districts. Generally, farmers' participation in irrigation increases the amount of gross HH income, however, such positive effect of irrigation on HH gross income cannot be sustainable unless there is sustainable provision of irrigation water sources during the time of chronic drought.

Table 5. Factors affecting HH income: Heckman selection model- two-step estimates/outcome model results

	Coefficients	**Sta.Err.**	**P>|z|**
Age	1387.876	1387.024	0.317
Age square	-19.163	15.876	0.227
Sex	-9275.06	5504	0.047**
Family size in adult equivalent	-1199	5328.207	0.024**
Family size adult equivalent square	784.565	474.565	0.098*
Dependency ratio	-954.716	2697.327	0.072*
Extension service	9164.423	5892.759	0.120
Credit service	7172.815	5593.258	0.200
Cultivated land size	1845.18	4467.645	0.010**
Number of livestock	94.575	975.703	0.923
Distance from farm plot to district Market	-68.429	35.899	0.057*
Educational status	540.297	3900.261	0.037**
Participation in irrigation	1830.18	22266.93	0.028**
Participation in farming related training	2378.028	4527.017	0.599
Lambda	5955.23	10889.1	0.000***
_Cons	14896.11	38279.84	0.698
Number of Obs = 411			
Censored Obs = 255			
Uncensored Obs = 156			
Wald Chi2 (15) = 77.93			
Prob > Chi2 = 0.0000			
***, ** and * significance at P-values 0.01, 0.05 and 0.1 respectively			

Sex of the HHH: In this study, MHHHs found to have better income compared to FHHHs. The main reason for this difference in income among the two sex groups is due to the situation in most cases FHHHs engage in share cropping and sometimes lease out their irrigable landholding. Hence, the economic benefit of irrigation farming is minimal for FHHHs. This has policy implication on the need to make SSI technologies to be gender sensitive. Thus, future policies and SSI practices needs to be framed to create equitable benefit among FHHHs and MHHHs in Ethiopia. Addressing gender-based equitable use of natural resources like water and land and agricultural technology use including SSI can lead Ethiopia into sustainable rural development. Gender inequality in access to productive resources such as land, water, credit, and technology are closely related to women's poverty and economic and social exclusion in the study conducted at Gamo Gofa Zone, Ethiopia (Mare & Girmay, 2016). Awulachew (2019) suggested that rural women can get more benefit from irrigation agriculture if they get access to land and water rights and actively participate in water user associations (WUAs).

HH size in adult equivalent: This variable influences HH income negatively and significantly (P<0.05) as can be seen in Table 5. However, the relationship between family size in adult equivalent and HH income is not linear. The positive and significant (P<0.1) coefficient of family size in adult equivalent square shows that after a certain point with increasing of family size the HH income also increases. Bacha et al. (2011) found similar result and termed U-shaped relationship. One of the reason might be as the family size increases, family members might engage in different income generating activities and might contribute to increase the HH income. The other contributing factor might be government's food aid provision for the farmers as relief for the chronic drought during the cropping season at the time of this data collection. As the size of the HH member increases, the amount of wheat distributed for the HH increases. Most of the farmers sell the wheat in order to get money to purchase other consumable items and this might likely affect the data on income generated due to the effect of other variables. Therefore, future investigation of the impacts of agricultural technologies like irrigation on HH income or other livelihood components should emphasis interventions like food aid provision in their research.

Size of cultivated landholding: In line with our prior expectation, as the size of cultivated land holding increases, HH income increase significantly (P<0.05) keeping other variables constant. The higher the cultivated landholding, farm income can be higher and it in return contributes to higher HH gross income. Land is the basic input in agriculture. Thus, HHs having more land have better opportunity to produce more and generate better income. This finding is in line with theory and some previous studies (Astatike, 2016; Yihdego et al., 2015). However, the discussants in the FGDs complained about the small landholding size, which constrained their benefit from SSI in both study districts. Hence, as there is limited alternative to reallocate land to increase HHs' landholding, it is better to design alternative and feasible strategies to increase the productivity of the existing farm lands through the adoption of soil and water conservation mechanisms by the farmers with the support of agricultural extension workers.

Number of livestock holding: In this study the number of livestock holding doesn't affect the income of HH, which is contrary to our hypothesis and to some previous findings like (Belay & Beyene, 2013; Yihdego et al., 2015). The FGD participants verified that the livestock sector was also adversely affected by the chronic drought due to lack of forage and water, which causes even the death of some livestock during the cropping season of this data collection. In addition, farmers were discouraged to sell their livestock due to low market price as livestock fattening was hindered due to drought induced vulnerabilities. Thus, although livestock is more resilient than crop production to climate variability, under severe drought situation the livestock sector can be under risky situation. Thus, agricultural development workers and climatologists have to work in collaboration to give the right early warning on expected climate variability induced risks on livestock sector. In such a way farmers can be supported not to lose their livestock either by destocking their livestock before it is damaged or to make ready fodder during good cropping seasons. This implies that appropriate management of the livestock sector is critically important to enhance the contribution of the sector for enhancing the HH income especially during the time of drought in which the crop production sector is highly vulnerable to the adverse damaging effects of drought.

