Pathways how irrigation water affects crop revenue of smallholder farmers in northwest Ethiopia : a mixed approach

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Abstract

The relationship between irrigation water availability and crop revenue is multifaceted. However, most of the previous studies focused only on the direct effect of irrigation water on crop revenue or considered that the indirect effect passes only through the farmers' improved farm inputs usage. Nevertheless, unlike previous studies, this study argues that a one-sided argument that irrigation water directly causes high crop revenue or indirectly affects crop revenue only via the farmers' improved farm inputs usage is incomplete, as irrigation water not only directly contributes to crop revenue but also indirectly conduces to crop revenue via both the type of crops produced and the farmers' improved farm inputs usage. Considering the previous studies' limitations, this study investigates pathways how small-scale irrigation water affects crop revenue and identifies challenges of small-scale irrigation farming in Fogera district, Ethiopia. Results endorsed that irrigation water has both direct and indirect effects on crop revenue. The indirect effect is 67 percent of the total effect and it is mediated by both the type of crops produced and farmers' improved farm inputs usage. The result also indicated that irrigation user farmers have a higher income, more livestock assets and resources and better food, housing, and cloths than the non-users. Moreover, challenges related to agricultural output and input market were identified as the most severe problem followed by crop disease. The findings of our study suggest that to utilize the benefits of irrigation water properly, it is crucial to encourage farmers to use more improved farm inputs and to shift from staple to cash crop production. Moreover, farmers are frequently exposed to cheating by illegal brokers in the output market, therefore it is also important to increase farmers' accessibility to output and input markets, the quality of improved farm inputs, and the bargaining power of farmers with market information.

Keywords: small-scale irrigation; farmers' livelihood; structural equation model; improved farm inputs; crop type.

1. Introduction

As a developing country where 80 percent of the population lives in rural areas and agriculture is the main source of income, Ethiopia relies heavily on agriculture. The agricultural sector contributes 66 percent of the employment (2018), and 34 percent of the gross domestic product (2017) (TheGlobalEconomy.com., 2017). However, poverty remains a challenge in Ethiopia, as over 22 million people are living below the national poverty line (INDP, 2018). In Ethiopia, the prosperity of agriculture has been heavily driven by rainfall availability. However, given the country's highly variable rainfall patterns, the unreliability of rainfall has negatively affected Ethiopia's economy in general and its agriculture sector in particular. Water scarcity combined with low use of improved farm inputs, decreases crop yields, which leads to low crop production, food insecurity, and poverty. The combination of low crop production, food insecurity, and poverty creates a vicious downward spiral, limiting people's ability to earn income, purchase food, and buy and use improved farm inputs, which again causes low crop production and income (Khonje et al., 2018). Therefore, improving Ethiopia's agricultural sector in general and crop production in particular is clearly vital for improving food security, accelerating poverty reduction, and boosting overall socio-economic growth (You et al., 2011). Improvements in crop production not only help to increase food supply, but also contribute to the growth of rural household incomes and facilitate the adoption of improved farm inputs (Bachewe et al., 2018; Langyintuo and Mungoma, 2008).

Among the challenges facing Africa south of the Sahara (ASS) in general and Ethiopia in particular regarding endeavors to increase crop production are restricted access to water, limited use of improved farm inputs and limited production of cash crops (Bachewe et al., 2018). Currently, as agriculture in Ethiopia is predominantly dependent on rainfall, crop failure risk limits farmers' willingness to use improved farm inputs and to shift from staple to cash crop production (Zewdie et al., 2019). This insufficient use of improved farm inputs and limited production of cash crops again results in low crop production, low income, low purchasing power of food, food insecurity, and poverty. A rainfall-dependent agriculture constitutes a restricting factor for farming and for improving crop productivity, as rainfall is not reliable. Therefore, irrigation has often been regarded as a promising solution to boost the level of agricultural productivity and to enhance the overall economic growth for effective poverty reduction (Nonvide et al., 2018; Yami, 2016). In recent decades, as crop production and crop revenue have increased in many areas where irrigation projects have been implemented, the agricultural development community in the world have promoted irrigation investments in ASS (You et al., 2011; Zewdie et al., 2019). On the other hand, many irrigation projects in ASS have not been as effective as expected (Cafer and Rikoon, 2018; Lemoalle and de Condappa, 2010). Therefore, extensive research efforts have been made worldwide to investigate the economic effect of irrigation water on crop production and crop revenue. The majority of research results have confirmed that irrigation water has a positive and statistically significant effect on poverty reduction in general and crop revenue in particular (Amarasinghe et al., 2005; Langyintuo and Mungoma, 2008; Mullally and Chakravarty, 2018; Zewdie et al., 2019). However, the empirical evidence about how irrigation water helps to increase crop production and reduce poverty at the household level are not very well documented in Ethiopia. Moreover, although small-scale irrigation farming has a positive economic impact on the livelihood of the farmers in Ethiopia, it suffers from different challenges (Amede, 2015; Mengistie and Kidane, 2016). The challenges influencing the performance of small-scale irrigation farming in Fogera district have not yet been clearly identified.

Furthermore, previous estimations of the economic effect of irrigation water on crop revenue have several limitations. For example, most studies on the relationship between irrigation water and crop revenue have used either qualitative or quantitative approaches and have not considered the indirect effect of irrigation water on crop revenue. Zewdie et al. (2019), for example, investigated the indirect effect of irrigation water availability on crop revenue, mainly focusing on testing whether the indirect effect of irrigation water on crop revenue is mediated by the receptivity of the farmers to use improved farm inputs. However, that model was estimated without considering potential factors that can significantly affect the use of improved farm inputs. For example, in addition to having access to irrigation water, receptivity of the farmers to use improved farm inputs can be affected by the number of livestock ownership, access to credit, information, supervision from the extension workers, and so on (Cafer and Rikoon, 2018; Langyintuo and Mungoma, 2008). In developing countries like Ethiopia, livestock ownership is a potential factor that determines the preparedness and ability of the farmers to use improved farm inputs. In times of emergency, farmers usually draw on these stocks and use them as a means of repaying loans to pay for farm inputs (Cafer and Rikoon, 2018). Zewdie et al.(2019) also considered that the indirect effect of irrigation water availability on crop revenue is mediated only by farmers' improved farm inputs usage. This indirect effect accounts only for 27 percent. Unlike Zewdie et al.(2019), in this study, we postulate that the indirect effect of irrigation water availability on crop revenue is mediated by both farmers' improved farm inputs usage and the type of crops produced.

Moreover, the potential of irrigation to improve crop production depends on a series of factors, such as the size (large-scale versus small-scale) of the system (Tilahun et al., 2011), access to agricultural inputs (credit, seeds, fertilizer, and so on), and its application rate (Xie et al., 2017). Zewdie et al.(2019) focused on the Koga large-scale irrigation scheme in the Mecha district of Ethiopia. Koga irrigation scheme is large scale and is well developed: the technical infrastructure of Koga consists of a main dam and a saddle dam which store water in a large reservoir. From there, water is brought to a cemented large canal network leading to the farm plots. On the other hand, the Fogera irrigation scheme is small-scale and is less developed: the technical infrastructure of Fogera consists of pump irrigation, small masonry river diversion structure and earthen canals via which water is brought to the farm plots. Thus, the study results of Zewdie et al.(2019) in Koga large-scale irrigation scheme (73 percent of the total effect of irrigation water availability on crop revenue is direct) may not be the same as the Fogera small-scale irrigation scheme. As the Fogera irrigation scheme is less developed, seepage and evaporation are among the challenges which limit the availability of irrigation water to the farm plots. Thus, in the Fogera irrigation scheme, the direct effect of irrigation water availability on crop revenue is expected to be lower than the Koga large-scale irrigation scheme. Therefore, it is important to test whether the indirect effect remains significant even in a less developed small-scale irrigation scheme such as Fogera.

