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ORIGINAL PAPER

Small-scale irrigation scheme governance - poverty nexus: evidence from Ethiopia

Fitsum Assefa Adela[1] · Joachim Aurbacher[2] · Gumataw Kifle Abebe[3]

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Abstract

Irrigated agriculture has been popularized as a key factor to improve crop yields and enhance food security in Africa. However, empirical findings are mixed. This study analyzes determinants of small-scale irrigation adoption and the impact this may have on food security in Ethiopia, where agricultural land is extremely fragmented and densely populated. Data were collected from 240 farmers, and the findings from the survey were triangulated with focus group discussions and key informant interviews. First, the Foster-Greer-Thorbecke indices indicated high poverty levels among farmers without access to irrigation. Second, accounting for a self-selection bias by using the endogenous switching regression (ESR) model, scheme governance, perceived water scarcity, and access to information were found to have significant effects on the adoption of irrigation schemes. Model estimates further indicated that access to small-scale irrigation resulted in better living conditions for both current users and non-users when compared to their counterfactual situations. Farm income of the user households would decrease by 42% (birr 151,419 or US$ 5,500 per ha) had they not used irrigation. Similarly, farm income of the non-users would increase by 149% had they used irrigation. Per adult equivalent consumption expenditure has also shown a decrease of 35% for irrigation users and an increase of 40% for non-users compared to their respective counterfactual situations. We conclude that much of the perceived water scarcity level is attributed to existing governance regimes more than the physical scarcity of water. The study draws several implications for household food security and local-based water use policies.

Keywords Small-scale irrigation · Ethiopia · Endogenous switching regression · Scheme governance · Poverty · Farm income

1 Introduction

Irrigated agriculture has been popularized as a key input to improve crop yields and enhance food security. It is expected to account for 53% of the projected increase in the global cereal crop production between 2000 and 2050 (Rosegrant et al. 2009). Irrigated agriculture is particularly important for developing countries (Josephson et al. 2014; Vanlauwe et al. 2014) as the average landholding is generally less than two hectares and continually declining (Vanlauwe et al. 2014). In fact, irrigation can have a multiplier effect through the enhancement of employment opportunities, consumption, and dietary changes (Rosegrant et al. 2009), and through the increased use of productivity-enhancing inputs such as fertilizer and improved varieties (Gebregziabher et al. 2009; Smith 2004; Namara et al. 2005).

Although small-scale irrigation schemes have been promoted in sub-Saharan Africa (SSA) to enhance the food security situation in the region (Burney and Naylor 2012; Dillon 2011; Xie et al. 2017), not more than 6% of the total cultivated area is covered by irrigation (You et al. 2011) and only 4% of renewable water is used for agriculture (Hanjra et al. 2009). Also, empirical studies are mixed regarding the impact of investment on small-scale irrigated agriculture. Several studies, particularly those related to Asia, have indicated a strong positive link between irrigated agriculture and enhanced productivity and food security (Bacha et al. 2011; Hussain and Hanjra 2004; Smith 2004; Wichelns 2014; De Haen 2003).

✉ Fitsum Assefa Adela
fitsumassefa@gmail.com

[1] Faculty of Business and Economics, Hawassa University, P.O.Box 05, Hawassa, Ethiopia

[2] Institute of Farm and Agribusiness Management, Justus-Liebig University of Giessen, Senckenbergstraße 3, 35390 Giessen, Germany

[3] Faculty of Agricultural and Food Sciences, American University of Beirut, Riad El Solh, Beirut, Beirut 1107 2020, Lebanon

Most of these studies have documented doubled or tripled incomes of farm households that used small-scale irrigated agriculture. Much of the success in Asia is often associated with the role of informal institutions in the governance of irrigation water, implementation of bottom-up approaches to select participants in irrigation schemes, and creation of market linkages for irrigation users (Mutambara et al. 2016; Mukherji 2012; Mwendera and Chilonda 2013). However, not much has been documented in SSA regarding the impact of small-scale irrigation schemes in improving rural livelihoods mainly due to factors related to infrastructure, institutions, and socioeconomics (Burney and Naylor 2012; Schuenemann et al. 2018; Mwendera and Chilonda 2013). Furthermore, various findings have indicated that farmers from households that successfully adopted small-scale irrigation were relatively better off than the ultra-poor ones (Mangisoni 2008; Namara et al. 2005).

Previous studies have generally indicated that small-scale irrigation schemes have the potential to enhance crop yields and rural livelihoods. However, the decision to participate in small-scale irrigated agriculture and the impact this may have on poverty reduction may be influenced by several factors, including farm and household characteristics, and institutional and context-specific variables. This study focuses on Ethiopia, where the government's stake in the construction and governance of small scale irrigation systems is high. We explore the factors influencing the adoption of small-scale irrigation schemes and analyze whether access to small-scale irrigation water enhances food security in areas where agricultural land is extremely fragmented and densely populated. Indeed, food security is a multidimensional concept, mainly defined in terms of food availability, access, utilization, and stability (FAO 2008). Several studies suggest that access to small-scale irrigation has the potential to increase incomes and reduce poverty in Africa where sustainable water access for smallholders is difficult owing to recurrent drought. Our study directly relates to the availability and access dimensions, which are the prerequisites for household food security (Barrett 2010; Denny et al. 2018).

Ethiopia provides an interesting perspective for the following reasons. First, Ethiopia has recently been aggressively pursuing several small-scale irrigation schemes aimed at improving rural livelihoods. Second, this study was carried out in a region where annual rainfall is relatively modest, and thus provides a better opportunity (i.e., based on economic theory) to determine the factors influencing the decision to enroll in irrigation schemes or stay with rain-fed agriculture. Third, there are very few impact studies related to small-scale irrigation schemes in Ethiopia; available studies have focused on identification and description of irrigation potentials and challenges (Awulachew et al. 2010), adoption of irrigation technology and estimation of probability of adoption (Gebregziabher 2012), optimal irrigation scheduling (Setegn et al. 2011), problems associated with small-scale irrigation intervention (Aberra 2004; Amede 2015), water-based growth challenges (Hanjra et al. 2009; Namara et al. 2010), and a few impact studies (Bacha et al. 2011; Belay and Bewket 2013). Furthermore, none of these few previous impact studies have paid attention to institutional factors (or scheme governance). Existing studies elsewhere also indicate mixed results regarding the role of institutions in the adoption of small-scale irrigation and its impact on household food security.

The remainder of the paper proceeds as follows. The next section presents a conceptual framework where the role of institutions is discussed as related to irrigation water access, governance, and management. This is followed by the methods, results, and discussion sections. The final section presents conclusions and policy implications.

2 Role of institutions in the governance of small-scale irrigation schemes

The concept of institutions has become a popular framework in natural resource economics in order to understand and analyze the governance of natural resources (Ostrom 1990, 2010). Ostrom provided pioneering work in expanding our understanding of the relationship between institutions and management of natural resources. According to Ostrom, successful management of common pool resources cannot be generalized to specific institutional arrangements or set of rules; it rather depends on the context under consideration. A key feature of Ostrom's 1990 seminal work is the eight design principles that set the conditions for effectively managing community-based natural resources such as irrigation systems, pastures, forests, and fisheries. Ostrom argued that such design principles are best practices for the sustainable management of common pool resources (see Ostrom 2010).

Studies focusing on the governance of natural resources in Africa have markedly shifted from centralized systems to more decentralized ones (Ribot et al. 2010; Andersson and Ostrom 2008). In a decentralized system, natural resource management is shaped by the informal institutions or local authorities who can entrust power in resource allocations. Although a decentralized system of natural resource governance is not new, the outcomes are mixed (see for example Andersson and Ostrom 2008). Andersson and Ostrom (2008) argue that "a perfect institution does not exist" and suggest a polycentric approach. A polycentric perspective relies on the complementarity of community-based institutions and policies in the governance of complex natural resources (Ostrom 2010; Andersson and Ostrom 2008).

