sustainability

Case Report

Integrating Socioeconomic Biophysical and Institutional Factors for Evaluating Small-Scale Irrigation Schemes in Northern Ethiopia

Amina Abdelkadir Mohammedshum [1,2,*], Chris M. Mannaerts [1], Ben H. P. Maathuis [1] and Daniel Teka [2,3]

1 Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands
2 Institute of Geo-Information and Earth Observation Sciences (I-GEOS), Mekelle University, Mekelle P.O. Box 231, Ethiopia
3 Department of Land Resource Management and Environmental Protection (LaRMEP), Mekelle University, Mekelle P.O. Box 231, Ethiopia
* Correspondence: a.a.mohammedshum@utwente.nl or amina.sued@gmail.com

Abstract: This paper characterizes and compares three types of small-scale irrigation scheme practices in Northern Ethiopia. A multidisciplinary survey approach, collecting information on socioeconomic, biophysical, and institutional aspects of irrigation by the smallholder farmers, was used to investigate and compare aspects of land, water use, and crop productivity, including farmer income and livelihood sustainability. The study was conducted in the Zamra catchment, a sub-basin of the large Tekeze river basin and Nile basin tributary. Three common small-scale irrigation scheme types, i.e., traditional diversion, modern diversion, and dam (reservoir) based irrigation, were compared using four pilot survey areas. From the total of 618 farmer households in the study areas, 242 farmers were selected using stratified random sampling and participated in the survey and research. More than 100 input data were collected from the farmers related to the biophysical, socioeconomic, and institutional factors affecting their work practice and livelihood. Focus group discussions were conducted with elders, the water users association committee, and women-headed households. Descriptive statistics and multivariate analysis were used for quantitative analysis. The result indicates a significant difference between the three irrigation schemes. One important conclusion of this study was that the explanatory value of a single factor (e.g., biophysical), as commonly done in irrigation research and assessment, was seldom sufficient to explain water use, crop yield, and farmer income. Institutional and/or socioeconomic drivers also played an important role in the entire farming practice, income generation, and livelihood of the farmers. This study highlighted the value-added of the multidisciplinary approach (socioeconomic, biophysical, and institutional) for the evaluation of small-scale irrigation practices and livelihood analysis of agricultural smallholders in climate-affected regions, such as the Northern Ethiopian highlands.

Keywords: biophysical; institutional; multidisciplinary; Northern Ethiopia; small-scale irrigation; socio-economic; Zamra catchment

Citation: Mohammedshum, A.A.; Mannaerts, C.M.; Maathuis, B.H.P.; Teka, D. Integrating Socioeconomic Biophysical and Institutional Factors for Evaluating Small-Scale Irrigation Schemes in Northern Ethiopia. *Sustainability* **2023**, *15*, 1704. https://doi.org/10.3390/su15021704

Academic Editors: Jan Hopmans and Tommaso Caloiero

Received: 3 November 2022
Revised: 24 December 2022
Accepted: 12 January 2023
Published: 16 January 2023

1. Introduction

Irrigation is vital for realizing the full potential of the agricultural sector and is an essential means of achieving food security in many arid and semi-arid countries, including Ethiopia [1]. To increase production, small-scale irrigation schemes have been introduced in several places, such as dams, check dams, diversions, springs, and wells (e.g., [2–7]). However, these schemes are managed poorly, and the results are unsatisfactory. Hence the contribution of these schemes does not meet the expected level [6,8].

The performance of the irrigation schemes is evaluated based on two major aspects summarized; (1) There have been numerous studies done to assess the effectiveness of irrigation schemes based on socioeconomic and institutional aspects [9–12]. In their research, some problems identified were institutional failure, access to credit and extension services, access to information, financial constraints, no market information, and postharvest technology. Furthermore, there was an issue of gender; the female-headed household was lower than the male-headed, for example, in annual income, land size, access to credit, and agricultural extension services; (2) technical and institutional factors also assess the effectiveness of the irrigation scheme [13–15]. Sedimentation of canals, structural failure, failure of operating gates, poor irrigation water management, lack of market access and transportation, poor crop choice, crop disease, lack of postharvest technology and regular maintenance, conflict among users, weak local institutional arrangements were identified as the problems of the small-scale irrigation scheme. Situational analysis is important to maximize the benefits of irrigation; however, there are limited studies in arid and semi-arid parts of Ethiopia that characterize existing irrigation developments from multi-dimensional perspectives. Moreover, there were attempts to evaluate the performance of small-scale irrigation schemes, but they were limited to scheme types, for instance, traditional diversion.

The present paper aims to integrate the socio-economic, biophysical, and institutional factors for evaluating the performance of small-scale irrigation schemes. Using a multidisciplinary survey approach, collecting information on socio-economic, biophysical, and institutional aspects of irrigation by the smallholder farmers was used to investigate and compare aspects of land, water use, and crop productivity, including farmer income and livelihood sustainability. Three common small-scale irrigation scheme types, i.e., traditional diversion, modern diversion, and dam (reservoir) based irrigation, were compared. It is assumed as the null hypothesis that no significant differences in yield or income generated among the three irrigation scheme types can be observed.