The objective of this study is to examine the pathways how irrigation water affects crop revenue and to identify the challenges of irrigation farming in the Fogera small-scale irrigation scheme. An integrated framework is developed that synthesizes the existing effect of having access to irrigation water on crop revenue. Previously tested hypotheses of the effect of irrigation water on crop revenue is replicated. However, our approach differs from previous studies in the following five ways: Firstly, in this study we postulate that the indirect effect of irrigation water availability on crop revenue is not only mediated by the preparedness and ability of the farmers to use improved farm inputs but also by the type of crops (cash or staple)[1] grown by smallholder farmers (Figure 1). Secondly - this study focused on the Fogera small-scale irrigation scheme which is less developed (majority of the canals are earthen, most of the cemented canals are broken and are not well constructed), and thus seepage and evaporation decreases the actual amount of water available for irrigation farming. Whereas, the previous studies (for example: Zewdie et al., 2019) focused on the Koga large scale irrigation scheme which is well developed (the canals are cemented and well-constructed) and hence the amount of water available for irrigation farming is relatively higher. Thirdly, as the area of this study (the Fogera small-scale irrigation scheme) is less developed and as we have considered crop type as a mediator variable –we hypothesized that in Fogera small-scale irrigation scheme the percentage of the direct effect of irrigation water on crop revenue is lower than its indirect effect. Fourth, we have also considered five potential observed exogenous variables which supposed to directly affect the latent variable (preparedness and ability of the farmers to use improved farm inputs) and indirectly the crop revenue as well. These variables are: livestock ownership, information sources of the household (such as television, radio, etc.), membership in a social group (is the household head a member of social groups?), access to credit, and frequency of contact of the household to extension workers. Moreover, we included household health[2] as a control variable which supposed to directly affect the performance of smallholder farmers and hence their crop revenue as well. Fifth, examining farmers' perceptions of the economic impact of small-scale irrigation farming and the challenges that influence the economic performance of small-scale irrigation farming at the farm level may require a nuanced reading of human expression and gesture (Frank et al., 2011). Therefore, we used both quantitative and qualitative analysis to provide a better understanding of the pathways how irrigation water affects crop revenues and to validate the quantitative results with qualitative and vice versa.

There are three reasons for using such a mixed approach in this study: to establish a conceptual framework for the quantitative method; to gain access to the views of the farmers and agriculture experts regarding the challenges that influence the economic performance of small-scale irrigation farming in Fogera district; and to provide evidence for the reliability of the outcomes of the

[1] In this study, cash crops are those crops which have been produced for the purpose of market and only small part of it will be consumed by the household. Staple crops are those crops which have been produced for the purpose of consumption and only small part of it will be supplied to the market.

[2] The total number of days that the active members of household had been sick in 2017/2018 cropping year.

quantitative analysis. A qualitative approach is important to interpret and validate the quantitative results (Bamberger, 2012) and vice versa. The present study offers a comprehensive and integrated framework by which we could simultaneously consider both the direct and indirect effects of irrigation water on crop revenue. Considering the research gap explained above, this study specifically addresses the following questions:

(1) Is the indirect effect of irrigation water availability on crop revenue is mediated by the type of crops (cash or staple) grown by smallholder farmers?

(2) Is the percentage of indirect effect of irrigation water availability on crop revenue higher than its direct effect in Fogera small-scale irrigation scheme?

(3) Do farmers' livestock ownership, their access to credit service and information sources, their contact with extension workers and their participation to the social group member significantly affect the preparedness and ability of the farmers to use improved farm inputs?

(4) What are the main challenges influencing the economic performance of small-scale irrigation farming in the Fogera small-scale irrigation scheme?

The remainder of the paper is organized as follows. The next section pronounces the conceptual framework on pathways how irrigation water affects crop revenue. This is followed by materials and methods, which includes the presentation of the study area and data collection procedure, and then the methods of data analysis. The results and discussions are presented in Section 4, followed by the conclusion of the study in Section 5.

2. Conceptual framework: Pathways how irrigation water affects crop revenue.

Figure 1 provides the conceptual model describing the interrelationship between irrigation water, crop revenue, the type of crops produced (cash or staple), and the preparedness and ability of the farmers to use improved farm inputs. We expect a positive and statistically significant effect of the latent variable (preparedness and ability of farmers to use improved farm inputs) to the outcome variable (crop revenue). We hypothesize that the indirect effect of irrigation water availability on crop revenue is not only mediated by the preparedness and ability of the farmers to use improved farm inputs but also by the type of crops produced by smallholder farmers. In other words, we expect a positive and statistically significant indirect effect of irrigation water on crop revenue via both the type of crops produced by stallholder farmers and the preparedness and ability of farmers to use improved farm inputs.

The hypothesized conceptual model includes one dummy exogenous observed variable (irrigation); one endogenous latent mediator variable (preparedness and ability of farmers to use improved farm inputs) with seven endogenous observed indicator variables; one observed outcome variable (crop revenue per hectare, CRPH); one observed endogenous mediator variable (crop type: cash or staple crops); five observed exogenous control variables that directly affect crop revenue (soil quality, marital status of the household head, education level of the household head, health status of active members of the household, distance of the household's home from the village market); and, unlike previous studies, we included five observed exogenous variables that directly affect the latent variable: livestock ownership, information sources of the household (such as television, radio, etc.), membership in a social group (is the household head a member of social groups?), access to credit, and frequency of contact of the household to extension workers, which are supposed to directly affect the latent variable (preparedness and ability of farmers to use improved farm inputs) and indirectly affect crop revenue. See Appendix 1 for the definition of the variables included in the conceptual model of this study.

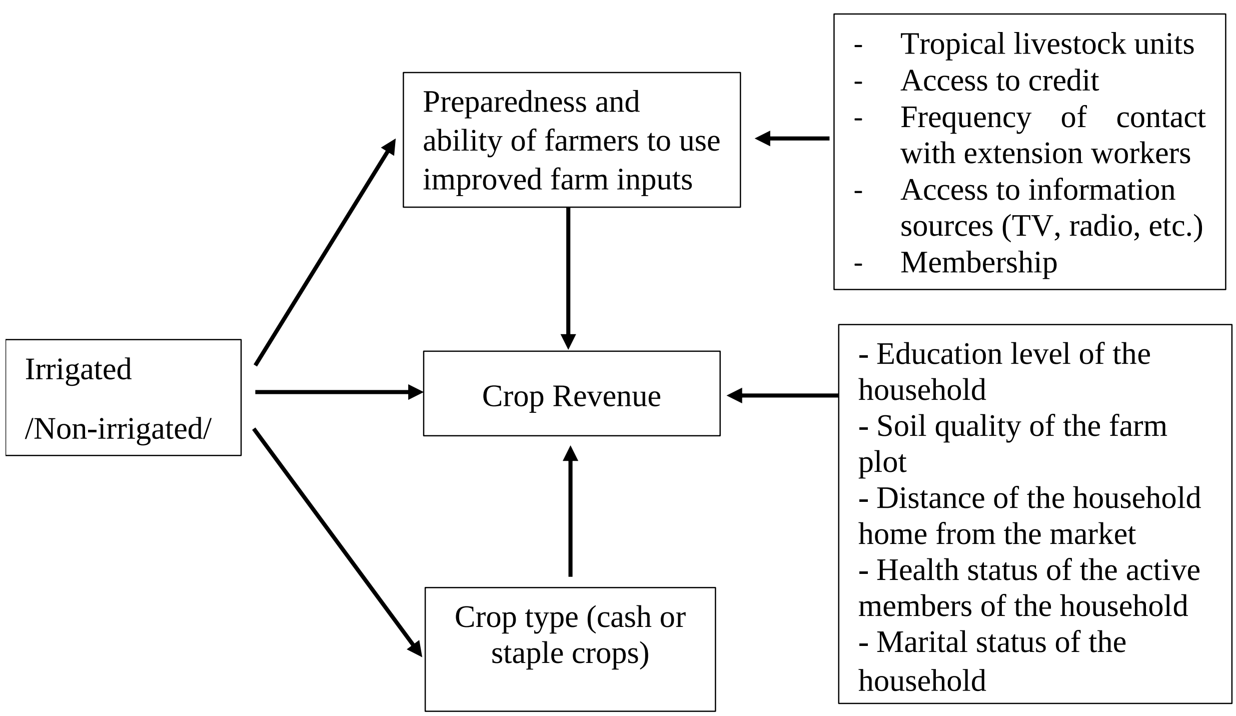

Figure 1: Conceptual model: pathways how irrigation water affects crop revenue. Modified from Zewdie et al. (2019).