A polycentric approach relies on the interplay among local, regional, and national actors to govern irrigation schemes (Baldwin et al. 2016; Lecoutere 2011). A key aspect of such a pragmatic approach is that institutions emerge from

structures and sets of rules but are constantly (re)shaped through individuals' practices; hence, resource scarcity would not necessarily result in conflicts but rather lead to institutional evolution (Lecoutere 2011). A polycentric approach may be preferable for bringing about sustainable use of irrigation water as it offers the option of combining government policies, collective action, societal norms, and the market. Most countries in SSA are challenged by economic water scarcity due to mismanagement, water theft, and turn abuses (Belay and Bewket 2013), and this has become a key source of failure for several small-scale irrigation schemes in SSA, including Ethiopia (Amede 2015; Yohannes et al. 2017).

In addition to the conventional farm- and household-related characteristics, several factors are suggested for the extremely low use of irrigation in SSA, including deficient institutions (Hanjra et al. 2009; Yohannes et al. 2017), poor irrigation infrastructure (Mdemu et al. 2017), mismanagement and corruption (Namara et al. 2010; Dudu and Chumi 2008), and context-specific factors (Yami 2016). Governance of small-scale irrigation matters because it affects the efficiency of water use, investment in irrigation infrastructure, and the decision to adopt irrigation practices (Baldwin et al. 2016). Although several government-sponsored small-scale irrigation schemes are present across Ethiopia, there is little evidence for the impact of governance on adoption and household food security. We argue that the low adoption of small-scale irrigation in Ethiopia is largely attributed to scheme governance; this can have a significant impact on farm income and consumption expenditure, which are associated with the availability and access dimensions of household food security (Barrett 2010; Denny et al. 2018). This relationship is depicted in Fig. 1.

3 Methodology and data

3.1 Poverty

The concept of poverty has evolved from the original idea of inadequacy of income, consumption and wealth (Watts 1969) to concepts of capabilities and functioning (Sen 1981) and further to include multidimensional aspects such as socio-political rights, access to important services and infrastructure, and vulnerability (Namara et al. 2010; Smith 2004). The food security literature classifies poverty into absolute and relative poverty. Absolute poverty refers to the headcount of households who are unable to afford a certain standard of basic goods and services. Relative poverty, on the other hand, measures the relative shortfall of a household's income from the economy's average. Another concept related to but wider than poverty is equity, which refers to the level of equality in income and wealth distribution. Poverty is also a dynamic concept, and thus, factors affecting poverty can change (Smith 2004). Commonly, the Foster-Greer-Thorbecke (FGT) indices (Foster et al. 1984) are used in poverty analysis:

$$P = \frac{1}{N}\sum_{i=1}^{H}\left[\frac{z-e}{z}\right]^{\varnothing} \quad (1)$$

Where Z is the poverty line, N is the number of observations, H is the number of households below the poverty line Z, e is the consumption expenditure per capita for the i^{th} person and ø is a poverty aversion parameter. At $\varnothing = 0$ P gives the headcount index: the number of people below the set poverty line. At $\varnothing = 1$, the resulting P is the poverty gap index, which measures the aggregate shortfall of the consumption of the poor from the poverty line Z. At $\varnothing = 2$ P is the squared poverty gap and measures the severity of poverty. As $\varnothing$ gets larger, the measure gives more emphasis to the poorest of the poor (Foster et al. 1984).

3.2 Theoretical model specification

The decision to adopt a technology can be modeled in a random utility framework by expressing the unobservable utility from adoption and non-adoption through observable variables (Khonje et al. 2015). Accordingly, the adoption decision is modeled, considering the assumption that smallholder farmers choose (not) to irrigate. It is assumed that farmers choose (not) to participate in irrigation schemes considering the benefits from participation through the farm income derived from crop production. The following model specifies the selection eq. P^*, where P^* is the latent variable which is not observed. P^* can be expressed as a function of some observed farm, household, and institutional characteristics.

$$P^* = \alpha Z_i + u_i$$
$$I_i = 1 \; if \; P^* > 0 \; and \; I_i = 0 \; if \; P^* \leq 0 \quad (2)$$

I_i is a binary variable which takes a value of 1 for farmers who irrigate and 0 for those who do not irrigate. Z_i represents factors that affect the irrigation decision. α denotes the vector of parameters indicating the magnitude and direction of each explanatory variable on the decision to irrigate. The residual u_i captures the unobserved factors and measurement errors.

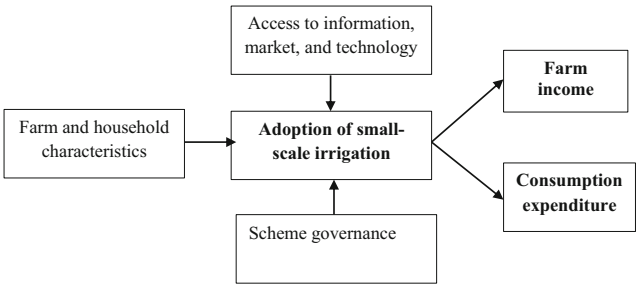

Fig. 1 Conceptual diagram

The following two regression equations represent the two regimes that the smallholder farmers fall into:

$$Regime\ 1: \quad Y_{1i} = \beta_1 X_i + \varepsilon_{1i} \quad if I_i = 1 \tag{3a}$$

$$Regime\ 2: Y_{2i} = \beta_2 X_i + \varepsilon_{2i} \quad if\ I_i = 0 \tag{3b}$$

Y_{1i} and Y_{2i} are the dependent outcome variables determined by the exogenous variables. X_i, $\beta 1$, and $\beta 2$ are parameters that show the direction and strength of the relationship between the outcome variables and the independent variables. $\varepsilon_{1i}$and ε_{2i} are error terms.

3.3 Empirical model specification

Farmers decide to irrigate if they assume that the net benefits from irrigating is higher than that of not irrigating. Several types of observable and unobservable factors may affect the farmers' decision to enroll in small-scale irrigation schemes. The latter may result in a selection bias if unobservable factors affect both error terms in the selection equation (u_i) and the outcome equation (ε). This results in a correlation between the error terms of the two equations: corr(ε,u_i) = $\rho \neq 0$. The correlation between the error terms implies endogenous switching (Maddala 1986).

The critical issue in impact study is acknowledging potential biases. Often, the literature mentions two sources of biases: observable (farm and household) characteristics and unobservable factors. In such cases, standard regression models (e.g., OLS) are biased and inconsistent (Khandker et al. 2009). Several methods are applied in impact studies, including Propensity Score Matching (PSM), Endogenous Switching Regression (ESR), and Heckman's selection model. The latter two are preferred over the former to account for a potential selection bias because PSM takes a strong assumption of unconfoundedness; i.e., in the context of the study, farm households' decision to participate in the irrigation scheme is based on observed characteristics. However, this assumption cannot be tested, and if violated, PSM would not be appropriate (Khandker et al. 2009). There are, however, differences between ESR and Heckman's selection model. Heckman's model is appropriate to account for selection bias due to selective sampling of potential outcomes (Khandker et al. 2009). Nonetheless, in our study, the two outcome variables (farm income and per adult equivalent consumption expenditure) are observed for both the irrigation users and non-users. In such a situation, ESR is the preferred method for impact assessment (Abdulai and Huffman 2014). ESR both tests and corrects any self-selection bias due to observable and unobservable characteristics.