2. Literature Review

Numerous research has concentrated on various areas due to the significance-performance of small-scale irrigation. [11], conducted on the socioeconomic, institutional, technological characteristics, and other related factors affecting farmer participation. Descriptive and econometric analysis was used to assess factors affecting community-managed irrigation schemes' utilization. In addition, Ref. [16] studied "Evaluation of small Farmer managed irrigation schemes in some Fadama communities of Oyo state, Nigeria" using descriptive and regression analysis. They interviewed the respondents from the rural area of the local government using a structured questionnaire. As a result, irrigation under the scheme gave profit, bringing economic prosperity to the Farmer. However, the insufficient water source delayed the development of more expanse of land. [12] used cross-sectional data to examine small-scale irrigation and household income. The respondents were selected through a multi-stage technique in eastern Ethiopia. The data was analyzed using the Heckman-two-step econometric model. They pointed out that institutional failure was a more important challenge than hydrological factors in managing the irrigation system.

Ref. [17] studied the impact of small-scale irrigation on the income of rural farm households in Tigray, Ethiopia. The techniques used to select the samples were multi-stage random sampling from three Tabiyas in Ahferom Woreda. The model used to analyze the data was using the Heckman treatment effect two-step model. They concluded that the biggest challenge in using small-scale irrigation was the loss of water, pests, and diseases. Moreover, they recommend that governments and other concerned bodies should work best on the quality, expansion, and distribution of small-scale irrigation schemes. Ref. [18] their work "Characterization of Smallholder Irrigation Schemes in Chirumanzu District, Zimbabwe," used different irrigation technologies. The data were analyzed using descriptive and inferential statistics. To finish, they recommend providing agricultural training to farmers in irrigation schemes to enhance their productivity. Similarly, in Ethiopia, [7,19] suggested empowering farmers through continuous capacity building through training on irrigation systems and managing efficiently. In addition, this approach should be farmers centered, like to practice, participate and adapt. Correspondingly, interventions were needed to develop the water user association's (WUA) technical, institutional, legal, and regulatory issues.

Ref. [14] investigated the performance of small-scale irrigation in Ethiopia using technical and institutional attributes. The assessment was based on 52 small-scale irrigation schemes and three case study sites. The data was collected via individual interviews, group discussions, key informant interviews, review of relevant documents, and field observations. He also used the pair-wise analysis method to identify the major constraints affecting small-scale irrigation in Ethiopia. As a result, many schemes were not operational due to design failures, excessive siltation, and poor agronomic and water management practice. Moreover, there was competition between upstream and downstream users, vegetable and cereal growers, farmers with large irrigable plots, and those with small plots. [20] the research focused on the technical performance of small-scale irrigation systems in Ethiopia. The performance was related to the water harvesting structure and delivery canals. As a result, sedimentation, structural failure, untreated upper watershed, poor irrigation water management, lack of knowledge, and lack of technical training were complications to the small-scale irrigation schemes.

According to [21], they compared the technical efficiencies of irrigated and rainfed plots in Tigray. In their research, when improving water allocation and distribution at the irrigation scheme level so that agricultural production can be more than double. Stochastic frontier and inefficiency models were used to compare the technical efficiencies of rain-fed and irrigated plots. The result shows that irrigated farms had higher production than rain-fed farms with significant inefficiencies. Ref. [22] evaluates the structure of water harvesting technology using technical criteria. The criteria were irrigation efficiency, output per command area, cost per hectare, and environmental effects. As a result, the output and investment cost per hectare was higher for dams than hand-dug wells and spate irrigation. Finally, they concluded that river diversion was the most productive technology considering the overall criteria.

Institutions management practices and challenges of small-scale irrigation systems in Ethiopia for two modern smallholders irrigation systems [23]. According to their research, the data was collected through a key informant and expert interview, desk review of different documents, group discussion, direct observation, and structured interview. In their research, the government uncritically supported the irrigation systems. In addition, irrigation institutions were not adequately planned and put in place. For instance, lack of established water use associations, Woreda level state irrigation agency not being established, a lack of enabling legal system of land and water rights, and policy-related problems. As a result, irrigation management was undermined, and the feasibility and sustainability of irrigated agriculture were risked. Moreover, water-related conflicts were not settled. At the same time, irrigation was indicated to positively impact irrigators' livelihood in terms of crop production, household income, housing, and employment generation.

In their work [24], "A comparative review of water management sustainability challenges in smallholder irrigation schemes in Africa and Asia." Their review highlights best practices from the Asian experience in which African countries learn to make irrigation schemes more robust. There were different records of achievement, for instance, institutional management, traditional knowledge, and management systems. In sub-Saharan Africa, water markets have been limited and disconnected from other markets due to low institutional capacity and poor water management practices. Furthermore, WUA in most African countries is weak and lacks legal backing to solve internal and external challenges independently. Resulting in undermined traditional management practices due to the heavy hand of the state in water management and the failure to contextualize the management practice.

3. Materials and Methods

3.1. Study Area

The study was conducted in the Zamra catchment, a tributary of the Tekeze sub-basin. The Tekeze sub-basin has a total area of 82,350 km^{2,} and the study area, the Zamra catchment, has an area of 1588 km^2 (Figure 1). The Zamra catchment is located between latitudes 12.966° N and 13.331° N and longitudes 39.003° E and 39.668° E. The altitude varies from 1248 to 3542 m above sea level (m a.s.l).