3. Materials and methods

3.1 Description of the study area and data collection procedure

The study was conducted in the Fogera district in northwest Ethiopia (Figure 2), the altitude of which ranges from 1774 to 2415 meters above the sea level. Woreta is the capital of the district and is located 625 km northwest of the national capital Addis Ababa, and 55 km from Bahir Dar, the Amhara regional state capital. The two main rivers in the Fogera district are the Rib and the Gummara, both of which drain into Lake Tana. Fogera district is rich in both surface and ground water that can be used for irrigation farming during dry crop seasons. A significant number of farmers are practicing small scale irrigation farming and growing different types of crops in the dry crop seasons. However, the irrigation facilities are not well developed. Majority of the canals are earthen, most of the cemented canals are broken and are not well constructed, and some of the farm plots are far from the sources of irrigation water. Thus, evaporation and seepage deplete the amount of water available for irrigation farming in the district. It also heightens the time and cost of bringing water from the source to the farm plots.

This study is based on a cross-sectional dataset collected through a structured household survey (n=558) prepared with Qualterics[3], and qualitative data collected through focus group discussions (FGDs), key informant interviews (KIIs), and field observation (FO) from eight different kebeles[4] of the Fogera district Ethiopia. We used a combined qualitative and quantitative approach for data collection. Firstly, the quantitative procedure included a survey of 558 farmers from the Fogera district. Of these 558 sampled households, 52 percent (290) had access to irrigation water in the dry season. The remaining 48 percent (268) depended only on rainfall. In the rainy season, all the sampled households (558) had no access to irrigation water and were solely dependent on rainfall.

[3] Qualterics is a web-based software that allows the user to create surveys and generate reports.
[4] A kebele is a small administrative unit in Ethiopia

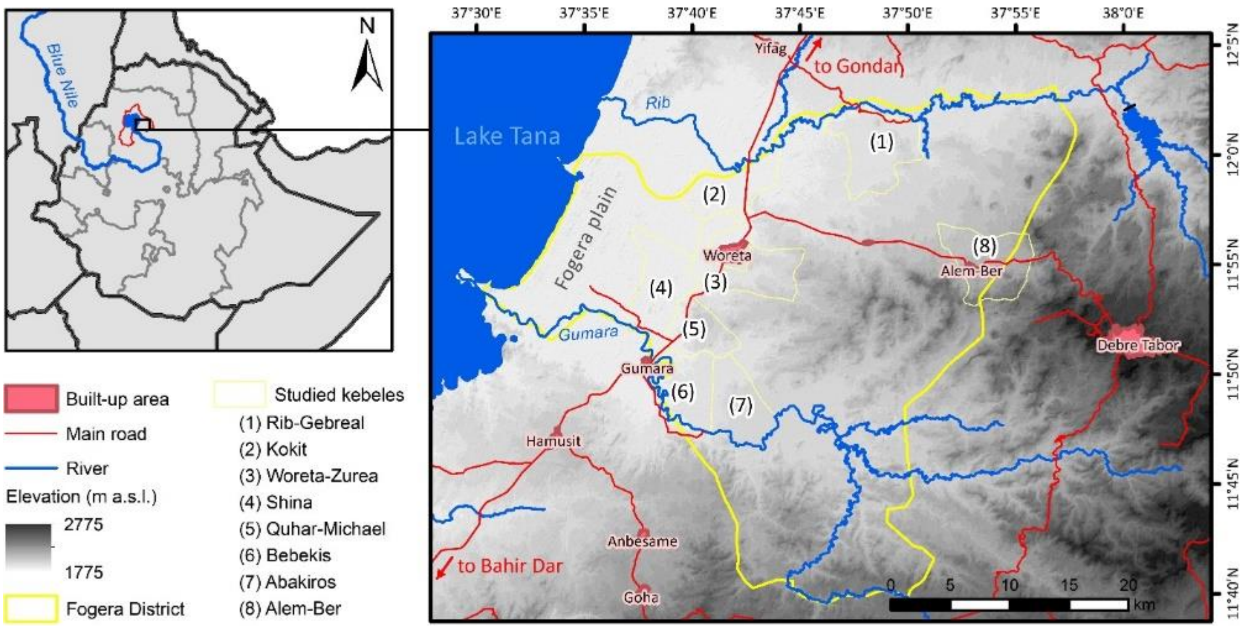

Figure 2: Location of the study area.

The survey covered family characteristics, plot-level characteristics, agricultural practices, yield, income, total number of livestock belonging to the household, available infrastructure, social relations, and interactions with institutions. The first author of this manuscript conducted the household survey. Before the interview, the field leader, who was a well-known and trusted member of the community, provided a preliminary introduction about the purpose of the study. Moreover, prior information from the field leader about the respondents' crop production, crop revenue, and plot size helped the researchers identify whether the information provided by the respondents were inflated or underestimated. We also conducted eight FGDs with irrigation user and non-user farmers, and eight KIIs with one agricultural expert from each kebele. The information from FGDs, KIIs, and informal dialogues with farmers and extension workers in the district was used to complement the quantitative survey data.

3.2 Method of data analysis

3.2.1 Quantitative method of data analysis

As explanatory variables of the dependent variable (crop revenue), we postulate irrigation, crop type, distance of farmers' house from the village market, soil quality of the farm plot, education level and marital status of the household head, health status of the active members of the household[5], and the preparedness and ability of the farmers to use improved farm inputs. Moreover, we hypothesize that the indirect effect of small-scale irrigation farming on crop revenue passes not only via the latent variable (preparedness and ability of the farmers to use improved farm inputs) but also via the type crops produced (cash or staple crops) by smallholder farmers. This hypothesis is based on the idea that farmers who have access to irrigation water are more prepared and able to use improved farm inputs and produce more cash crops than those farmers who have no access to irrigation water. The potential explanation is that in ASS in general and in Ethiopia in particular, farmers are highly dependent on rainfall, therefore the probability of crop failure is high. This high probability of crop failure limits the preparedness and ability of the farmers to use improved farm inputs and their willingness to produce cash crops. Conversely, having access to irrigation water reduces the risk of crop failure and uncertainty of water availability. Therefore, having access to irrigation water helps farmers to be prepared and able to use improved farm inputs, and thus to produce more cash crops so that crop yields and crop revenues increase (Kassie et al., 2011; Zewdie et al., 2019). We take households' preparedness and ability to use improved farm inputs as a latent variable. Latent variable or theoretical construct refers to a phenomenon that is supposed to exist, but cannot be directly observed (Treiblmaier et al., 2011). To measure the variable − preparedness and ability of the farmers to use improved farm inputs − as a latent variable the survey asked for the application of seven yield-enhancing modern farm inputs: (1) improved seed, (2) chemical fertilizer, (3) manure, (4) pesticides, (5) insecticides, (6) herbicides, and (7) line planting. Each variable was measured using a five-point scale[6]. Irrigation water is expected to have direct and indirect effects on crop revenue. This direct and indirect effect of irrigation water on crop revenue are estimated with structural equation model (SEM).

SEM is a multivariate data analysis and an extension of factor analysis technique that helps the researcher to test substantive theory from empirical data. It is a system of linear equations that allows complicated variables and causal relationships to be expressed through recursive and non-recursive structural equations. A SEM consists of two sub-models: a measurement model

[5] Active members of the household are those members of the household who directly and actively participated in the crop production of the 2017/2018 cropping year.

[6] Responses to each question were scaled qualitatively, as illustrated by the example on the application of manure: "How many times did you apply manure in your field during the previous 12 months of 2017/18 cropping year?" (0 if not applied throughout the year; 1 if yes only for once throughout the year; 2 if yes only for two times; 3 if yes only for three times; and 4 if yes for four times throughout the year).