Provided that different farm and farmer characteristics determine whether the farm household decides to irrigate or not, the following specification gives the outcome regression equations for the two regimes:

$$users: \quad Y_{1i} = \beta_1 X_i + \varepsilon_{1i} \quad if I_i = 1 \tag{4a}$$

$$non{-}users: Y_{2i} = \beta_2 X_i + \varepsilon_{2i} \quad if\ I_i = 0 \tag{4b}$$

The error terms $\varepsilon_{1i,}$ $\varepsilon_{2i,}$and u_i are assumed to have a trivariate normal distribution, with mean vector zero and covariance matrix (Lee et al. 1982),

$$\mathrm{Cov}(ui, \varepsilon 1i, \varepsilon 2i) = \begin{bmatrix} \sigma_u^2 & . & . \\ \sigma_{\varepsilon_{1i}u} & \sigma_{\varepsilon_{1i}}^2 & . \\ \sigma\varepsilon_{2i}u & . & \sigma_{\varepsilon_{2i}}^2 \end{bmatrix} \tag{5}$$

Where σ_u^2 variance of the error term in the selection equation, $\sigma_{\varepsilon_{1i}}^2$ and $\sigma_{\varepsilon_{2i}}^2$ are variances of the error terms in the outcome equations. $\sigma_{\varepsilon_{1i}u}$ and $\sigma_{\varepsilon_{2i}u}$ are covariance of ui and ε1i and ε2i respectively. Since Y_{1i} and Y_{2i} are not observed simultaneously, a covariance of the corresponding error terms is not defined (Maddala 1986). This structure of the error terms indicates that the error terms of the outcome equation and the error term of the selection equation are correlated which results in non-zero expected value of ε_{1i} and ε_{2i} given u_i- error term of the selection equation (Abdulai and Huffman 2014). Therefore, the expected values of the truncated error terms $E(\varepsilon_{1i}|\ I = 1)$ and $E(\varepsilon_{2i}|\ I = 0)$ are given below:

$$E(\varepsilon_{1i}|\ I = 1) = E(\varepsilon_{1i}|\ u > -Z\alpha) = \sigma_{\varepsilon_{1i}u} \frac{\varphi\left(\frac{Z\alpha}{\sigma}\right)}{\Phi\left(\frac{Z\alpha}{\sigma}\right)} \equiv \sigma_{\varepsilon_{1i}\,u}\lambda_1 \tag{6a}$$

And,

$$E(\varepsilon_{2i}|\ I = 0) = E(\varepsilon_{2i}|\ u \leq -Z\alpha) = \sigma_{\varepsilon_{2i}u} \frac{-\varphi\left(\frac{Z\alpha}{\sigma}\right)}{1-\Phi\left(\frac{Z\alpha}{\sigma}\right)} \equiv \sigma_{\varepsilon_{2i}u}\lambda_2 \tag{6b}$$

φ and Φ are the probability density and cumulative distribution function of the standard normal distribution, respectively. The ratio of φ and Φ evaluated at $Z\alpha$ is referred to as the inverse Mills ratio λ_1 and λ_2 (selectivity terms). If the estimated covariance $\sigma_{\varepsilon_{1i}u}^2$ and $\sigma_{\varepsilon_{2i}u}^2$ are significantly different from 0, the decision to irrigate and the outcome variables are correlated, and indicates the presence of a selectivity bias (Maddala and Nelson 1975; Maddala 1986).

Full Information Maximum Likelihood method is suggested as an efficient method for estimating the model. Following this argument and considering the assumption regarding the distribution of the disturbance terms, the

logarithmic likelihood function for the system of eqs. (5a) and (5b) is given below:

$$lnL_i = \sum_{i=1}^{N} I_i \left[ln\varphi \ \frac{\varepsilon_{1i}}{\sigma_{\varepsilon_{1i}}} - ln\sigma_{\varepsilon_{1i}} + ln\Phi(\rho_1) \right] + (1-I_i) \left[ln\varphi \ \frac{\varepsilon_{2i}}{\sigma_{\varepsilon_{2i}}} - ln\sigma_{\varepsilon_{2i}} + ln(1-\Phi(\rho_2)) \right] \quad (7)$$

Where ρ_1 and ρ_2 are correlation coefficients between the selection equation error term u_i and the error terms of the outcome equations ε_{1i} and ε_{2i}.

Furthermore, estimations of treatment effects were made. Average Treatment Effect on the Treated and Untreated (ATT and ATU) are computed using the results for expected values of the dependent variable for users and non-users in actual and counterfactual scenarios:

$$E(Y_{1i} \mid I_i = 1, X_{1i}) = \beta_1 X_{1i} + \sigma_{\epsilon_{1i}u}\rho_1 \frac{\varphi(Z\alpha)}{\Phi(Z\alpha)} \quad (8)$$

$$E(Y_{2i} \mid I_i = 0, X_{2i}) = \beta_1 X_{2i} - \sigma_{\epsilon_{2i}u}\rho_1 \frac{\varphi(Z\alpha)}{(1-\Phi(Z\alpha))} \quad (9)$$

$$E(Y_{2i} \mid I_i = 1, X_{1i}) = \beta_2 X_{1i} + \sigma_{\epsilon_{2i}u}\rho_2 \frac{\varphi(Z\alpha)}{\Phi(Z\alpha)} \quad (10)$$

$$E(Y_{1i} \mid I_i = 0, X_{2i}) = \beta_2 X_{2i} - \sigma_{\epsilon_{1i}u}\rho_2 \frac{\varphi(Z\alpha)}{(1-\Phi(Z\alpha))} \quad (11)$$

ATT is the difference between the expected value of the outcome variable from eqs. (8) and (10) and measures the difference in the expected value of the dependent variable for users with and without the use of irrigation. ATU is the difference between eqs. (9) and (11) and estimates the difference in the expected value of the outcome variable for non-users had they used irrigation.

3.4 Study area, study design, and data

Wondo Genet is located in the south-central rift valley of Ethiopia, about 263 km south of Addis Ababa. It covers an area with altitude ranging from 1600 to 2580 m above sea level. The mean annual temperature is between 17 °C and 19 °C and the climate is characterized as sub-humid with bi-modal rainfall distribution. The area receives an annual average rainfall of 1079.7 mm; February to April is a low rainfall period, and June to September is the main rainy season. According to the Ethiopian Central Statistical Authority (CSA), the study area has a population of 191,116, and 78.13% live in rural areas. It is one of the most densely populated areas in the country. The average landholding of the sampled households is 0.40 ha versus the national average of 1.37 ha. Small-scale perennial crop production is the dominant farming system in the area with '*enset*', khat, and sugarcane being the major crops (Dessie and Kinlund 2008).

Wondo Genet district was purposively selected for its relative long years of practice in small-scale irrigation. There are two major rivers (Worka and Wosha) currently being used for irrigated agriculture. The Worka river irrigation scheme was selected for the study because it is the oldest modern scheme in the area and covers a wide area, with the potential to irrigate about 272 ha of agricultural land. The '*kebele*'[1] selected for this study is clustered into 33 farmer groups, and only nine farmers groups were users of the irrigation scheme. A farmer group includes 40 to 75 households. There are a total of 680 (660 male- and 20 female-headed) households currently using the irrigation scheme.

The study used both qualitative and survey methods to gather data.

For the qualitative study, we carried out key informant interviews, focus group discussions (FGDs) and direct observations to explore the irrigation infrastructure, scheme governance, and water use practices, and triangulated the survey results. Key informants were held with three experts from the district agriculture and rural development office (i.e., the heads of the district, irrigation, and crop production work processes). The questions were related to irrigation practices and implementation modalities of the Worka river irrigation scheme. Likewise, three FGDs were held with irrigation users and non-users, and one with water users' associations (WUA) committee members. The results of the FGDs and key informant interviews were mainly used to analyze the irrigation infrastructure, scheme governance, and water use practices as well as to triangulate the survey results.