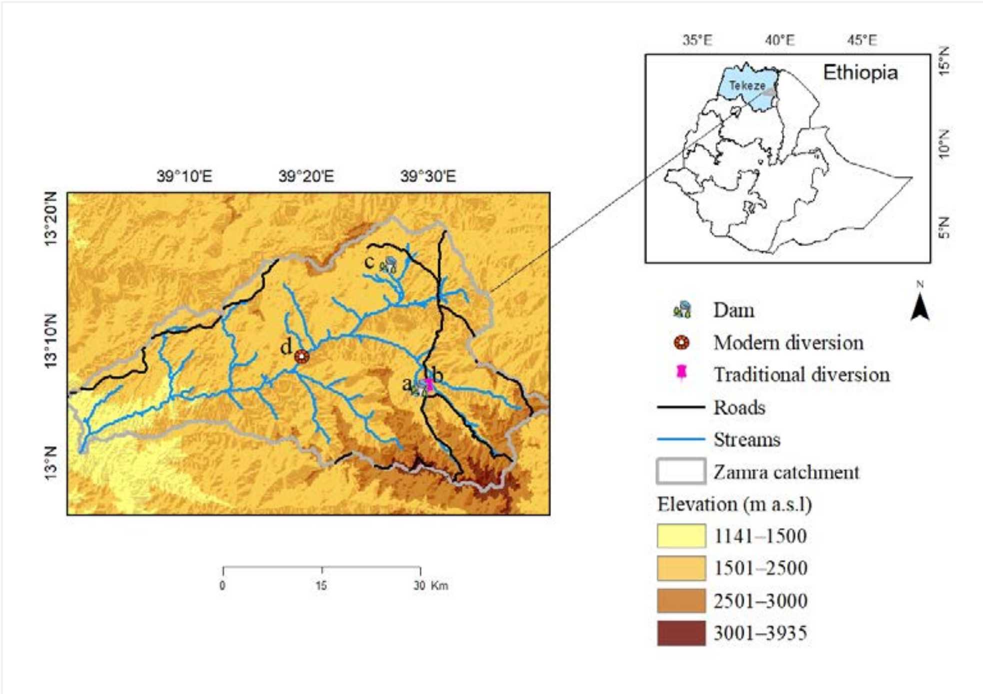


Figure 1. Location of the study area: (a) Shilanat-2 dam, (b) Gerebehiwane traditional diversion, (c) Adibashye dam, and (d) Gojibere modern diversion.

Three common small-scale irrigation scheme types, i.e., traditional diversion, modern diversion, and dam (reservoir)-based irrigation, were compared using four pilot survey areas (Figure 1). The climatic condition of the Tigray region varies from arid to semi-arid [25]. The climate of the study area is mainly semi-arid; the primary rainfall season lasts from June to mid-September, with some areas obtaining rainfall from February to May. Rainfall in the Tigray region is erratic, and sometimes heavy rains cause flooding [3]. The annual precipitation values for 2009–2021 for the Zamra catchment were analyzed using the WaPOR database [26], and the average annual precipitation was 600 mm. In the Zamra catchment, the minimum and maximum yearly precipitation over the analysis period were 514 mm and 715 mm, respectively.

3.2. Sampling Procedures and Data

In this case study, quantitative and qualitative research approaches were used; mixed techniques improve the accuracy of data obtained by allowing cross-validated findings [27,28]. The data was collected from household surveys and secondary data from relevant government and non-government offices involved in irrigation water use management. Survey data were collected from August 2020 to September 2020. From the total of 618 farmer households in the study areas, 242 farmers were selected using stratified random sampling and participated in the survey and research. First, we selected the type of irrigation scheme (source of irrigation water) commonly used in the study area. Next, we randomly select farmers of different ages and also gender in the irrigation systems to not create any sample bias in the population. Structured questionnaires were prepared for each group. After pretesting the questionnaires, 89 farmers from the first group, 120 from the second group, and 33 from the third group were interviewed. More than 100 input data were collected from the farmers related to the biophysical, socioeconomic, and institutional factors affecting their work practice and livelihood.

After the interview, focus group discussions (FGDs) with elders, the irrigation committee, and water distributors were held to verify ambiguous issues related to irrigation water use management. In addition, women-led household discussions with 13 women-led households were held to assess any issues related to irrigation water use management. FGD is one of the most widely applied data collection methods for qualitative research in a mixed-method approach [29]. Key informant's interview (KII) occurred in two selected Districts, including Kebele experts and government and non-governmental organizations.

3.3. Methodology

Descriptive statistics and Multivariate analysis using the One-way Analysis of Variance (ANOVA) were used for quantitative analysis. First, descriptive statistical methods such as arithmetic mean, percentages, and univariate analysis were used to describe and examine the respondents' characteristics. Second, the One-way ANOVA was used to show the significant difference between irrigation schemes on farmers' income. The analysis determined the farmer's income that influences the utilization of different irrigation schemes. The One-way ANOVA involved dependent variables and factors. The dependent variable is farmers' income from irrigation schemes, based on the water source they utilize. Therefore, depending on the farmers' income, there may be a significant difference between irrigation schemes. The data was analyzed using Statistical Package for Social Sciences (SPSS 20) software. Based on literature reviews, variables that capture individual socioeconomic, biophysical, and institutional characteristics and the use of different irrigation schemes are identified to find a possible explanation for the characterization of small-scale irrigation schemes, as given in Table 1.

Table 1. The synthesis of the study variables and measurement indicators.