(Equation 1) and a structural model (Equations 2−4). The measurement model specifies the relationship between the latent variable (preparedness and ability of farmers to use improved farm inputs) and its observed indicators. Latent (unobserved) variables could be either formative or reflective. In this study, the latent variable (preparedness and ability of farmers to use improved farm inputs) has been considered as a reflective latent variable because the households' preparedness and ability to use improved farm inputs is reflected in their adoption and use of a range of improved farm inputs, such as improved seeds, chemical fertilizer, manure, pesticides, insecticides, herbicides, and line planting. The structural model represents the relationships between the latent variable (preparedness and ability of farmers to use improved farm inputs) and its observed indicators as well as the relationships among one latent endogenous variable, one dependent variable (crop revenue per hectare, CRPH), one observed endogenous variable (crop type), and 10 observed exogenous control variables. Specifically:

$$Y = \Lambda_{\gamma} X + \varepsilon \quad (1)$$
$$X = \Lambda_{x} \eta + \omega \quad (2)$$
$$C = \Lambda_{c} I + e \quad (3)$$
$$Z = \beta_1 I + \beta_2 X + \beta_3 C + \Theta\xi + \mu \quad (4)$$

Where Y is a p x 1 vector of endogenous observed variables (improved seed, chemical fertilizer, manure, pesticides, insecticides, herbicides and line planting), X is a 1x1 vector of latent endogenous variable (the preparedness and ability of farmers to use improved farm inputs), and η is a $q \times 1$ vector of observed exogenous variables (irrigation, tropical livestock units, credit access, information sources, extension service, and membership) that affect the latent variable of this study. C is a 1x1 vector of observed endogenous variable (crop type). I is a 1x1 vector of observed exogenous variable (irrigation). Λ_{γ}, Λ_{x} and Λ_{c} are, respectively, p x 1, 1 x q, and 1 x 1 matrices of regression coefficients. Z is a 1x1 vector of the outcome variable, crop revenue per hectare. β_1, β_2, and β_3 are 1 x 1 matrices representing, respectively, the effect of the irrigation, the use of improved farm inputs and the crop type on crop revenue. Θ is a vector of q x 1 matrix with Θij representing the effect of the j^{th} exogenous observed variable on the crop revenue. ξ is a 1 x q vector of exogenous observed variables: education, health, distance, marital status, and soil quality. ω and e are a 1x1 vectors of measurement errors of X and C, respectively. ε is a px1 vector of measurement errors of Y. Finally, μ is a 1x1 vector of disturbances of the structural model.

SEM is comprised of two parts: (a) a measurement part: the relationship between the latent variable and the observed indicator variables; and (b) structural part: the relationship between observable or unobservable dependent variables to other unobservable variables (constructs) and observed independent variables. The measurement part corresponds to a confirmatory factor analysis (CFA). In this study, using STATA-15 SEM builder, we apply a CFA to assess the measurement properties of the latent variable, the preparedness and ability of farmers to use improved farm inputs. The adequacy of the measurement model was based on the standardized estimates of the loadings (> 0.3, positive and statistically significant), which was deemed acceptable; and the composite reliability indices (CR) and average variance extracted (AVE) > 0.6 and > 0.5, respectively, which were also deemed acceptable. Moreover, all of the modifications provided from STATA-15 revealed that no parameter could be released to significantly improve the model fit (Bagozzi, Richard and Youjae, 1988). The SEM fit was also based on chi-squared plus recommended criteria for a set of fit indices. The chi-squared/degree of freedom < 3.0, which indicates adequate fit of the model (Marsh HW, 1985). The Tucker Lewis Index [TLI] and Comparative Fit Index [CFI] > 0.90 were deemed acceptable (Yuan et al., 2016). Values lower than 0.05 of the root mean square error of approximation (RMSEA) were considered a good fit (Bentler, 1990); 0.05 < RMSEA < 0.08 indicated a reasonable fit (Chen et al., 2008). Values for the standardized root mean square residual (SRMR) ranged from 0 to 1, with well-fitting models obtaining values lower than 0.05; that is, (SRMR < 0.05) was also deemed acceptable as a well-fitted model (Hooper, D., Coughlan, J., and Mullen, 2008).

3.2.2 Qualitative method of data analysis

The qualitative analysis investigated three aspects: farmers' perceptions regarding the economic impact of small-scale irrigation farming, the use of improved farm inputs, and the main challenges influencing the performance of small-scale irrigation farming in the Fogera district. Focus group discussion (FGD), key informant interview (KII), and filed observation (FO) were used for exploratory analysis. We conducted eight FGDs involving a total of 64 farmers from eight kebeles of the Fogera district (see Figure 2). Eight people participated in each FGD. Participants included both irrigation users and non-users. To capture the widest local diversity, we selected participants purposively with the help of local extension workers. We excluded field leaders (extension workers) to allow the participants to speak without obstruction. The FGDs were designed to gather in-depth qualitative data related to beliefs and perceptions of the farmers towards small-scale irrigation farming and the use of improved farm inputs in the district, as well as the challenges influencing the economic performance of small-scale irrigation farming. Questions were flexible so that the farmers could provide further information. To triangulate the data from the FGDs we also conducted eight KIIs, one from each kebele of the Fogera district. The interviewees were agricultural experts who have worked for more than four years as agricultural extension worker in the district. The main data collection was done between October and December of 2018. We audio-recorded all eight FGDs from the kebeles of the Fogera district with prior agreement from participants via the field leaders, and then transcribed and analyzed the data qualitatively. The interview texts were qualitatively categorized and coded to identify the main challenges influencing the performance of small-scale irrigation farming, farmers' opinions on the use of improved farm inputs, and their perceptions of the economic impact of small-scale irrigation farming. We illustrate emerging themes and issues by using quotes from the FGDs. We also used the preference ranking tool to investigate the perceived importance of irrigation farming and challenges influencing the performance of small-scale irrigation farming in the district during FGDs and KIIs.

3.3 Quantitative data sample

In the 2017/18 cropping year, the mean crop revenue per hectare of the farmers who have had access to irrigation water in the dry season was 255 percent higher than the mean crop revenue per hectare of the farmers who have not had access to irrigation water throughout the year (Table 1).

Table 1: Crop revenue of 2017/18 cropping year; crop revenue of 2017 rainy cropping season; and tropical livestock unit differences between irrigation users and non-users.

	Irrigation user (290)	**Non-users (268)**	**Percentage difference**
Average crop revenue per hectare in 2017/18 cropping year (in Ethiopian Birr).	127,343	35,840	255***
Average crop revenue per hectare in the cropping season of 2017 when all sampled farmers are depended only on rainfall (in Ethiopian Birr).	54,061	35,840	51 ***
Average Tropical Livestock Units (TLU)	5.2	4	30***

Notes: At the time of survey, 1 United States Dollar (USD) = 27.8729 Ethiopian Birr (ETB). Differences between irrigated and non-irrigated were tested for statistical significance. *P<0.1, **P<0.05, and ***P<0.01.

Table 2: Use of improved farm inputs by irrigation user and non-user farmers.

	Irrigation users		**Non-users**		**Significance level**
	Mean	Standard errors	Mean	Standard errors	
Improved seed	1.93	(0.04)	0.26	(0.03)	***
Chemical fertilizer	2.07	(0.03)	0.82	(0.02)	***
Manure	1.69	(0.05)	0.08	(0.01)	***
Pesticides	2.03	(0.03)	0.18	(0.02)	***
Insecticides	1.99	(0.04)	0.08	(0.01)	***
Herbicides	1.91	(0.04)	0.18	(0.02)	***
Line planting	1.84	(0.05)	0.41	(0.03)	***

Notes: *P<0.1, **P<0.05, and ***P<0.01

In the rainy season, all sampled farmers were dependent solely on rainfall. However, the mean crop revenue difference between irrigation user and non-user farmers remains significant, even in the rainy cropping season of the 2017 cropping year. The mean total Tropical livestock unit[7] (TLU) difference between irrigation users and non-users was also significant at the one-percent significance level. The mean TLU of irrigation users was 30 percent higher than that of the non-user farmers. Moreover, the use of improved farm inputs was significantly higher for irrigation users compared to non-user farmers (Table 2). This difference can explain the observed significant difference in average crop revenue per hectare in the 2017/18 cropping year and in the rainy cropping season of 2017 as well.