Following the qualitative study, a large quantitative survey was carried out using a structured questionnaire. First, a sampling frame was prepared based on a list of farm households obtained from the district agriculture and rural development office registry. It was necessary to stratify all farm households based on their relative location along the scheme (i.e., the 'Worka' river) because spatial variation in irrigation water use can lead to disputes (e.g., D'Exelle et al. 2012; Kalu et al. 1995). Accordingly, the farm households were categorized into three categories: upstream, middle-stream, and downstream. For this purpose, a two-stage sampling procedure was performed. In the first stage, the households farming in the upstream, middle stream, and downstream parts of the 'Worka' river were identified. In the second stage, 80 households (each) were randomly drawn (using a systematic random sampling technique) from the three categories. The two-stage approach increases variation and ensures that households from the three locations are represented. Furthermore, the application of ESR in our study would account for a potential selection bias in our sample. Second, the survey questionnaire was pre-tested for potential ambiguity in the survey questions. Finally, data were collected from 240 smallholder

[1] Peasant association, which is the lowest administrative unit in Ethiopia

farmers located in Wotera Kechema '*kebele*' and based on information about the 2014/15 cropping season. The sample represents 35% of the irrigation users along the 'Worka' river irrigation scheme. Five enumerators undertook the household survey following intensive training and practice. The selected enumerators spoke the local language (*Sidamu Afo*), which was used to conduct the survey. The principal investigator also speaks the local language, which made it easier to supervise and coordinate the data collection process.

4 Results and Discussion

4.1 Analysis of the irrigation infrastructure and scheme

The modern irrigation scheme was built in 1993 (with the help of an NGO) with the potential to irrigate 272 ha of land both in the upstream and downstream part of the river. The headwork of the scheme on the river channels water into two diversions (Wotera Kechema and Wosha diversions), serves two '*kebeles*', and currently covers a total of 245 ha. The main canal used to divert the river to '*Watera Kechema*' is 4.6 km long from the headwork. Only part of the major canal (1.648 km), which is used to divert the river from the headwork, is concrete and cement lined. The rest of the waterway is an earthen canal dug by the farmers themselves, leading to heavy water loss during transportation. Generally, rainfall in excess of evapotranspiration and groundwater recharge is required for a profitable investment in small-scale irrigation (You et al. 2011). The study area has an average annual rainfall (i.e., 1079.7 mm), which is 35 mm above the African average and only 71 mm less than the world average. This problem is not unique to the study area. Water loss through seepage and runoffs is also a common problem in other irrigation schemes in Ethiopia (Yohannes et al. 2017).

Records obtained from the district agriculture and rural development office indicates an average conveyance efficiency of canals at 65%, suggesting high water loss in the study area. A similar study in India (Rath and Swain 2018) reported a conveyance efficiency of 90.5% (Senhapali distributary) and 81.2% (Paramanpur distributary). In the study context, the mode of irrigation is only furrow, and modern irrigation technology is nonexistent. Furthermore, communal or private water storage facility is almost zero in the area; only one farmer reported having some kind of water storage system. Of the farmers who did not have any water storage mechanism (reservoir), 13.7% of them claimed to have either a small farm, no storage space or a steep slope; 24% of the farmers lacked surplus water to reserve; and 53% of the farmers reported to have let the water go. The results imply limited awareness of water storage systems that could be used to harvest water during the rainy season. Supplemental irrigation in the study area is mostly practiced from December to March. During these months, khat and sugarcane, on average, get 3 and 4 days of irrigation per week, respectively. As per the bylaws of the WUA, the allocation of water is based on the size of the irrigable plot for all users. However, water requirements of crops, distribution and use are not considered.

Currently, the irrigation scheme is constrained by a high level of 'water scarcity', according to the district agriculture and rural development office. This was later confirmed by 99% of the farmers in the survey; they claimed to have perceived ever decreasing precipitation in the area over the last 10 years. The allocation of irrigation water has been carried out by the WUA. Before the establishment of the modern scheme, irrigation use was governed through informal institutions, called '*water fathers*' – a well-respected and trusted group of individuals in the community. Our FGDs revealed that little or no problem was observed when the allocation of irrigation water was administered under these traditional leaders. However, disputes over the allocation of irrigation water surfaced with the introduction of the modern irrigation scheme. More importantly, '*water fathers'* were left out of governance of the scheme (i.e., allocation decisions, dispute resolution, etc.) and replaced by the WUA.

Key informants, which involved only local government officials, however, did not attribute the current irrigation water scarcity to governance of the scheme but rather to physical water scarcity and population pressure. Approximately 92% of the households in the survey d that irrigation water was not sufficient to meet their current needs. The remaining 8% of the households, who responded positively, were all from upstream areas. Despite differing views on the source of the problem, both the FGDs and key informant interviews confirmed increasing irrigation water scarcity in the study area, suggesting the necessity of more effective governance of the scheme.

4.2 Analysis of the institutional environment

The study provides an overview of three types of institutions influencing the use of irrigation water in the study area: collective action (WUA), market characteristics, and access to information.

4.2.1 Water user association (WUA)

Like most water use associations in Ethiopia, the WUA was established in 1993 by the government in 1993, which dismantled the traditional practices of irrigation water use that had existed for many years (see section 4.1). Participants of the FGDs revealed that members paid no fees for membership or the use of irrigation water. However, users were expected to contribute (1) free labor to clean and maintain the tertiary canals, mostly once a year, just before the start of the irrigation

season; (2) contribute money if the main canal was damaged and needed to be repaired; and (3) pay 20 to 50 birr[2] to cover part of the expenses related to irrigation canal operators and water guards.

The use of irrigation water is managed by a committee whose members are elected by the WUA. Depending on the number of members, each farmer group in the study area is represented by one or two individuals of the committee. A committee usually consists of 11 individuals: a chairperson, deputy, and secretary; two controllers; three water distributors; and three members of the conflict resolution sub-committee. A committee member is supposed to serve for a year but can be re-elected for an unlimited number of times. According to the bylaws, a committee member could be suspended or dismissed from the committee for violating the stated rules. According to the participants of the FGDs, local authorities and development agents have undue influence on the (re)election process. As a result, committee members often align themselves with local authorities, further eroding the users' trust in the association. As per the bylaws, the committee should meet once per week to discuss the maintenance of the irrigation canals, watershed management, water allocation, distribution schedules and other outstanding issues related to the irrigation scheme. But participants during the FGDs revealed that the committee members do not meet regularly.

There is no local water use policy in place to guide the committee's decision making. According to participants of the FGDs, the current water use practices were flawed . Over-abstraction of water by upstream users and water theft were common despite the stated fine of 500 birr[3] for such acts and there were repeated complaints against committee members and the current scheme of governance. Most of the complaints were related to the lack of established water use policies and corrupt practices. Some of the direct quotes from the FGDs related to the current scheme governance include the following:

- "*There should be fair distribution of water between the rich and the poor, and the committee members should have integrity.*"
- "*The committee should distribute the water fairly between people in the upstream and downstream part of the river.*"
- "*The committee should create awareness programs on the use of irrigation water.*"
- "*They should create a forum for all the users to find better solutions about current use of irrigation water.*"
- *The committee should work on improving relationships among users in the community.*
- "*Though there is scarcity, there are ways to get more water. If you can bribe the committee and water guards, you can get enough water*".
- "*They are deceivers, and highly corrupt; something must be done about it.*"

The current conflicts over the use of irrigation water in the study area appear systematic. The conflicts were largely attributed to governance rather than physical water scarcity. In the words of one of the participants, "*It is the committee that is creating the scarcity. We are trying to adapt to it by bribing its members*". Indeed, the problem is expected to be worse in the future as the physical water scarcity increases. Therefore, despite a huge investment in small-scale irrigation projects in Ethiopia, the existing practices of irrigation water use are largely ill-defined (Amede 2015). Several studies in Africa have documented the increasing importance of a polycentric approach in the governance of small-scale irrigation schemes (e.g., Lecoutere 2011; Baldwin et al. 2016). This approach has proved to be effective in searching for new solutions (i.e., institutional arrangements) as disputes emerge.