Variables	Indicator
Demographic	Age and gender
Household resources	Land access and irrigation season crops grown
Access to irrigation	Access to irrigation water and flexibility in irrigation based on crop type
Participation in extension	Participate in demonstrations, access to credit, and frequency of advisory service
Irrigation production	Own production (quintal), total irrigated area (ha), irrigation experience, average yield, and income (birr)
Challenges	Shortage of irrigable land, water shortage for irrigation, shortage of improved seed, high post-harvest loss, pests and disease, canal problem, siltation, lack of maintenance, price fluctuation, transport problems, and distance to market
Major opportunities	Food self-sufficiency, teaching their children, building a house, and purchasing livestock

Data generated from the KII and FGDs were analyzed using thematic analysis, an inductive approach grounded in the participants' views [19,20]. The thematic analysis provides a flexible and useful research tool that has the potential to provide a rich and complete explanation of the data.

4. Results

4.1. Characteristics of the Sample Household

Figure 2 shows the characteristics of the sample households. The descriptive results indicate that the heads of the dam and modern diversion households were younger (48 years and 49.53 years) than those of traditional diversion households (51.33 years). The number of male-headed households in all the irrigation schemes was higher than that of female-headed households: 15% of the modern diversion, 12% of the dam, and 12% of traditional diversion households were female-headed (Figure 2).

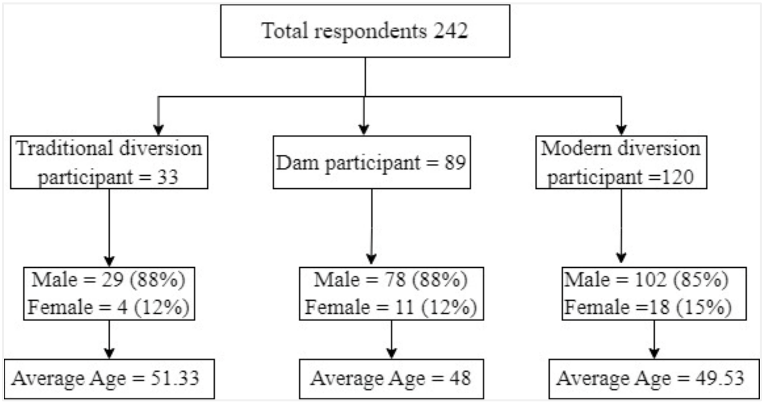


Figure 2. Characteristics of the sample households.

4.2. Factors Affecting Small-Scale Irrigation

Results of the interview (Figure 3) present access to irrigation water between the irrigation schemes, traditional diversion (79%), modern diversion (75%), and dams (52%). The factor influencing irrigation water use is the water availability throughout the year.

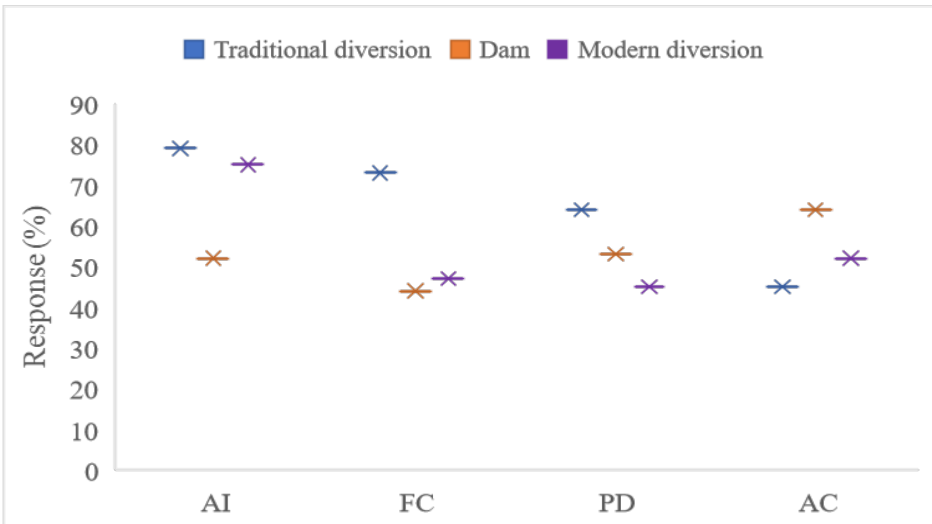


Figure 3. Accessibility to irrigation and extension services (AI: Access to irrigation water, FC: Flexibility in crop type, PD: Participation in a demonstration, AC: Access to credit) for all irrigation schemes.

Regarding flexibility in irrigation timing based on the crop type, traditional diversion, modern diversion and dam were 73%, 47%, and 44%, respectively (Figure 3). As shown in Figure 3, more than 64% of the traditional diversion households had access to participate in the demonstration, and 45% of the households had access to credit services. Households in modern diversion and dam had 53% and 45 % access to participate in the demonstration, respectively. 64% of dam households and 52% of modern diversion households had access to credit.

The frequency of advisory service received is daily, weekly, bi-weekly, monthly, and unconditional. Traditional diversion households are 33% weekly, 27% unconditional, 18% monthly, 18% bi-weekly, and 3% daily. Dam households are 36% monthly, 31% weekly, 21% bi-weekly, and 12% unconditional. Modern diversion households received advisory services 49% monthly, 26% weekly, 26% bi-weekly, 5% of the time unconditionally, and 2% daily (Figure 4). The result shows that the location of the irrigation scheme is one factor for the advisory service to be received.