4. Results and discussion

4.1. Quantitative data assessment results

4.1.1. Measurement model

The confirmatory factor analysis (CFA) of the measurement model of the reflective latent variable estimation asserted that the standardized coefficients are loaded significantly for all seven indicators of the farmers' preparedness and ability to use improved farm inputs. However, the fit of the initial measurement model estimation was not satisfactory and the modification indices by STATA 15 indicated that, by allowing the error terms to be correlated, the fit of the measurement model could be improved. Running the modification indices (correlating the error terms) meant that at least one common unmeasured variable would influence the corresponding observed

[7] Tropical Livestock Units (TLU) is livestock numbers converted to a common unit. Conversion factors are: cattle = 0.7, sheep = 0.1, goats = 0.1, pigs = 0.2, chicken = 0.01 (HarvestChoice, 2011).

variables (for instance, manure and insecticides). These variables are: households' off-farm income and agricultural government policy. For example, input subsidies increases the preparedness and ability of the farmers to use improved farm inputs on the farm plot (Shin et al., 2019). Therefore, it is logical to allow the error terms to be correlated and run the modification indices for the measurement model of this study. The standardized coefficients of all indicators of the latent variable are greater than 0.79 and are positive and statistically significant at the 1 percent significance level (Appendix 2). The measurement adequacy of the latent variable was also assessed using several tests of reliability and validity: the composite reliability indices (CR) and average variance extracted (AVE) are 0.98 and 0.90, respectively. The cut values for CR and AVE of the good measurement model are 0.6 and 0.5, respectively. The measurement model with values of CR>0.6 and AVE>0.5 is more valid and reliable, and it confirms that the measurement of the theoretical construct was valid and reliable. Moreover, the goodness of fit statistics of the measurement model indicated that all the seven indicators were suitable for measuring the latent variable, preparedness and ability of farmers to use improved farm inputs. Goodness of fit statistics of the measurement model are presented in Appendix 3.

4.1.2. Structural equation model (SEM)

The SEM result is presented in Figure 3. The outcomes of SEM showed that irrigation water has a positive and statistically significant effect on crop revenue. Irrigation water has also a positive and statistically significant effect on the preparedness and ability of the farmers to use improved farm inputs, and the type of crops produced (cash or staple). Having access to irrigation water, by decreasing the risk of crop failure and uncertainty of water availability, increases farmers' preparedness and ability to use improved farm inputs in the farm plot and encourages the farmers to shift from staple to cash crop production. The latent variable, the preparedness and ability of the farmers to use improved farm inputs, and the type of crops produced have also had a positive and statistically significant effect on crop revenue. In agreement with the result of Zewdie et al.(2019) and Xie et al.(2017), the quantitative outcomes of this study indicated that having access to irrigation water has an indirect effect on crop revenue via the preparedness and ability of the farmers to use improved farm inputs. However, unlike the result of Zewdie et al.(2019), the indirect effect of irrigation water availability on crop revenue does not only passes via farmers' use of improved farm inputs but also via the type of crops produced. Moreover, in line with this study's hypothesis but dissimilar to the results of Zewdie et al.(2019), the percentage of the indirect effect of irrigation water availability on crop revenue is higher than the direct effect. The total effect is the sum of direct effect[8](0.22[9]= 33%) and indirect effect[10][0.45= (0.30=0.89[11] * 0.34[12]) + (0.15=0.64[13] * 0.23[14]) = 67%] (Figure 3). This means that in this study, a large portion (67 percent) of the total effect[15] of small-scale irrigation farming on crop revenue was an indirect effect and was mediated by both the preparedness and ability of the farmers to use improved farm inputs (0.30=0.89 * 0.34=45%) and the type of crops produced (0.15=0.64*0.23=22 %). The larger indirect effect of irrigation water on crop revenue compared to its direct effect can be attributable to the less efficient condition the Fogera small-scale irrigation scheme operates (majority of the canals are earthen, most of the cemented canals are broken and are not well constructed, and some of the farm plots are far from the sources of irrigation water), which deplete the actual amount of water available for irrigation farming through evaporation and seepage lowering its direct effect on crop revenue. Crop revenue is also directly and significantly affected by the soil quality of the farm plot, the marital status and the distance of the road from farmers' home to the village market. While the marital status, and the soil quality of the farm plots positively affects crop revenue, the distance of the road from farmers' home to the village market negatively and significantly affects crop revenue. The higher the distance of the road between the farmer's home and the village market, the smaller the crop revenue that the farmers could earn. Unexpectedly, the education level of the household head and health conditions of the active members of the household have no significant effect on crop revenue.

[8] Direct effect is the path that directly links irrigation with crop revenue per hectare (Figure 3).
[9] 0.22 is the value of the path from irrigation to crop revenue per hectare (Figure 3)
[10] Indirect effect is the paths that indirectly link irrigation with crop revenue per hectare via the preparedness and ability to use improved farm inputs and the type of crops produced (Figure 3).
[11] 0.89 is the value of the path from irrigation to the preparedness and ability to use improved farm inputs (Figure 3).
[12] 0.34 is the value of the path from the preparedness and ability to use improved farm inputs to crop revenue per hectare (Figure 3).
[13] 0.64 is the value of the path from irrigation to crop type (Figure 3).
[14] 0.23 is the value of the path from crop type to crop revenue per hectare (Figure 3).
[15] Total effect = (direct effect = 0.22 + indirect effect = 0.45) (Figure 3).

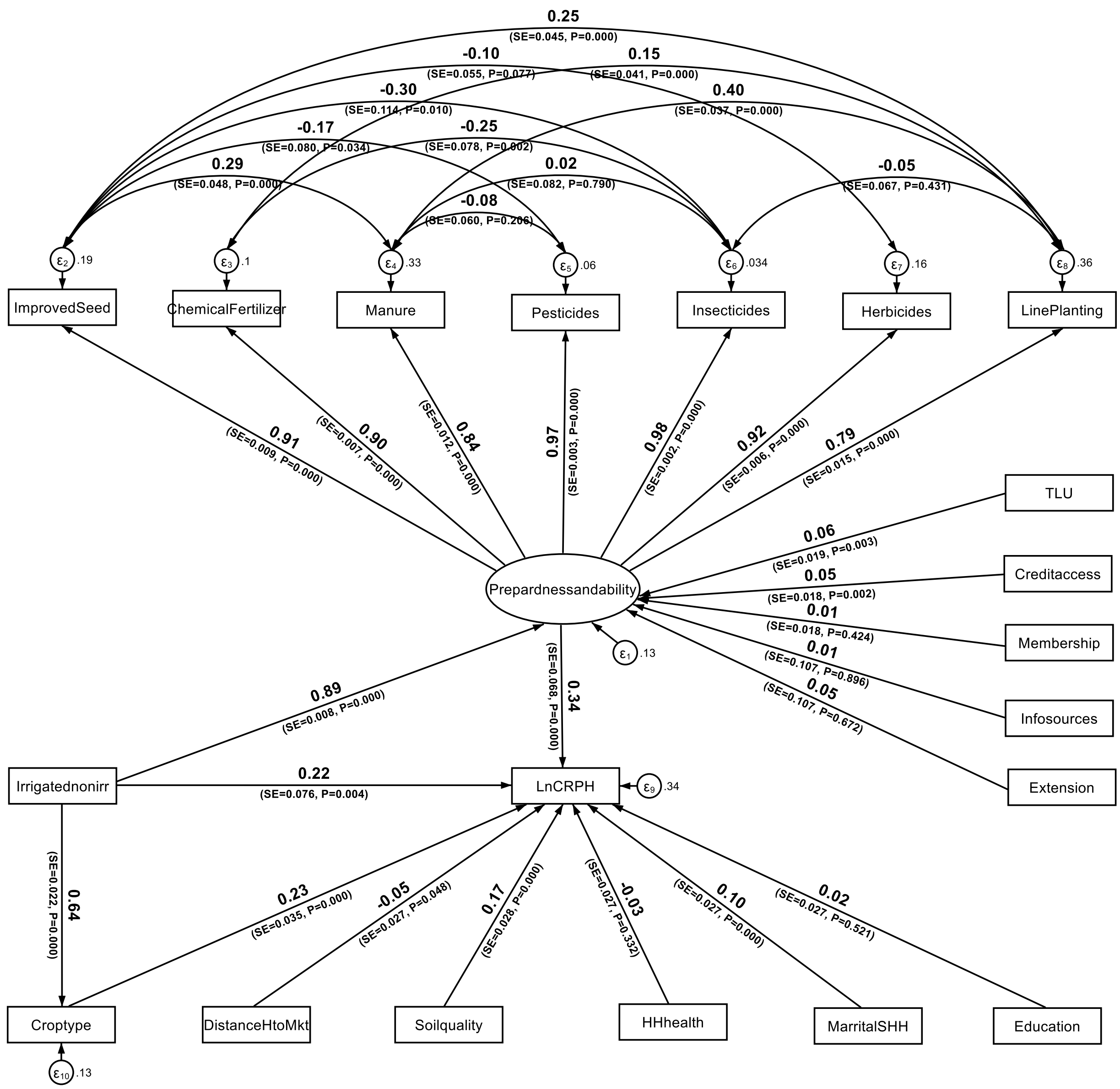

Figure 3: Results of structural equation model (n=558). All the estimated parameters are standardized, and the standard errors (SE) and p-values are for the standardized estimates of the parameters.