Educational level of the HHH: In the current study educational level of the head positively and significantly influences the HHs' income. As the formal years of schooling of the head increases, the head can have wider understanding on how to work to attain the objective of maximizing HH income using different livelihood strategies. Moreover, as the educational level of the HHH increases, the head might have multiple opportunities to participate in income generating activities. Such situations can produce positive and significant relationship between income and HHH's level of education. The findings of Ayele et al. (2013) confirms our result. However, some previous findings like Belay & Beyene (2013) indicated that educational level of the HHH have no effect on the HH income in Deder district, Ethiopia. Such variation in relation to the effect of heads' level of education on HH income might be affected due to existing situations related to farmers' access to education and other accompanying farming related trainings. Thus, interventions have to be done to increase farmers' access for educational services in rural areas in order to improve the level of farmers' school attendance and their level of education. Farmers' having better educational level can become more knowledgeable about different productivity enhancing techniques such as various irrigation practices, water and soil conservation, livelihood diversification and the like. This implies that the more the farmers are educated, they can get more income and other benefits from irrigation and they can use practices different livelihood strategies that can ensure sustainable rural livelihood development.

Distance from farm plot to district market: The relationship between HH income and distance from farm plot to district market is negative and significant in line with our prior expectation. In all the FGDs farmers strongly mentioned market constraint as a big challenge in accessing agricultural inputs and selling their production from irrigated fields. Sometimes, farmers even left their perishable vegetables like tomato, cabbage and onion in the farm plot for livestock to graze it when the price is too low and having limited transportation and market access. Furthermore, the far walking distance from farm plot into district market reduces farmers' income gain from their irrigation due to the intervention of brokers in fixing irrigated products prices. The FGD discussants of Shelde SSI users view can be taken as a good account for this case.

> *The income we get depends on market situation, which is governed by brokers. We have no link with merchants of our product rather brokers play the role in deciding the price of our production. We are equally sharing our income obtained from irrigation with brokers. No one is controlling the brokers, they decide price of productions as they want. We farmers have no means to change the price once decided by the brokers. For example in 2015 production year, I produced 48 quintals of onion and sold 8000 Birr. I have lost; there is no profit. Let alone profit, I was unable to cover my input expenses.*

This implies that access to market and market linkage are crucial factors that determine the amount of income that can be obtained from SSI. This has big implication on the role of market and transportation linkage on the contribution of SSI on household income and sustainable rural livelihood development. Hence, the Ethiopian government has to prioritize and work strongly on creating good market access and transportation services for farmers in ATJK and Zeway Dugda districts to enable farmers to be better benefited from their agricultural production in terms of generating better HH income and enhancing sustainable rural livelihood development. Mengistie & Kidane (2016) have similar finding as they pointed out transportation, far distance from market, low bargaining power and low prices of irrigated products as the major challenges that hindered the economic benefit of SSI in North Wollo, Ethiopia.

Effect of SSI on HH income and its implication on sustainability of rural livelihood

The study proofed that irrigation user farm HHs characterized with higher gross income than non-irrigation users in the drought prone CRV of Ethiopia. Hence, farmers' participation in irrigation affects HH income positively and significantly. Yet, the contribution of SSI towards enhancing agricultural production and generating HH income has been facing challenges to ensure sustainable rural livelihood based on the perspectives of sustainable development. According to Chambers (1987) the livelihoods and survival of human individuals, households, groups and communities are vulnerable to stresses and shocks. Stresses are normally continuous and cumulative, predictable and distressing, such as seasonal shortages, rising population or declining resources. Shocks are impacts which are typically sudden, unpredictable, and traumatic, such as fires, floods (Chambers, 1987). Hence, any definition of livelihood sustainability has to include the ability to avoid, or more usually to withstand and recover from such stress and shocks. The study districts are characterized with the occurrence of chronic drought and erratic rainfall pattern. Consequently, crop failure, food shortage, lack of adequate HH income and other challenges become the serious livelihood threats of both irrigators and non-irrigators. In such circumstances, both irrigation users and non-users have received food aid from the government. This implies that in ATJK and Zeway Dugda districts SSI has limited capacity to enhance sustainable rural livelihood development because SSI failed to support smallholder farmers' livelihood system to avoid shocks and recover from drought and other climate variability induced livelihood stressors. Hansen, Dilley, Goddard, Conrad & Erickson (2004) emphasized that climate variability has impact on HH's access to food by affecting agricultural production, income, local food prices and in some cases the economy of an entire region.