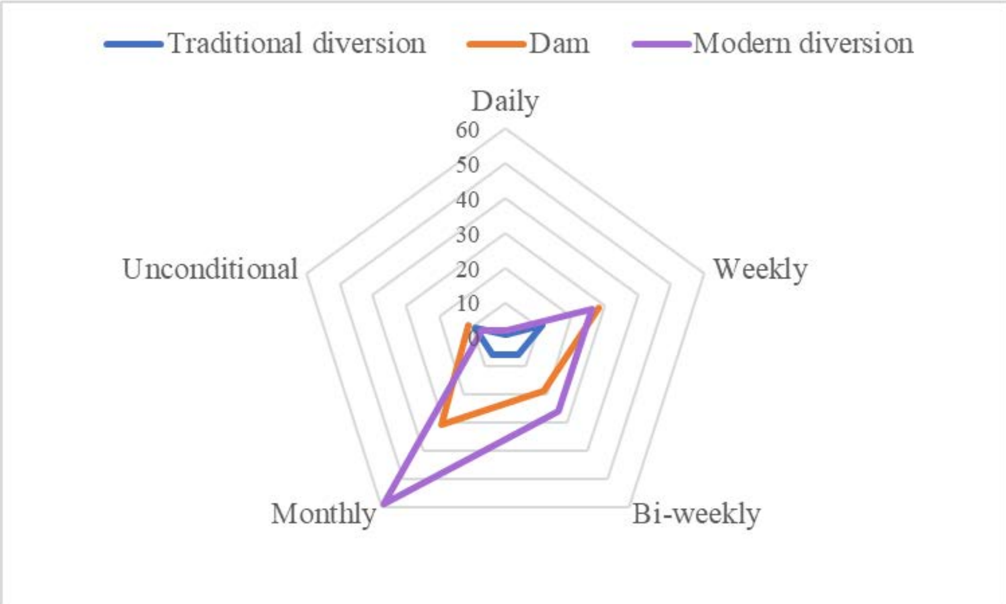


Figure 4. Frequency of advisory service received for the dam, traditional and modern diversions.

Regarding land access, 95% of the modern diversions, 78% of dams, and 79% of the traditional diversion farmers had access to their land. At the same time, farmers had shared access land, 5% modern diversion, 18% dam, and 21% traditional diversion. Farmers from the dam accounted for 5% of users who had rented land (Figure 5). The land size was critical in having a positive impact in terms of increasing income [10].

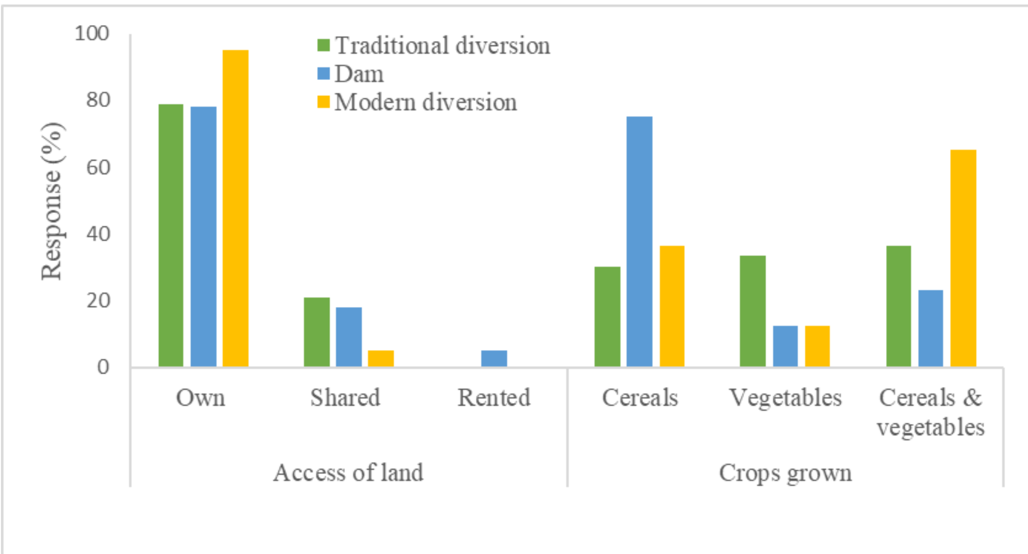


Figure 5. Access to land and type of crops grown in the irrigation season for the irrigation schemes.

In terms of crops growing in the irrigation season, that is, cereals, vegetables, and both. It was discovered that 30% of traditional diversion households, 12% of modern diversion households, and 75% of dam households grow cereal crops. Furthermore, cereals and vegetables were grown with modern diversion 65%, traditional diversion 36.5%, and dam 12.5% (Figure 5).

4.3. Production from Irrigation

The traditional diversion households also had more experience in irrigation (21.61 years) than modern diversion (19.33 years) and dam (15.19 years) households. Moreover, about their production, the traditional diversion households gained more production than the dam and modern diversions (Table 2).

Table 2. Mean of irrigation production and experience of farmers in irrigation.