4.2.2 Market characteristics

Market characteristics are one aspect of the institutional factors considered important in this study for two main reasons. First, the decision to grow crops during the off-rainy season (and thus become a member of the WUA) may be influenced by the households' market orientation. Second, the two most important crops frequently grown using irrigation water (i.e., sugarcane and khat) are the most important cash crops in the study area.

The local markets are located approximately within a 5.4 km radius of the study area. Considering a cut-off travel time of five hours to the nearest market (You et al. 2011), the households in the study area have modest access to market. Nonetheless, the marketing system in that part of the country is underdeveloped; most farmers sell their produce at the farm gate and often involve brokers (Abebe et al. 2016). For example, approximately 48% of sales from all crops and 91% of sales related to sugarcane and khat involve brokers. There are no well-functioning marketing cooperatives in the area. Like many other places in Ethiopia, farmers in the study area are dependent on the government for the supply of modern inputs such as fertilizers and improved seed varieties. Access to formal credit is very limited even though two micro-finance institutions – Sidama and Omo– have branches located in the district; only 4.5% reported to have had access to credit from both formal and informal sources.

4.2.3 Access to information

Access to information and extension services is critical to understanding the importance of irrigation water and the enhancement of food production and food security in rural communities. In the context of this study, the district agriculture

[2] One US dollar is approximately equivalent to 27.3 Ethiopian birr.
[3] One US dollar is approximately equivalent to 27.3 Ethiopian birr.

and rural development office is responsible for the provision of extension services. These were provided by four extension agents, specializing in crop production, natural resource protection, livestock husbandry and veterinary work. The extension agents were primarily responsible for: (1) the promotion and dissemination of modern agricultural inputs; (2) the provision of technical support and advice to farmers; (3) organizing and training farmers in new farming practices; and (4) providing up to date information related to weather and market conditions. The study area was strategically located close to the regional research center (South Agricultural Research Institute) and an agriculture-based academic institution (Hawassa University College of Forestry). However, extensions services from such institutions were fragmented and limited to their thematic areas and research priorities.

4.3 Descriptive statistics of variables used in model estimation

Table 1 presents descriptive statistics of the survey data for the relevant variables included in the model estimation. Chi-square test and t-test were used to test for statistical differences between irrigation users and non-users on the mean values of the categorical and continuous variables, respectively.

Irrigation users had a significantly higher mean value for all the variables except for those related to gender, education level, off-farm income, and extension services (Table 1). The number of households among the non-users who acknowledged high level of water scarcity was significantly higher than the user households. Mean values for ownership of radio and mobile phone, which are used

Table 1 Summary statistics for irrigation users and non-users

Variable and variable definition	Measure	Users ($n = 160$)	Non-users ($n = 80$)	p value
Household characteristics				
Head of the household (1 = male)	Dummy	0.95	0.98	0.20[1.61]
Age of the head of the household (year)	Continuous	46.95	43.58	0.038**
Household size in adult equivalent units	Continuous	5.61	5.09	0.024***
Labor endowment in adult equivalent units	Continuous	3.86	3.26	0.003***
Education level of the head (school years)	Continuous	2.96	2.73	0.285
Highest education by an adult member of the household (school years)	Continuous	4.22	3.37	0.038**
Farm characteristics				
Landholding per plot (ha)	Continuous	0.172	0.148	0.02***
Land covered by cash crop	Continuous	0.780	0.613	0.000***
Asset				
Landholding (ha)	Continuous	0.436	0.323	0.007***
Household asset value (ETB)	Continuous	66,709	26,928	0.000***
Income and Consumption				
Farm income per ha (ETB)	Continuous	432,507	101,689	0.000***
Non-farm income (ETB)	Continuous	3,166	4,033	0.230
Total per adult equivalent food consumption expenditure (ETB)	Continuous	3965	2848	0.000***
Access to market and modern technology				
The distance of the nearest market (km)	Continuous	5.29	5.74	0.060**
Chemical fertilizer use per ha (kg)	Continuous	929.5	621.8	0.000***
Insect/herbicide use per ha (ETB)	Continuous	21.5	12.7	0.002***
Institutional and information access related variables				
Visit by extension agent during last 6 months (Yes = 1)	Dummy	0.88	0.87	0.776[0.08]
Perceived water scarcity (highly scarce = 1)	Dummy	0.50	0.97	0.000[52.41]***
Ownership of radio (Yes = 1)	Dummy	0.63	0.46	0.013[6.21]***
Ownership of mobile phone (Yes = 1)	Dummy	0.66	0.35	0.000[21.12]***
Extent of scheme governance problem (1 = little/no; 5 = high	Ordinal	4.3	4.9	0.000[33.68]***
Measures taken to increase water share (1 = little/no effort 5 = high efforts including bribing)	Ordinal	3.41	3.3	0.000[42.99]***
Role of WUA committee in the prevailing scheme governance problem (1 = little/no, 4 = high)	Ordinal	3.5	3.7	0.12[5.71]*

****significant at 1% level, **significant at 5%level, significant at 10% level. Chi-square in square brackets*

Source: own calculation from survey data

to access information, were significantly different between the users and non-users.

In addition, sampled households were asked several questions regarding the governance of the irrigation scheme including: (1) their level of agreement/disagreement regarding the prevailing water scarcity and governance scheme (2) actions taken at the household level to increase water share, and (3) the role of the WUA committee in the prevailing water scarcity and governance issues. The first variable was measured using a five-point Likert scale. A score of five to the question "*To what extent do you agree that the current water scarcity problems are largely due to mismanagement rather than physical scarcity of water"* demonstrates the highest level of agreement. A limitation with the odd-number response Likert scale is the central tendency bias (related to interpreting a midpoint scale such as "indifferent", "no opinion", etc.). In our study, this problem was minimized as the survey was administered in person; respondents were encouraged to ask for clarification and whether they understood the questions before giving their answers. The other two variables – 'Measures taken to increase water share' and 'Role of WUA committee in the prevailing scheme governance problem' – were constructed by developing indices based on responses to several questions.

Scheme users and non-users generally agreed that the prevailing water scarcity was due to poor governance; however, the mean score of the latter was significantly higher (Table 1). Tests for the indexed variables were also significant. The mean value for the current irrigation scheme participants was higher than the non-users, meaning that the former tend to take some measures (including bribing WUA committee members) to maximize their water share (Table 1). The third variable measured the role of WUA committee in the prevailing governance problem. The mean values were close to four for both users and non-users, indicating poor governance. A similar result was found in a study undertaken in Southern Ethiopia, where farmers rated fairness of water allocation by WUA as 'poor' (Yami 2013).

The descriptive statistics, however, provides only the observable situation and mean differences cannot be used to make conclusions about the factors that affect farmers' decisions whether to irrigate or not. Furthermore, the above analysis does not account for unobservable characteristics. Results of the econometric analysis are presented and discussed below.

4.4 Econometric results and discussion

4.4.1 Poverty analysis

The level of poverty between irrigation water users and non-users was tested using Foster-Greer-Thorbecke (FGT) indices. Based on the recommended daily energy requirement of the 2100Kcal, Poverty line (Z) of Birr 3,329.27 (=USD 123.30) per adult equivalent per year was used to estimate the FGT indices of poverty. The poverty line was constructed using food and non-food per adult equivalent consumption expenditure of the households (Table 2).