Furthermore, the study indicated that the income of FHHHs is less than that of MHHHs, which showed the existing discrepancy on the effects of SSI on HH income in terms of gender. Equity is the key concept in the perspective of sustainable development. Thus, the gap in the income gain from SSI based on gender undermines its role for running sustainable rural livelihood development. Hence, it is essential to give more attention in policy design and implementation strategies of SSI practices to be gender friendly so as to be in line with equity principle of sustainable development. In such situation of gender inequality, in the view of Yohannes and Gebrerufael (2016), all development efforts that on-going in Ethiopia are just like clamping with one hand. Thus, attaining the goal of sustainable development can be facilitated by addressing the gender gap in the participation of the community in different sectors including agriculture.

Moreover, sustainable development relies on the adequate availability of environmental resources such as water and land, which are key resources for irrigation. Based on the data obtained from FGDs, scarcity of irrigation water is one of the critical challenges that has constrained the benefit of SSI on sustainable basis during chronic drought seasons as the rivers dry and the volume of Lake Ziway shrank. Getnet, Hengsdijk, & van Ittersum (2014) further elaborated this situation in the area as they reported increased evapotranspiration consumed 207 Mm^3yr^{-1} more water (1990-2007) of lakes and land surface in CRV of Ethiopia. These authors also reported the trend of increasing water abstraction for irrigation purpose from ±20 to 285 Mm^3 yr^{-1}. Therefore, priority should be given on how to provide sustainable source of irrigation water for smallholder farmers even during severe drought situation and other extreme climate change and variability context to maximize the benefit that has to be generated from irrigation. Lefore, Giordano, Ringler & Barron (2019) also noted that the poor performance of irrigation institutions restrict the resource-poor farmers' access to natural resources and it might lead to serious environmental degradation, which affects the sustainability of irrigation based livelihoods. Moreover according to Hansen et al. (2004), the application of climate information on how to manage risks in agricultural system among vulnerable rural communities and within a range of institutions is important to avoid the damaging effects of drought and other climate variability induced challenges.

Small irrigable landholding is the other factor that constrain the role of SSI on HHs' income and its benefit on sustainable basis. In the views of FGD participants in Shelad and Arata Chufa SSISs, farmers complained about the need for government's intervention to introduce pressurized irrigation system by providing motors to pump river water to increase the irrigable command area rather than being simply dependent on gravity irrigation system to increase the number of irrigation beneficiaries. Awulachew (2019) emphasized that the Ethiopian government should work to provide equitable surface water access and expand sources of surface water during irrigation seasons by employing appropriate planning and basin-wide management. Moreover, increasing the fertility of the land is the other option that has to be taken into consideration to ensure the sustainability of the benefits of SSI. Feleke et al. (2019) reported that land degradation is one the serious threat that hinder the sustainability of irrigation based livelihoods in CRV of Ethiopia. Therefore, this has implication on the need to work on land fertility enhancing techniques to increase the productivity of the land and its contribution for improved HHs' income and sustainable development.

In the current study lack of financial capital found to be the other big constraint that hindered farmers' investment potential on SSI covering the high financial demand for fertilizer, pesticide, labour, improved seeds and the like. Financial capital directly affects farmers' decision to participate in SSI, the amount of HHs income and it has strong implication for sustainable development. Farmers participated in FGDs reported the inaccessibility of credit services for them and boldly noted this as their big challenge to pursue sustainable livelihood strategies. Although there are some credit services, farmers lack the willingness to take credit due to the fear of interest rate and ability to pay back the loan as farmers feel insecure whether they can gain or loss from their irrigated crop in the coming cropping season. Holden & Shiferaw (2004) emphasized that the provision and adoption of credit can lead to increased grain production and improved household welfare. These authors also noted about the risks of taking credit. This has implication on the need to provide credit service with low or no interest rate to enable farmers to invest in irrigation without financial limitation to enhance the contribution of SSI to HH income and livelihood sustainability in drought prone areas. Yet, simple provision of credit might not bring the expected result in the livelihood of the farmers. Hence, farmers should be trained on how to use the loan taken to invest on sustainable income generating activities including SSI and other livelihood strategies that enable them to cope up unexpected climate variability and drought occurrences.