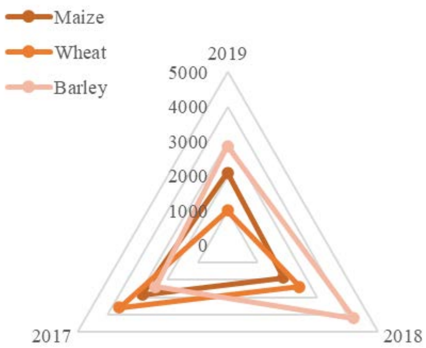
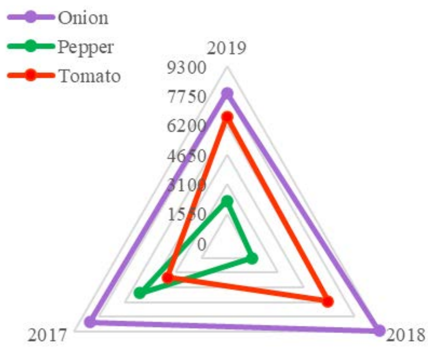
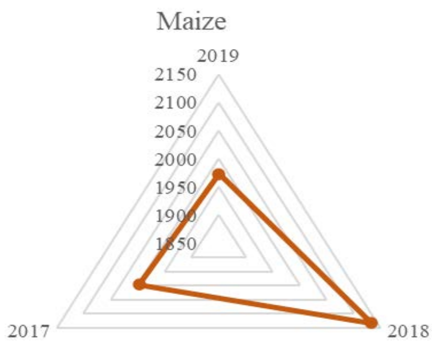
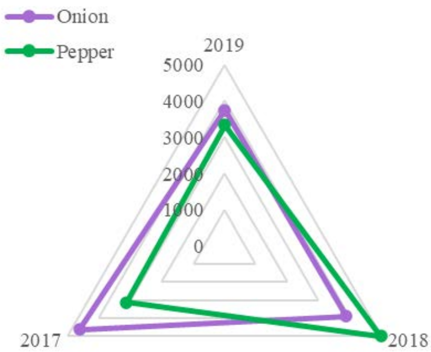
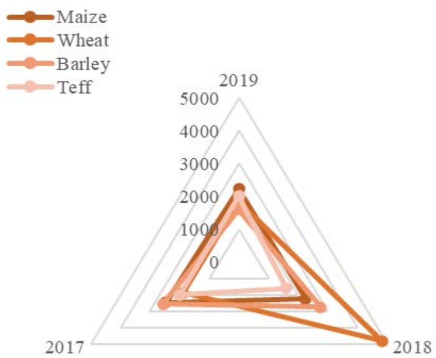
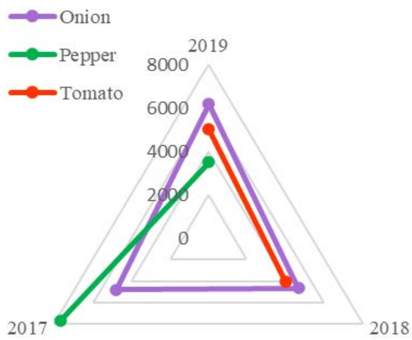
		Traditional Diversion	Dam	Modern Diversion
		Mean	**Mean**	**Mean**
	Irrigation experience (year)	21.61	15.19	19.33
Irrigation production	Total irrigated area (ha)	0.36	0.34	0.26
	Own production (kg)	2145	1892	1095
	Income (birr)	19,582.4	17,475.2	12,923.3

In addition, the FGD participant also confirmed that the income of the traditional diversion is more than the dam: "I have used both irrigation schemes for more than 18 years. When I compare the income, traditional diversion generates more than the dam. Because most of the time in the traditional diversion grows vegetables, the income of vegetables is more than cereals and improves well-being" (57-year-old male farmer in Gerebe hiwane and Shilant-2).

Table 3 shows the average yield of major crops produced during three consecutive years, 2017, 2018, and 2019 using traditional diversion, dam, and modern diversion. The yield (kg/ha) was computed using the ratio of the total yield (in kilograms) to the irrigated area (ha). From the interview, all the irrigation schemes have good experience growing maize and onion crops. Most of the time during the irrigation season, the farmers in modern diversion planted pepper; it was observed from the field visit and discussed with the farmers and agricultural experts in the irrigation scheme. Other crops grown in the study area were pepper, wheat, tomato, barley, and teff. For instance, in the 2019/2020 irrigation season, the Central Statistical Agency (CSA) [30] reported that in the Tigray region, the average maize and onion yield was 3075 kg/ha and 6361 kg/ha, respectively. The comparison with the previous report shows a 17% and 3% yield decrement, respectively.

As indicated in Tables A1 and A2, compare each irrigation scheme production with different indicators like access to sufficient irrigation water, credit, and weekly and bi-weekly advisory services were obtained high production in the traditional diversion. In the modern diversion, the highest production was obtained when access to irrigation water and unconditional advisory service (Table A2). But, there had no access to credit and had a transport problem (Table A1). The dam irrigation scheme had sufficient irrigation water, and the monthly advisory service obtained the highest production (Table A2). Moreover, there was access to credit services, but there was a price fluctuation, distance to the market, and transport problems (Table A1).

Table 3. Radial diagrams show major crop yield (kg/ha) during 2019, 2018, and 2017.

	Cereals	Vegetables
Traditional Diversion		
Modern Diversion		
Dam		

The current study (Table 4) presents the significant difference between irrigation schemes on farmers' income based on the One-way ANOVA. The mean difference indicates a significant difference in farmers' income between the modern diversion and the dam, as well as between the traditional and modern diversion. However, there is no significant difference between the dam and traditional diversion.

Table 4. Mean differences between irrigation schemes on farmers' income.