In addition to irrigation farming total tropical livestock units (TLU) and access to credit directly and significantly affect the preparedness and ability of the farmers to use improved farm inputs and indirectly affect the crop revenue. However, unlike the results of Cafer and Rikoon (2018) and Emmanuel et al. (2016), the frequency of contact with agricultural extension workers on the preparedness and ability of the farmers to use improved farm inputs is positive but statistically insignificant. This is because − as indicated by the results of the FGDs, KIIS, and FOs of this study

− farmers did not fully trust or respect agricultural extension workers. Similar to the results of Yami (2016), the informal discussion with farmers indicated that agricultural extension workers have been involved in activities that are not related to their normal duties. In Ethiopia in general, and particularly in the Fogera district, extension workers have usually been involved in political activities that are not explicitly their normal duties. This could explain why farmers did not fully trust and respect agricultural extension workers. Table 3 shows goodness of fit statistics of the SEM.

Table 3: Goodness of fit statistics of the SEM.

Statistics	χ^2	**RMSEA**	**CFI**	**TLI**	**SRMR**
Values	243.77(df=102, p=0.00) (χ^2/df)244/102=2.4	0.05 (90% [CI]: 0.04 to 0.05)	0.98	0.97	0.03

Note: The values for χ^2, RMSEA, CFI, TLI, and SRMR indicating a good fit. The cut values of χ^2, RMSEA, CFI, TLI, and SRMR for the good fit are insignificant P value or (χ^2/df < 3), (< 0.08), (> 0.90), (> 0.90), and < 0.1, respectively.

4.1.3. Robustness check

To test for the mediating partial relationship, the predictor variable (irrigation) must significantly affect the outcome variable in the expected direction. After controlling for the effects of the mediator variables (the preparedness and ability of the farmers to use improved farm inputs and crop type), the impact of the predictor variable (irrigation) on the dependent construct (crop revenue per hectare) should be either not significantly different from zero (full mediation) or smaller but significantly different from zero (partial mediation) (Baron and Kenny, 1986; Holmbeck, 1997). In line with the procedure outlined by Baron and Kenny (1986) and Holmbeck (1997), when we introduced the mediator variables (the preparedness and ability of the farmers to use improved farm inputs and crop type) to the model, the direct effect of irrigation water on crop revenue decreased but remained statistically significant (Appendix 3). The direct path from irrigation to crop revenue per hectare decreased from (β= 0.68) to (β= 0.22) as soon as we introduced the mediator variables (the preparedness and ability to use improved farm inputs, and crop type) in the model. Thus, as hypothesized, the effect of irrigation water on crop revenue is partially mediated by both the preparedness and ability of the farmers to use improved farm inputs, and the type of crops produced.

4.2. Qualitative data assessment results

4.2.1. The impact of small-scale irrigation farming

In line with You et al. (2011), Zewdie et al. (2019), Amarasinghe et al. (2005), Amede (2015), Mengistie and Kidane (2016), Tilahun et al. (2011), Nonvide (2018a, 2018b), the qualitative assessment result provided evidence that small-scale irrigation farming had a positive impact on the livelihood of the farmers in the Fogera district. The FGDs results indicated that farmers with access to irrigation water have a higher income and more livestock and resources and better food, housing, and cloths than the farmers without access to irrigation water. In agreement with the quantitative results, all the FGD results of this study confirmed that irrigation user farmers were more acquainted with improved farm inputs and produced more cash crops than the non-user farmers (Table 4). All KIIs also responded, on a five-point Likert scale (ranging from "definitely yes" to "definitely no"), that irrigation users have higher crop production and are more acquainted with improved farm inputs than the non-users. Moreover, these outcomes were corroborated by the direct field observation. Therefore, the qualitative assessment result of this study provided evidence for the reliability of the outcomes of the quantitative assessment result that irrigation water positively affects crop revenue, the preparedness and ability of the farmers to use of improved farm inputs, and the type of crops produced.

Table 4: FGDs, KIIs, and FOs results on the impact of small-scale irrigation farming by kebeles.

Category	Irrigation users	Non-users	FGDs, KIIs and FOs	WZ	A	RG	S	K	QM	AB	B	Relevant quotes from FGDs
Income	Relatively high income	Relatively low income	FGDs	*	*	*	*	*	*	*	*	"…farmers with access to irrigation water produce crops more than once in a year and hence they are earning more crop revenue. As a result, some of them have houses in the capital of the district, Woreta, and some others even have car." (FGD participant, RG)
			KIIs	*	*	*	*	*	*	*	*	
			FOs	-	-	-	-	-	-	-	-	
Food	Relatively enough food	Inadequate food	FGDs	*	*	*	*	*	*	*	*	"… irrigation user farmers are producing different types of crops such as onion, cabbage, tomatoes … and thus their children are eating a balanced diet." (FGD participant, QM)
			KIIs	-	-	-	-	-	-	-	-	
			FOs	-	-	-	-	-	-	-	-	
Livestock ownership	large number of livestock	Some livestock	FGDs	*	*	*	*	*	*	*	*	"… let alone their numbers being high, the irrigation user farmers' livestock are better in quality." (FGD participant, S)
			KIIs	-	-	-	-	-	-	-	-	
			FOs	*	*	*	*	*	*	*	*	
Housing	Owns big house with iron sheets	Small house	FGDs	*	*	*	*	*	*	*	*	"… irrigation user farmers have better houses compared to non-users. They have even additional houses with iron sheets in the center of the village." (FGD participant, S)
			KIIs	-	-	-	-	-	-	-	-	
			FOs	*	*	*	*	*	*	*	*	
Clothing	Clean cloths	Few and dirty cloths	FGDs	*	*	*	*	*	*	*	*	"… when you come to church, see and meet farmers with clean and white cloths, he/she must be irrigation users." (FGD participant, B)
			KIIs	-	-	-	-	-	-	-	-	
			FOs	*	*	*	*	*	*	*	*	
Resource endowments	Owns various assets	Owns few assets	FGDs	*	*	*	*	*	*	*	*	"… it is the irrigation users who are lending us agricultural assets such as oxen." (FGD participant, A)
			KIIs	-	-	-	-	-	-	-	-	
			FOs	*	*	*	*	*	*	*	*	
Acquaintance of improved farm inputs	More acquainted	less acquainted	FGDs	*	*	*	*	*	*	*	*	"… as they are relatively rich, they are more prepared and able to purchase and use improved farm inputs such as fertilizer." (FGD participant, WZ)
			KIIs	*	*	*	*	*	*	*	*	
			FOs	*	*	*	*	*	*	*	*	
Crop type	More cash crops	More staple crops	FGDs	*	*	*	*	*	*	*	*	"… irrigation user farmers are producing different types of crops such as onion, cabbage, tomatoes …" (FGD participant, QM)
			KIIs	-	-	-	-	-	-	-	-	
			FOs	*	*	*	*	*	*	*	*	

Note: FGDs = focus group discussions; KIIs = key informant interviews; FOs = field observations; WZ = Woreta-Zurea; A = Abakiros; RG = Rib-Gebreal; S = Shina; K = Kokit; QM = Quhar-Michael; AB = Alem-Ber; and B = Bebekis. (*) = FGDs, KIIs and FOs acknowledged the economic difference between irrigation users and non-users; and (–) = not applicable (FGDs, KIIs and FOs participants were not able to evaluate the difference between irrigation users and non-users).

4.2.2. Challenges of small-scale irrigation farming in Fogera district

Several different factors have been identified as challenges for small-scale irrigation farming in the Fogera district (Table 5). These include limited reliability of agricultural output and input markets, limited access to efficient credit service, limited knowledge of the farmers on crop production, predominance of subsistence-oriented farming, ineffective agricultural support service, crop diseases, poor canals and seepage, poor infrastructure (road), lack of trust towards extension workers, and limited access to improved farm inputs such as fertilizer and pesticides. Among these challenges, problems related to agricultural output (illegal acts of brokers who link farmers with merchants in the village) and input market (limited access to improved farm inputs such as fertilizer and pesticides), as well as crop disease are considered as the main challenges of small-scale irrigation farming in the district (Table 5 and 6).