The incidence of poverty was measured by the headcount index and shows that 67% of the households that did not have access to irrigation fell below the consumption-based poverty line (Z) of ETB 3,329. On the other hand, only 28% of the farmers who participated in the irrigation scheme were below the poverty line. This result reinforces the claim that prevalence of poverty is higher among households relying heavily on rain-fed agriculture as opposed to those that irrigate (Bacha et al. 2011; Hanjra et al. 2009). The depth and severity of poverty were also higher among the non-users. The consumption expenditure of the non-users should be increased by 18% of its current amount if they were to be lifted out of poverty but only by 3% for users. These results are in line with most micro level empirical studies on poverty and irrigation linkages. Bacha et al. (2011), for instance, reported the depth of poverty among non-irrigation users in the Ambo district of Western Ethiopia) at 21% while it was only 10% among users.

4.4.2 Endogenous switching regression (ESR) model estimation results and discussion

Consistent with the descriptive and poverty analysis above, there is a significant difference between the users and nonusers in several relevant variables and welfare indicators. These differences could be due to several observable and unobservable factors in addition to differential access to irrigation. Two outcome variables were used as proxies for food security: farm income per ha and adult equivalent food consumption expenditure. Such indicators have been frequently used in past studies (Amare et al. 2012; Shiferaw et al. 2014). Table 3 presents the estimation results for the model with farm income per hectare as the outcome variable.

The second column of Table 3 reports the estimates for the determinants of small-scale irrigation adoption. Education and age have a positive non-significant association with farmers' decision to participate in the irrigation scheme though other studies have indicated a positive relationship (e.g., Deressa et al. 2009; Nhemachena and Hassan 2007). Huffman

Table 2 Foster-Greer-Thorbecke indices on consumption at $\alpha = 0$, 1, and 2 and Z = ETB 3746.77

Poverty estimates	Groups	
	Users	Nonusers
Incidence	0.28	0.67
Depth	0.03	0.18
Severity	0.008	0.06

Source: computation on own survey date

Table 3 Estimates of the switching regression model for farm income per ha

Variables	Model Estimates		
	Irrigation 1/0	Users	Non-users
Highest education level of adult member	0.023(0.64)	−0.018(1.58)*	0.004(0.21)
Age of the household	0.011(1.23)	−0.003(0.89)	0.002(0.33)
Log of distance to the nearest market	−0.001(0.03)	−0.021(1.09)	−0.040(1.21)
Visit by extension workers	0.078(0.24)	0.198(1.61)*	0.178(0.84)
Log of landholding	0.434(1.34)	0.415(3.73)***	0.578(2.45)***
Log of landholding per plot	−0.441(1.08)	−0.267(1.95)**	−0.652(2.33)***
Log of percentage of land covered by cash crop	1.27(3.48)***	0.423(3.10)***	−0.295(1.39)
Log of time endowment in adult equivalent units	−0.003(0.01)	0.019(0.19)	0.110(0.53)
Log of non-farm income	−0.096(2.80)***	−0.001(0.09)	0.046(2.51)***
Log of chemical fertilizer applied	0.115(0.86)	0.202(3.81)***	0.095(1.18)
Log of pesticide applied	0.092(1.09)	0.149(4.09)***	0.142(2.61)***
Owned radio(Yes = 1)	0.594(2.50)***		
Owned mobile phone (Yes = 1)	0.959(4.02)***		
Perceived water scarcity (High = 1)	−1.911(5.10)***		
Extent of scheme governance problem (1 = little/no; 5 = high	−0.846(3.35)***		
Measures taken to increase water share (1 = little/no effort 5 = high efforts including bribing)	0.149(1.85)**		
Role of WUA committee in the prevailing scheme governance problem (1 = little/no, 4 = high)	−0.330(2.12)**		
Constant	4.49(2.48)***	11.40(27.15)***	9.31(12.51)***
ρ_1, ρ_2		−0.822[0.115]***	−0.518[0.232]**
Model diagnosis			
Wald x^2	115.40**		
Log-likelihood	−255.09		
LR test of independence	19.76***		

Absolute value of z statistics in parenthesis standard errors in square brackets

**Significant at the 10% level, ** Significant at the 5% level, ***Significant at the 1% level*

Source: Own calculation using survey data

(2001), however, argues that when an intervention has been there for a relatively long time, education and experience may not significantly affect the decision to participate. Thus, the positive but non-significant relationship between education and age and adoption could be because irrigation has been practiced for at least the last 30 years in the study area.

Land covered by cash crops has a positive impact on the decision to irrigate; households with a larger share of their land covered by cash crops are more likely to irrigate than others with smaller proportions of land covered by cash crops. In the study area, irrigation was practiced in the cultivation of the most important cash crops, sugarcane and khat. Land size per plot, on the other hand, had a negative effect on the decision to irrigate. This is possibly because farmers with smaller plots increase their food production through irrigation in addition to relying on the occurrence of rain. Previous studies, however, documented mixed results on relationship between plot size and the adoption of agricultural technology (Bradshaw et al. 2004; Deressa et al. 2009; Khonje et al. 2015).

Similarly, time endowment shows a negative association with the decision to irrigate. This can be attributed to the high population density and land fragmentation in the study area. This result is consistent with one study in Ethiopia (Tizale 2007) but different from another study which showed a positive association between labor endowment and adoption decision (Deressa et al. 2009). In southern Ethiopia, however, the rural youth is forced to search for alternative livelihood options because of the scarcity of agricultural land (Bezu and Holden 2014). It is worth noting that the average land holding of the surveyed households is 0.4 ha, which is significantly less than the national average of 1.37 ha (Central Statistical Agency and the World Bank 2013).

Non-farm income has a negative and significant impact on the practice of irrigation. This result is consistent with economic theory that participation in non-farm activities may constrain the amount of labor available for farming.

As expected, intensive use of chemical fertilizer and pesticide is positively correlated with the decision to

irrigate. This result is in keeping with previous studies (Gebregziabher et al. 2009; Namara et al. 2010; Smith 2004) and confirms the view that a stable supply of irrigation water would encourage farmers to invest in productivity-enhancing inputs (Aberra 2004).

Variables for access to information (proxied by ownership of radio and mobile phones), perceived level of water scarcity, and scheme governance (proxied by three variables) were used in the selection equation but not in the outcome equation. This is because a correct specification of the model requires the inclusion of at least one explanatory variable in the former which directly affects the irrigation decision but not the outcome variable (Abdulai and Huffman 2014; Khonje et al. 2015). Estimates for ownership of radio and mobile phone variables were positive and significantly different from zero. Farmers' perception of the scarcity of water in their area was negatively and significantly correlated with the likelihood of irrigation water use. This is supported by previous studies from developing countries, including Ethiopia (Hanjra et al. 2009; Namara et al. 2010).

Scheme governance is the main focus of this study, and was measured by three variables – 'Extent of the scheme governance problem', 'Measures taken to increase water share', and 'Role of WUA committee in the prevailing scheme governance'. As shown in Table 3, all three variables are significantly correlated with farmers' decision to participate in the irrigation scheme. Accordingly, the existing scheme governance in the study area is affecting the irrigation water use in three ways. First, it is creating additional scarcity unrelated to the physical availability of water due to the poor management of the physical infrastructure and corrupt practices. Second, due to the perceived water scarcity, some farmers are excluded from participation and forced to rely soley on rain-fed agriculture. Finally, other farmers have to incur additional expenses for bribing committee members and water guards. About 78% of the respondents believe that members of the WUA committee were corrupt with regard to the allocation of irrigation water. Farmers who have an adaptation strategy (e.g., bribing committee members and water guards) are more likely to be users of the irrigation scheme. Of the households that currently have access to the irrigation scheme, 34% stated that they had bribed committee members or water guards to get more water during the last irrigation season. Other studies in Northern and Eastern Ethiopia have also indicated the existence of 'bribery', 'corruption', and 'rent-seeking' behavior among WUA committee members (Deneke et al. 2011; Yami 2013). Sampled farmers perceived that the WUA committee was responsible for the prevailing governance problem of the scheme. Current bylaws authorize theWUA committee to develop a system that ensures fair distribution and efficient use of irrigation water for both upstream and downstream farmers in the area. However, the findings of the survey suggest otherwise. These were consistent with the results of both the FGDs and past studies. These show that poor governance is a key factor in small-scale irrigation schemes in SSA (Belay and Bewket 2013; Dudu and Chumi 2008).