(I) Major Sources of Irrigation Water	(J) Major Sources of Irrigation Water	Mean Difference (I–J)	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Traditional Diversion	Modern Diversion	6659.09091 *	0.007	1806.5069	11,511.6749
	Dam	2107.14334	0.410	−2924.4193	7138.7060
Modern Diversion	Traditional Diversion	−6659.09091 *	0.007	−11,511.6749	−1806.5069
	Dam	−4551.94757 *	0.010	−8005.4714	−1098.4237
Dam	Traditional Diversion	−2107.14334	0.410	−7138.7060	2924.4193
	Modern Diversion	4551.94757 *	0.010	1098.4237	8005.4714

Note: * The mean difference is significant at the 0.05 level.

4.4. Irrigation Challenges and Opportunities

4.4.1. Quantitative Results

According to this study (Figure 6), major challenges of the traditional diversion irrigation scheme affect the production and productivity of the irrigated crops. From the interview, 64% of the farmers perceived a shortage of water, a shortage of irrigable land and pests and disease (61%), and a canal problem (42%). Furthermore, farmers who use dams for irrigation perceive (63%) that there was a shortage of water, pests, and disease (58%), a shortage of irrigable land (51%), lack of maintenance (45%), and a shortage of improved seed (43%). On the other hand, modern diversion farmers see a major challenge to crop production and productivity of irrigated crops. 91% lack maintenance, 79% perceived pests and disease, 73% scarcity of improved seeds, 55% scarcity of irrigable land, and 34% high post-harvest loss. Therefore, from this study, the major challenge for traditional diversions and dams is water shortage. In the modern diversion, a lack of maintenance and improved seed poses a significant challenge to the production and productivity of irrigated crops (Figure 6). This study found that the major challenge was a water shortage and a lack of improved seeds, similar to [31].

Figure 6. Major challenges of irrigation schemes like dams and diversions (traditional and modern).

Marketing is one of the challenges affecting the income of farmers. The major challenges for modern diversion households are transport problems (70%) and distance to the market (55%). Concerning traditional diversion (64%) and dam (56%) households, the major challenge in marketing is price fluctuation (Figure 6). Similar to the findings of this study, price fluctuations happen due to targeting planting dates, and market incentives are not considered [32]. In addition, market access and transport problems are also challenging for small-scale irrigation schemes [20,33].

Generally, irrigation use in the study area has made a significant contribution to food self-sufficiency (33%) and teaching their children (31%), as shown in Figure 7. Irrigation users enabled their children to attend school and acquire livestock [33]. As a result, this paper's findings align with those scholars who indicate a positive impact on the use of irrigation.

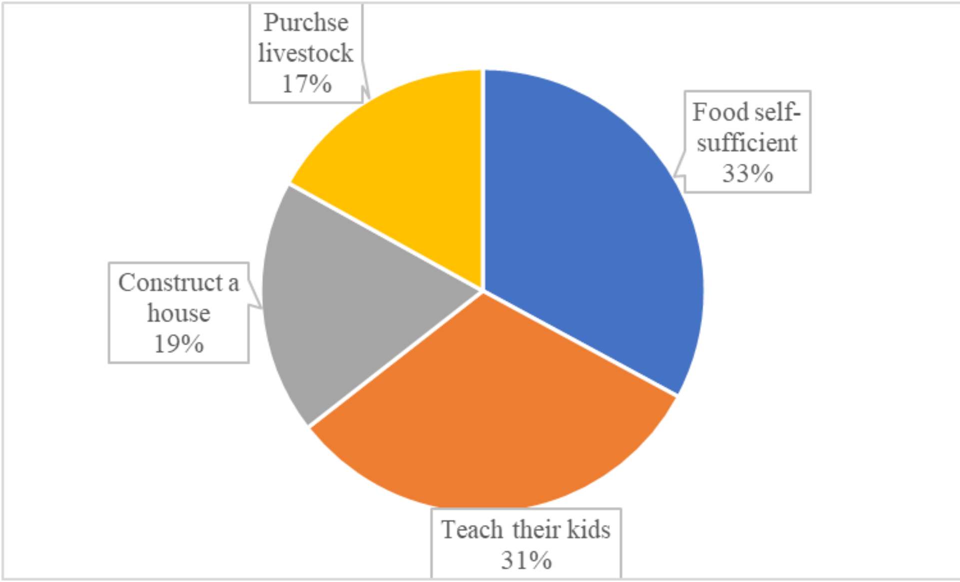


Figure 7. Irrigation major opportunity for all irrigation schemes.

4.4.2. Qualitative Results on Challenges and Opportunities

Similarly, irrigation challenges were also described by an FGD participant in the irrigation schemes as follows: the shortage of water for irrigation, lack of access to credit and extension service, pests and disease, transport problems, and price fluctuation.

For example, a participant in an FGD said,

> "I have a scarcity of irrigable land because my irrigated field is in the lower stream area, which is never irrigated during the irrigation season due to water shortages in the irrigation scheme. Accordingly, my production was lower as compared to other farmers". (40-year-old female farmer in the Adibashay irrigation scheme)

Female households had lower access to irrigation and credit service than males. In addition, the advantage of credit is mentioned by female participants in the irrigation scheme,

> "I am the female head of the household in the irrigation scheme. Now I rent oxen for plowing the field. If the government provided me with a credit service, I would buy oxen and reduce rent expenses. As a result, I will improve the well-being of the children and mine". (37-year-old female farmer in Shilant-2 irrigation scheme)

Follow-up of the agricultural extension was also a challenge

> "I participated in demonstrations from my side to get feedback and from other farmers to gain experience. I understand there is a follow-up from agricultural extension in one of the demonstrations, and I see the farmers have a good experience. When I compare my irrigation scheme, there is no follow-up from the agricultural extensions. So, I have a problem not getting updated information from District and Kebele experts". (53-year-old male farmer in Adibashay irrigation scheme)