Table 5: Challenges of small-scale irrigation farming in the Fogera district by FGDs participants and KIIs from different kebeles.

		FGDs and KIIs from different kebeles of Fogera district							
Problems	Source	WZ	A	RG	S	K	QM	AB	B
Limited reliable market of agricultural output and input	FGDs	*	*	*	*	*	*	*	*
	KIIs	*	*	*	*	*	*	*	*
Limited access to efficient credit service	FGDs	*	*	*	*	-	-	-	-
	KIIs	*	*	-	-	-	-	-	-
Limited knowledge of the farmers on crop production	FGDs	*	*	*	*	*	*	*	-
	KIIs	*	*	*	*	*	*	*	*
Poor infrastructure (road)	FGDs	*	-	-	-	-	*	-	*
	KIIs	*	*	-	-	-	-	-	*
Ineffective agricultural support service	FGDs	*	*	*	-	*	*	*	-
	KIIs	*	-	-	-	*	*	-	-
Predominance of subsistence-oriented farming	FGDs	*	-	-	-	-	-	-	-
	KIIs	*	-	*	*	-	-	-	*
Crop disease	FGDs	*	*	*	*	*	*	*	*
	KIIs	*	*	*	*	*	*	*	*
Poor canals and seepage	FGDs	-	*	*	-	-	-	*	-
	KIIs	-	-	-	-	-	-	-	-
Farmers' perceptions towards extension workers (lack of trust)	FGDs	*	-	-	-	*	-	-	-
	KIIs	*	*	*	*	*	*	*	*
Limited access to improved farm inputs such as fertilizer and pesticides	FGDs	*	*	*	*	*	*	*	*
	KIIs	*	*	*	*	*	*	*	*

Note: FGDs = focus group discussions; KIIs = key informant interviews; WZ = Woreta-Zurea; A = Abakiros; RG = Rib-Genreal; S = Shina; K = Kokit; QM = Quhar-Michael; AB = Alem-Ber; B = Bebekis;

(*) = FGDs and KIIs participants considered the stated problem as a main challenge; and

(–) = FGDs and KIIs participants not considered the stated problem as a main challenge.

Pairwise ranking has revealed variations in the relative importance of the main challenges of small-scale irrigation farming across kebeles in the district. However, problems related to agricultural output and input markets, especially illegal brokers who link farmers with village merchants in the output market, are considered the most severe issue across all kebeles of the district except Shina and Alem-Ber (Table 6). As one of the FGD participants of Abakiros kebele stated:

"… although small-scale irrigation farming (SSIF) is important for the livelihood of the farmers in the district, we are not able to produce the most profitable crops such as onions and we are not able to get the full benefits of SSIF in the district. This is actually because of poor market linkages. For instance, the farmers have no power to determine the price of their crops; it is completely determined by illegal brokers who link the farmers with the merchants in the village. They are powerful, dominating the output market and abusing us. As a result, farmers are crying, and no one is trying to dry our tears. Therefore, we are forced to shift from the production of onion and garlic to teff and maize, on which we have a little bit more power to determine the price."

FGDs participants from Shina and Alem-Ber kebele considered limited access to improved farm inputs and limited knowledge of farmers on crop production as the most severe problems facing irrigation farming. The next most severe problem in the district is crop disease.

Table 6: Relative importance of challenges of small-scale irrigation farming in Fogera district by FGDs and KIIs.

	Biggest obstacle		2nd biggest obstacle		3rd biggest obstacle	
Kebeles	FGDs	KIIs	FGDs	KIIs	FGDs	KIIs
Woreta Zurea	LRMAOI	LRMAOI	CD	LAIFI	LAIFI	PI
Abakiros	LRMAOI	LRMAOI	CD	LAIFI	LAIFI	CD
Ribb Gebreal	LRMAOI	CD	LAIFI	LRMAOI	CD	LAIFI
Shina	LAIFI	LRMAOI	LRMAOI	LAIFI	CD	PSF
Kokit	LRMAOI	LRMAOI	LAIFI	CD	CD	LKFCP
Quar Mekaheal	LRMAOI	CD	LAIFI	LRMAOI	CD	LAIFI
Alem-Ber	LKFCP	LKFCP	LAIFI	LRMAOI	CD	CD
Bebekis	LRMAOI	LRMAOI	LAIFI	LAIFI	CD	PI

Note: LRMAOI = limited reliable market of agricultural output and input; CD = Crop disease; LAIFI = limited access to improved farm inputs; PI = poor infrastructure (road); PSF = predominance of subsistence farming; LKFCP = limited knowledge of farmers on crop production.

Similar with the result of Murugani and Thamaga-Chitja (2018), farmers lack the capacity to find or take advantage of existing markets. Limited market access is a severe challenge, as limited market access combined with poor infrastructure (roads) severely restricts the flow of goods in and out. As a result, the farmers are exposed to transportation and other related costs to sell their products. In Ethiopia and in the Fogera district, inputs are subsidized and distributed by the government to small-hold farmers. However, farmers perceive that inputs are not distributed fairly. For instance, one of the FGD participants of Shina kebele stated:

"… irrigation farming is positively affecting our livelihood in general and our income in particular. I also agree that there are problems, like limited input supply such as fertilizer, pesticides, insecticides, herbicides, fuel for water pump, … But I want to emphasize the limited and unfair supply of the fertilizer especially urea. The way that the government officers distribute it to the farmers is unfair and corrupt. Only some of the farmers who have special relationship with the officers have access to these inputs. Sometimes, with no reason, inputs could be taken by local merchants and then farmers would be obliged to buy it from the local merchants with extremely high and unfair prices."

In the Fogera district, illegal brokers who link farmers with merchants in the village are considered a severe problem in the output market because farmers have no bargaining power over their own products − it is the broker who always determines the price of the crops in the village market. Both the qualitative and quantitative assessment of this study revealed that producing cash crops has a positive effect on crop revenue. However, because of the illegal act of the brokers who link farmers with the village merchants, farmers are forced to shift from producing profitable crops such as onion and garlic (cash crops) to teff and maize (staple crops). Moreover, as brokers are very powerful, they may sometimes forcefully restrict the farmers from selling their products directly to the village merchants and even to other brokers. For instance, one of the FGD participants of Woreta-Zurea stated:

"… last year, I had produced onions and the production was so good. However, because of the illegal brokers in our village, I was not able to sell it, the production was on the farm plot for more than a week looking for a buyer. Because one of the brokers in our village forced me to sell it to him at a cheaper price, and he even warned other buyers to not to buy it, I finally sold it to another broker at a very cheap price."

The results from the FGDs and the KIIs revealed that crop disease was the third most severe challenge facing small-scale irrigation farming in the Fogera district. It represents a significant yield and quality constraints for the farmers in the district. In the 2017-2018 cropping year, the diseases of red pepper, tomato, and onion were the most severe problem across all kebeles. Farmers and even agricultural extension workers could not obtain a correct diagnosis. For instance, one of the FGD participants of Woreta-Zurea stated:

"… most of the time fertilizer, pesticides, herbicides, and insecticides are supplied by the village merchants at a very high price. Besides its price being high, the pesticides, herbicides, and insecticides that are supplied by the local merchants are not able to cure the crop diseases."

All these factors reduce the contribution of small-scale irrigation farming in the district. In general, small-scale irrigation farming in Fogera suffers from low payments for agricultural products, high payments for agricultural inputs, and crop diseases.