The model estimates of the variables against farm income per ha for users and non-users are presented in the third and fourth columns of Table 3. Correlation coefficients ρ_1 and ρ_2 show that they were statistically significant for both adopters and non-adopters. Indeed, the use of ESR was proved to be appropriate in our study, as the results indicated the existence of selection bias. The estimate was also negative for both users and non-users indicating positive selection bias such that farmers with above-average farm income tended to irrigate. The likelihood ratio test was also significant, indicating the existence of joint dependence between the outcome and selection equation between users and non-users.

Education showed a negative and marginally significant effect on farm income per ha for the adopters. Di Falco et al. (2011) also found a similar result in Ethiopia. Accordingly, households with a high education level in the family tend to be involved in nonfarm employment. This, however, may come at the expense of the farm income because of less time being allocated to farm activities. Distance to the nearby local markets also negatively and significantly affected the farm income per ha for both users and non-users. The proxy variable measuring access to information (agricultural extension agents) showed a positive association with farm income for both users and non-users. This is in line with the theory that farmers with better information and access to extension agents are likely to have better productivity (Abdulai and Huffman 2014). Landholding had a positive and significant impact on the outcome variable for both users and non-users. This is consistent with an earlier study in Ethiopia (Belay and Bewket 2013). On the contrary, landholding per plot had a negative and significant impact on farm income for both users and non-users. This may be due to an inverse farm size-productivity relationship. Past studies have indicated that small farms are more productive than big farms (Abdulai and Huffman 2014). A study in Ethiopia also found a strong association between land pressure, crop yield, and income (Headey et al. 2014). The amount of non-farm income was positively correlated with non-users. This may suggest that failure to participate in irrigation schemes may force farmers to look for alternative sources of income. As expected, intensive use of chemical fertilizers and insecticides/herbicides was positively associated with farm income of both users and non-users; this relationship was very strong for irrigation scheme users. The proportion of farm covered by cash crops, such as khat and sugarcane, had a significant and positive impact for irrigation users. For example, scheme beneficiaries harvested khat, one of the most traded cash crops in the area, at least twice per year (mostly three times), while non-users harvested the same crop only once per year (due to their reliance on rainwater). The strong correlation between the share of

irrigable land and cash income was also confirmed by a similar study in other parts of Ethiopia (Amede 2015).

Model estimation was also carried out using total per adult equivalent food consumption as the dependent variable. Table 4 presents the model estimates.

The results of the selection equation with food consumption considered as outcome variable are presented in the second column of Table 4. The direction of relationships reported in Tables 3 and 4 are similar, with some variation in the level of significance. New explanatory variables such as farm income and the value of household assets had a positive and highly significant effect on the farmers' decision to irrigate; these findings are consistent with those of Bacha et al. (2011) and Deressa et al. (2009).

The factors that affect food consumption are reported in the third and fourth columns of Table 4. Estimates for variables related to household were negative and significantly different from zero for both users and non-users. This may be because, other things kept constant, large household size means less consumption per-head. Similar results were reported by Khonje et al. (2015) and Bacha et al. (2011) in the context of Eastern Zambia and Western Ethiopia, respectively with positive and significant relationships reported between non-farm income and increased consumption for non-users. This is expected as non-users tend to augment their income and consumption expenditure from non-farm activities (Dorward et al. 2004). Similarly, in keeping with earlier findings (Bacha et al. 2011), the value of household assets was positively and significantly correlated with consumption expenditure for both groups of farmers.

Finally, the average treatment effect on the treated (ATT) and untreated (ATU) is presented in Tables 5 and 6.

As presented in Tables 5 and 6, access to irrigation significantly affects both outcome variables for both groups. For the current irrigation users, their farm income per hectare and annual per adult equivalent food consumption expenditure would have decreased by 42% and 35%, respectively if they had not used irrigation. This suggests that current irrigation users would have lost farm income per ha of birr 151,419 (or US$ 5,500) and per adult equivalent consumption expenditure level of birr 1,338 (or US$ 49) had they not used irrigation water, respectively. Similarly, the farm income per ha and annual per adult equivalent food consumption expenditure of non-users would respectively increase by 149% and 40% if

Table 4 Estimates of the switching regression model for per adult equivalent food consumption

Variables	Model Estimates		
	Irrigation 1/0	Users	Non-users
Log of farm income	1.55(5.75)***	0.075(2.16)**	0.061(0.87)
Highest education level of adult member	−0.013(0.28)	0.001(0.23)	0.002(0.29)
Age of the household head	0. 013(0.91)	2.6 e-05 (0.02)	4.2–04(0.16)
Log of landholding	−0.919(2.07)**	0. 033(0.65)	0. 060(0.83)
Log of land size allocated to cash crops	0. 394(1.20)	0. 032(0.93)	0. 056(1.15)
Log of adult equivalent household size	−0.559(1.23)	−0.365(7.26)***	−0.597(5.81)**
Log of productive adult equivalent labor to total adult equivalent household size	−0.123(0.17)	−0.218(2.69)***	−0.157(0.94)
Log of non-farm income	−0.036(0.90)	−0.001(0.25)	0. 017(2.26)**
Log of value of household assets	0. 219(2.63)***	0.034(3.13)***	0. 029(1.73)*
Log of number of extension officers visit	−0.254(1.68)*		
Owned radio(Yes = 1)	−0.208(0.65)		
Owned mobile phone (Yes = 1)	0. 575(1.70)*		
Perceived water scarcity (high = 1; Low = 0)	−1.355(2.86)***		
Mismanagement of the scheme	−1.318(3.34)***		
Measures/Actions to get more water	0.145(1.17)		
Constant	−13.609(3.58)***	7.66(15.60)***	8.06(9.92)***
ρ1, ρ2		0. 35[0.250]*	0. 34[0.459]*
Model diagnosis			
Wald x2	81.59***		
Log-likelihood	−35.77		
LR test of independence	2.03*		

Absolute value of z statistics in parenthesis and standard errors in square brackets

**Significant at the 10% level, ** Significant at the 5% level, ***Significant at the 1% level*

Source: Own calculation using survey data

Table 5 Impact of irrigation on farm income and consumption-ATT

Outcome variable	Mean outcome		ATT		t-value
	I = 1	I = 0			
Log of farm income per ha	356,407	204,916	151,419	42%	7.73***
Log of total per adult equivalent consumption	3,817	2,479	1,338	35%	18.47***

****significant at the 1% level, Source: own calculation from survey data*

Source: own calculation from survey data

they had had access to irrigation. The better livelihoods of beneficiaries of the irrigation scheme was also confirmed through direct observations of the housing conditions by the principal investigator and during FGDs and key informant interviews. In one of the FGDs, for instance, one of the participants described the situation as follows"…*It is a pity that our fellow farmers who are using irrigated agriculture are making lots of money while those of us who rely on rain-fed agriculture run out of cash off the rainy season and sell our produce in seasons when everything is cheap*…" Another participant added that "*Lack of irrigation water has reduced my production potential by more than half*." This assessment is consistent with previous studies that reported a positive direct link between irrigation use and farm income (Amede 2015; Bacha et al. 2011; Belay and Bewket 2013; Smith 2004; Wichelns 2014). According to De Haen (2003), the use of irrigation has the potential to increase crop yields by 100 to 400% compared to the rainfed crop production system.