The finding of this research indicated that poor transportation infrastructural development constrained farmers' market access for agricultural input and output in both ATJK and Zeway Dugda districts. In our field investigation and in the discussion we had with farmers, transportation problem is more severe in Zeway Dugda district. Poor transportation service and the associated weak market linkage has strong negative effect on the income that has to be generated from selling irrigated products. FGD participants in Shelad SSIS complained a lot about the poor transportation infrastructure, which hindered them to have access even to the nearby district market. Consequently, most of the farmers lose the interest to invest on irrigation and even to quit irrigation. This implies that transportation and market access have strong effect on the income contribution of SSI, which directly affects the sustainability of rural livelihood development. Moreover, farmers' limited access for market gives opportunity for brokers to intervene between farmers and merchants. In such situation the brokers take the economic advantage at the cost of farmers' economic gain by fixing the price of irrigated products. FGD participants in both study districts noted that farmers feel highly peeved with acts of brokers as they are aware of the high economic gain of the brokers from their irrigated products. In line with this, farmers' strongly underlined the need for government intervention to control the role of brokers through the provision of farmers' cooperatives for marketing agricultural inputs and outputs. Generally, governments should bear attention on transportation infrastructural development and market access together with the introduction of productivity enhancing technologies. Otherwise, the agricultural technologies failed to contribute for short term economic gain let alone to contribute for sustainable development and livelihood sustainability.

Conclusion

The study provides empirical pieces of evidence that SSI is an important key intervention in the drought-prone areas in creating a better opportunity for farmers to resist the erratic nature of rainfall and to avoid crop failures. Different socio-economic, demographic, and institutional factors determine farmers' decision to participate in irrigation besides government policy intervention and advocacy on SSI. The analysis of the Heckman two-step model indicates that the amount of HH income is affected by different factors, which has its implication for the sustainability of rural livelihood. Farmers' participation in irrigation affects HHs' income positively and significantly. However, the effect of irrigation on HH income is failed to ensure the sustainability of rural livelihood in the study districts. For instance, in some severe drought situations like the drought in 2015/16 in the area, both irrigation users and non-users were under government food aid. This implies that the existing SSI couldn't be the only viable solution to enhance the HHs' economy during chronic drought seasons to pursue sustainable development. Lack of adequate irrigation water in all seasons, small irrigable land holding, lack of credit service, degradation of the fertility of farmland, poor transportation infrastructure, weak market linkage, and gender inequality in generating income from irrigation entangled the role of SSI to contribute for sustainable development and livelihood sustainability.

The present study revealed that the existing SSI system is not gendered friendly, which is not convenient for FHHHs, and as a result, the income of FHHHs is less than MHHHs. Therefore, gender-sensitive SSI practices and management options should be considered in future policies towards enhancing the equitable benefit of the technology to achieve the goal of sustainable development. Future research areas are recommended on the need assessment of women's irrigation technology preference. The poor transportation infrastructural development and weak market linkage created limited access to input and output markets. This has constrained farmers' capacity to generate better income from irrigation in the study sites. The intervention of brokers between farmers and merchants further aggravates the problem by minimizing the income that has to be generated from SSI by farmers as the brokers take the role in fixing the price of irrigated products for the sake of the economic gain overriding on the interest of farmers. This has a strong implication in undermining the achievement of the goal of sustainable rural development as it discourages farmers' investment in SSI. Hence, appropriate development intervention should be designed to create transportation and market linkage for the farming community to ensure sustainable rural development.

Furthermore, irrigation demands more investment for fertilizer, labor force, pesticide, and improved seed than rain-fed farming. However, the majority of the farmers don't use credit service as they are uncomfortable with the interest rate. Accordingly, irrigation user farmers noted the need for better credit service providers to help them to work better in irrigation on a sustainable basis. Thus, appropriate credit and rural financial provision service should be emphasized in future policy direction to facilitate farmers' beneficence from credit service. HHH's level of education affects HHs income positively. This indicates that education plays a key role in the success of agricultural technologies like irrigation. Therefore, future agricultural technology and rural development policies should be given due attention to creating access for educational services in rural areas. Lack of sufficient irrigation water during the dry season especially in the case of river diversion irrigation systems and during the time of drought further aggravates productivity decline, low-income gain, and negatively affecting the sustainability of irrigation-based livelihoods in return. Besides, small irrigable landholding and the degradation of farmland fertility has hindered the sustainability irrigation-based livelihoods. It is plausible to introduce and accustom drought-resistant crops in drought-prone areas, promoting a pressurized irrigation system instead of a gravity system and working on soil and water conservation tasks to enhance the sustainable benefit from SSI. Moreover, farmers have to diversify their livelihood strategies like livestock rearing, non-farm activities, and the like. In line with this, the role of extension service is very essential to support farmers to diversify their livelihood strategy. Yet, the extension service provision is poor in the study sites. Hence, extension and communication services should be improved to enhance the sustainability of agricultural productivity in both irrigation and rain-fed farming systems.

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