5. Conclusion

In order to improve our understanding of the pathways how irrigation water affects crop revenue, we adopted an approach that integrates quantitative and qualitative analysis. The structural equation modeling (quantitative) identified the direct and indirect effect of irrigation water on crop revenue, while the qualitative assessment allowed for the contextualization of these effects and for the identification of the challenges influencing the performance of small-scale irrigation farming in Fogera district, Ethiopia. In this study, the qualitative assessment result provided evidence for the reliability and validity of the quantitative assessment results. Both the quantitative and qualitative assessment results revealed that small-scale irrigation farming in the Fogera district has a positive and significant effect on crop revenues, the preparedness and ability of the farmers to use improved farm inputs, and it enables farmers to shift from staple to cash crop production. Moreover, the study confirmed that irrigation water has both direct and indirect positive effects on crop revenues, and this indirect effect is mediated not only by the preparedness and ability of the farmers to use improved farm inputs but also by the type of crops grow by smallholder farmers. Irrigation water is positively related to higher income, and large livestock ownership, as well as better food, housing, cloths, and resources. Unlike the result of previous studies, for example (Zewdie et al., 2019), in Fogera irrigation scheme the indirect effect of irrigation water on crop revenue is higher than its direct effect. Two-thirds of the total effect of irrigation water availability on crop revenue is indirect and passes via the type of crops produced (22 percent of the total effect) and the preparedness and ability of the farmers to use improved farm inputs (45 percent of the total effect). The preparedness and ability of the farmers to use improved farm inputs is not only affected by irrigation water availability but also by the farmers' livestock ownership and their access to credit services. We also identified the main challenges of the performance of small-scale irrigation farming. Challenges related to agricultural output and input market were the most severe problem, followed by crop disease. Problems related to input market, limited supply of improved farm inputs, and output market, illegal brokers in the village, and poor infrastructure (road) combined with long distance of farmer's home from the village market reduced the contribution of small-scale irrigation farming in the district. Moreover, the contributions of education and agricultural extension workers in Fogera district was insignificant.

The findings of our study imply that providing irrigation water is not enough to improve the livelihood of the farmers; the relevant bodies should also design strategies to guarantee fair access to input and output market. The credit access, agricultural extension workers service and the way that the officials are distributing farm inputs such as fertilizer should also be rechecked. The results of this study indicate that if the concerned bodies fail to keep supporting the irrigation user farmers to grow cash crops and to have better access to improved farm inputs, the 67 percent crop revenue gain might disappear, as the type of crops produced and the preparedness and ability of the farmers to use improved farm inputs is dependent on access to facilities to grow cash crops and access to improved farm inputs respectively. Therefore, to utilize the positive effect of irrigation water availability on crop revenue properly, we suggest that the concerned bodies should facilitate farmers' access to improved farm inputs and credit, provide means to produce cash crops and increase their livestock assets. As farmers are exposed to cheating by brokers, improving the bargaining power of farmers with market information is also important.

Conflicts of interest

The authors have no competing interests to report.

Acknowledgements

The authors would like to thank Bahir Dar University – Institutional University Cooperation (BDU-IUC) VLIR_UOS project for providing funds for the completion of this study. The authors gratefully acknowledge Fogera District Agricultural Office managers and kebele-level officers for their support during the data collection. The authors also acknowledge the farmers (respondents) for their willingness to spend time and answer questions honestly.

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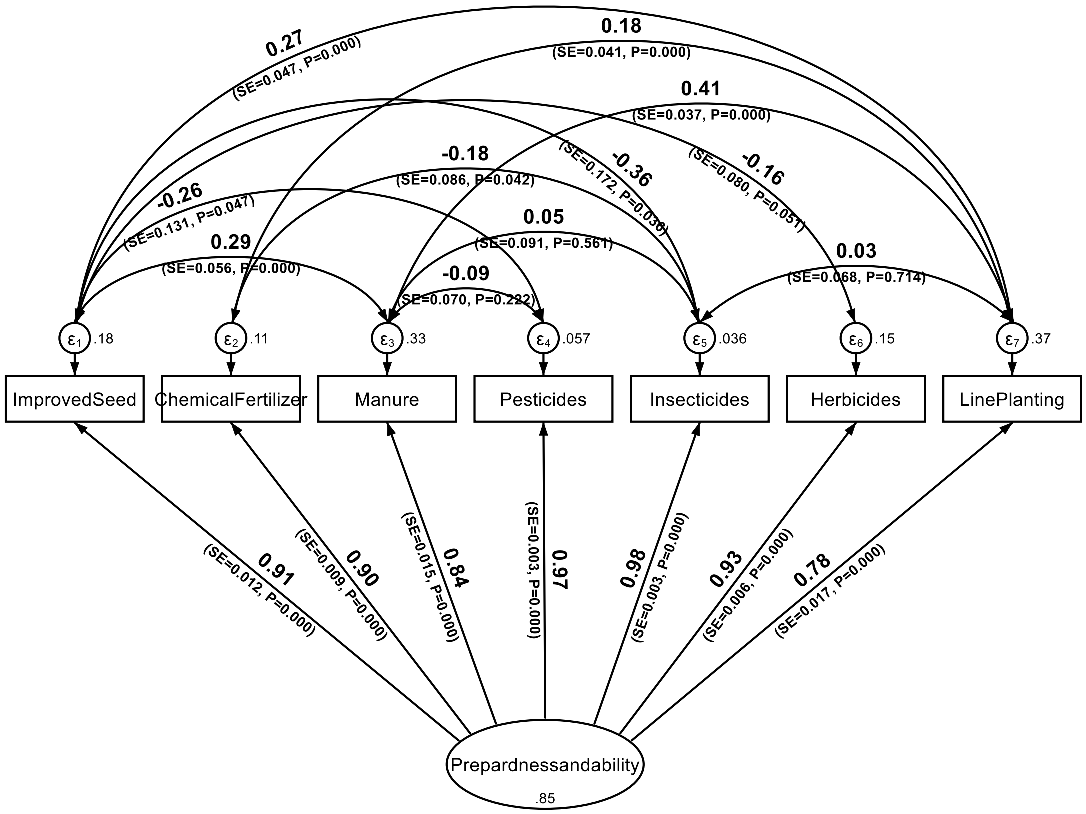
Appendices

Appendix 1: Definition of variables included in the SEM

Variable	Description
Dependent variable	
Average crop revenue per hectare of the 2017/18 cropping year.	Crop production in 2017/18 cropping year multiplied by the average price of crops, and then divided by the size of land where crops are cultivated (in Ethiopian Birr).
Main variables of the study	
Preparedness and ability of the farmers to use improved farm inputs	A reflective latent variable measured with seven manifest variables (see appendix 1).
Irrigation	Access to irrigation (dummy: 1= having access and 0 otherwise).
Control Variables	
Household Characteristics	
Education	Household head education (years in schooling).
Marital status	Marital status of the household (dummy: 1= married and 0 otherwise).
Household health	The total number of days that the active members of household had been sick in 2017/2018 cropping year.
Resources	
Livestock	Total number of tropical livestock units (Total Tropical Livestock Units).
Credit access	Access to credit (dummy: 1= have access to credit for the previous three years and 0 otherwise).
Information sources	Access to information sources such as television or radio (dummy: 1= having access to information sources and 0 otherwise).
Social capital/network/	
Social group member	Membership of social groups: (0=if the household head is not a member of any social group; 1= if the household head is a member of 1 social group;…..5= if the household head is a member of 5 social group in the study area).
Access to service	
Market distance	Distance of the road (km) between the household's home and the main market.
Extension	Frequency (days) of contact of the extension workers with the farmers in the cropping year of 2017/18.
Plot level characteristics	
Soil quality	The farmers opinion about the soil fertility of the farm plot (Likert scale 1 to 5, 1 = very unsatisfactory and 5 = very satisfactory).
Crop type	Cash crops or staple crops (dummy: 1= the crop produced in the 2017/18 cropping year is cash and 0 otherwise). In this study, cash crops are those crops which have been produced for the purpose of market and only small part of will be consumed by the household. Staple crops are those crops which have been produced for the purpose of consumption and only small part of will be supplied to the market.

Appendix 2: The measurement model with standardized coefficients. All the estimated parameters are standardized, and the reported standard errors (SE) and p-values are for the standardized estimates of the parameters.



Appendix 3: Goodness of fit statistics of the measurement model.

Statistics	χ^2	RMSEA	CFI	TLI	SRMR
Values	5.19(df=3, p=0.1581)	0.036(90% [CI]: 0.000 to 0.087)	1.000	0.997	0.005

Note: The values for $\chi^{2,}$ RMSEA, CFI, TLI, and SRMR indicating a very good fit. The cut values for the good fit are insignificant P value (χ^2/df < 3), < 0.05, > 0.90,> 0.90, and < 0.1, respectively.

Appendix 4: Model validation.