In sum, the findings confirm that access to a small-scale irrigation scheme was significantly correlated with increased farm income and food consumption (Tables 5 and 6) and has addressed the availability and access dimensions, which are prerequisites for household food security (Barrett 2010; Denny et al. 2018). Irrigation allows year-round production of two of the locality's most important cash crops, sugarcane and khat. Unsurprisingly, irrigation users had a lower incidence of poverty (28%) than the non-irrigation users (67%). This is consistent with several studies in Ethiopia (e.g., Tesfaye et al. 2008; Bacha et al. 2011; Hussain and Hanjra 2004). For example, Tesfaye et al. (2008) reported a household food security rate of 70% for small-scale irrigation users while the corresponding rate for non-users was only 20%. However, our study went a step further in order to identify key determinants of participation in irrigation schemes and found scheme governance to be an important factor (Table 3). Both the FGDs and survey results confirm that the governance of the existing irrigation scheme was highly deficient, discouraging households from participating in the scheme. Thus, if small-scale irrigation schemes are to contribute to food security by means of increased farm income (i.e., food availability) and improved consumption (i.e., accessibility), the existing irrigation scheme of governance (i.e., the allocation of irrigation water via the WUA committee) has to be improved. One way to do this is to involve informal institutions such as 'water fathers' in the decision-making process. Ironically, the current situation has created additional scarcity, excluding some farmers from being users and leaving others to obtain water through corrupt practices.

5 Conclusions

Although past studies generally highlight the potential impact of investment on small-scale irrigated agriculture in enhancing productivity and food security, empirical evidence is varied and context-specific. Among the less explored but perhaps the most important in agricultural irrigation is the role of institutions. Only a few studies have documented the importance of governance and informal institutions in enhancing the contribution of small-scale irrigated agriculture to food security (Mutambara et al. 2016; Mukherji 2012).

This study has analyzed the determinants of adopting small-scale irrigation schemes and the impact these may have on food security in the case of Ethiopia, where agricultural land is extremely fragmented and densely populated. Ethiopia provides an interesting perspective as it has been

Table 6 Impact of irrigation on farm income and consumption-ATU

Outcome variable	Mean outcome		ATU		t-value
	I = 1	I = 0			
Log of farm income per ha	197,404	79,097	118,307	149%	10.46***
Log of total per adult equivalent consumption	3779	2,690	1,089	40%	12.44***

****significant at 1% level*

Source: own calculation from survey data

aggressively pursuing small-scale irrigation schemes across the country. Empirical work was carried out in a region where relatively modest annual rainfall is present, providing a good opportunity to determine behavioral and institutional factors influencing the decision whether or not to enroll in irrigation schemes. Assessment of the physical irrigation infrastructure revealed performance problems of the canals, leading to significant water loss during transportation. Irrigation technology was only a furrow, and there were no water storage facilities.

Poverty analysis was made using the FGT indices based on an own constructed consumption poverty line. The incidence, depth, and severity of poverty were found to be higher among farmers who did not have access to irrigation. Further analysis was made, using ESR, to examine the determinants of farmers' decisions to irrigate and the impact of irrigation on household food security. The results indicated selection bias among users and non-users. Variables relating to institutions – governance of the irrigation scheme, access to information – and perceived water scarcity had a significant impact on farmers' decisions to irrigate. The use of irrigation water was managed by the WUA committee, which was described as untrustworthy, unfair, corrupt and exacerbating water scarcity. Among the other factors that affected farm income were intensive use of chemical fertilizers and pesticides, total landholding, landholding per plot, and distance to nearest market. Regarding per adult equivalent food consumption, farm income, non-farm income, household assets, household size and dependency ratio had significant impacts. The treatment effects (ATT and ATU) were positive and significant for both users and non-users, indicating that access to irrigation has resulted in a significant positive impact on farm income and consumption expenditures. Our findings show that even with poor irrigation infrastructure and technology and small plot sizes (0.4 ha on average), participation in small scale irrigation schemes had significantly improved farm income by 42% (or approximately birr 151,419 or US$ 5,500 per ha) and consumption by 35% for users compared to their counterfactual situations. Controlling other variables related to assets, farm and household characteristics, we found institutional factors had strong negative effects on the adoption of small-scale irrigation schemes. Consequently, much of the perceived water scarcity was attributed to governance rather than scarcity of water.

In conclusion, the study has demonstrated that adoption of small-scale irrigation schemes improves food security through increased farm income (availability) and consumption (access). However, access to small-scale irrigation is significantly influenced by governance, in addition to the conventional farm and household characteristics associated with adoption of agricultural technologies. In the study area, the mismanagement of irrigation use has severely affected participation and the potential for reducing poverty through primary food production. These findings also provide several policy implications. We showed that access to irrigation water had a significant positive impact on rural livelihoods but required intervention in several aspects. Regarding physical infrastructure, renovating and improving the canals is the best starting point for reducing wastage and ensuring access of more people to irrigation water. Additional water storage facilities could significantly enhance the availability of water and its multiple uses such as in fisheries.

These findings highlight the need to design appropriate governance schemes to enhance the contribution of small-scale irrigated agriculture for household food security. Raising managerial skills and preventing corrupt practices of the WUAs that are mushrooming across the country is crucial for the improvement and welfare of rural households. WUAs should be supported by sound policies for water use with appropriate oversight by local authorities to enhance the efficiency and equity of irrigation water use. We suggest the involvement of the traditional leaders (i.e., the so-called "*water fathers*") to build trust in the governance of irrigation schemes. Several studies in Africa have documented the increasing importance of "institutional pluralism" that involves local communities (informal institutions) but provides local governments with more authority in the governance of small-scale irrigation schemes (e.g., Lecoutere 2011; Baldwin et al. 2016). This approach has proved to be effective in searching for new solutions (i.e., institutional arrangements) as disputes emerge. Targeted technical support from extension officers could play a significant role in making effective use of irrigation water. The findings also highlight the increasing reliance of non-irrigation users on non-farm income, which may aggravate rural-urban migration. Farmers in the study area use irrigation water for growing khat and sugarcane. Thus, it would be beneficial for farmers if they organized themselves as producer or marketing cooperatives. With the construction of several heavy sugar industries underway, there would be a huge market for sugarcane farmers. Creating access to small and medium credit facilities could also improve farmers' capacity to invest in alternative irrigation water sources such as shallow well and rainwater harvesting facilities.

Compliance with ethical standards

Conflict of interest This is to declare that there is no conflict of interest to report.

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Mrs. Fitsum Assefa Adela is a final year PhD student at Justus-Liebig University, Giessen at the Institute of Farm and Agribusiness Management. Her research project focuses on Sub-Saharan Africa and Ethiopia with multi-disciplinary thematic areas including impact of technology adoption on food security, factors affecting adoption of improved technology with emphasis on institutional and governance settings, bio-economic modeling of optimal water allocation among upstream and downstream users, and scenario analysis of different policy interventions in order to trigger actions for creating a sustainable bio-economy.

Joachim Aurbacher is professor of Agricultural Production Economics at the Institute of Farm and Agribusiness Management of **Justus-Liebig University, Giessen**. His research focus is on the interplay of farm business management and environmental impacts. He is involved in research projects concerning adaptation of short term farm management with regard to climate change, evaluation of crop rotations and novel crops concerning the provision of bioenergy and the role of agriculture in remote areas. His study area focuses on West and East European countries.

Gumtaw Kifle Abebe (PhD, Wageningen University) is Assistant Professor of Agribusiness Marketing and Management at the Faculty of Agricultural and Food Sciences, American University of Beirut, Lebanon. He has several years of experience teaching business and agribusiness courses at undergraduate and postgraduate levels. He has experience in interdisciplinary research related to agri-food supply chains in sub Saharan Africa, the Middle East and North Africa. His research focuses on exploring the efficiency and effectiveness of agri-food supply chains in response to recent trends for food safety and food quality; food retail expansion, its drivers and impact on food security; and economics of agricultural technology adoption in arid and semi-arid regions.