> "In the irrigation scheme, there is a shortage of chemicals for pests and diseases. Moreover, there is no scientific research on pests and disease". (54-year-old male farmer in Shilant-2 irrigation scheme)

> "There is a transportation issue for selling our vegetables and fruits at the district market, so I used a donkey to transport them. As a result, vegetables are perishable, lowering their quality and reducing profit". (50-year-old male farmer in Adibashay irrigation scheme)

> "I plant a crop that is similar to my neighbor's. It depends on water availability in the irrigation scheme, not market-oriented. Nevertheless, it is not profitable because all the farmers simultaneously sell the same crop type". (68-year-old male farmer in Shilant-2 irrigation scheme)

Research findings [14] indicate that in Ethiopia, there was market saturation that affected many farmers due to producing the same crops simultaneously with a limited number of traders and consumers. This result is in line with this study.

Another challenge the FGD participants said was that irrigating the whole field completely flooded is a problem in their respective irrigation schemes. As stated by the following participants,

> "Farmers are concerned that the fields are becoming flooded and believe more water is beneficial. However, there is a problem with the plant. In this regard, when the amount of water is reduced from the dam, the irrigating time is reduced, for instance, from 3 h to 1 h". (53-year-old male farmer in Shilant-2 irrigation scheme)

The damage caused by fields becoming flooded was also mentioned by another participant:

> "It is difficult to control the farmers as they lack an awareness of irrigating the field. However, the committee has decided to reduce the interval of irrigating cereals from 3 weeks to one month and vegetables from one week to two weeks". (46-year-old male farmer in Adibashay irrigation scheme)

Irrigation Major Opportunities

Irrigation use in the study area has made a significant contribution. For example, a participant in an FGD said, "The use of irrigation is essential. My house is always whole, and irrigation provides me with similar benefits to what a mother can provide" (55-year-old female farmer in Gerebe hiwane irrigation scheme).

Another participant also mentioned the use of irrigation, "Before irrigation started, I irrigated 2 ha of land using rainfall. However, building the dam reduced the irrigated land to 1 ha. However, when I compare the income from the previous one, it increases even if the irrigated land is reduced" (50-year-old male farmer in Adibashay irrigation scheme).

A participant in one of the FGDs said, "Even if you don't produce the crop yourself, it is easy to get goods locally all the time and at reasonable prices" (a 45-year-old male farmer in the Adibashay irrigation scheme).

5. Discussion

5.1. Importance of the Multidisciplinary Approach

The study shows the importance of a multidisciplinary approach in characterizing small-scale irrigation schemes. It is because the success of irrigation development depends on various socioeconomic factors, institutional arrangements, and technical considerations [3]. As indicated in the result section, smallholder farmers' socioeconomic, biophysical, and institutional aspects of irrigation were used to investigate and compare the irrigation schemes.

As shown in Figure 3, the traditional diversion users had better access to irrigation water, flexibility in crop type to irrigation, and participation in demonstration than modern diversion and dam. However, the price fluctuation was higher when compared to the other irrigation schemes (Figure 6). Moreover, there is a canal problem in the traditional diversion because the river diversion is made through the pilling of brushwood, wood logs, and river bed material [34,35]. The traditional diversion households gained more production than the dam and modern diversion (Table 2). As shown in Figure 5, the traditional diversion users grow most of the time vegetables. This study's findings align with those [32], who indicated that households could diversify production to new marketable crops, such as vegetables, to increase farmers' income in Ethiopia.

The modern diversion users had grown cereals and vegetables more than traditional and dam users (Figure 5). However, there is a problem with transportation and market distance; this irrigation scheme is 20 km away from the District and has no transport service (Figure A1). It is located downstream of the catchment, and the climate is hotter than the other irrigation schemes. Access to participation in the demonstration and frequency of advisory service from the extension service had a problem. According to [10,18,31], follow-up from extension staff could play a significant role in effectively using irrigation water and enhancing their productivity. Compared to other irrigation schemes, the modern diversion had more affected by pests and disease, a shortage of improved seeds, a lack of maintenance, and high post-harvest loss (Figure 6). Crop disease prevalence negatively impacted irrigation due to low productivity [7,17]. Therefore, the household production was lower than the traditional diversion and dam (Table 2).

The dam irrigation scheme was located in the upper parts of the Zamra catchment. The accessibility of irrigation water and flexibility based on crop type was lower than the other irrigation schemes (Figure 3). However, access to credit service had better than modern and traditional diversions. Therefore, increasing farmers' access to credit facilities could improve their ability to participate in irrigation [10,12].

Table 3 and Figure 5 show that the dam irrigation schemes irrigated more cereal crops than vegetables. The planted crop was selected based on the availability of water in the dam. It was decided by the community of the farmers and agricultural extension. Both the dam and traditional diversion had price fluctuations. However, the production from the dam was lower than the traditional diversion, as the dam users have grown more cereals than vegetables. The dam canal was constructed with concrete structures, but the study area canal lacked maintenance (Figure A2). This study agrees with previous studies in that there is a lack of maintenance and canal problems [8,36,37], which provides that there are technical constraints and knowledge gaps in the operation and maintenance of irrigation facilities.

Generally, the result indicates a significant difference in farmers' income among the irrigation schemes (Table 4). The farmers' income differed based on biophysical, institutional, and socio-economic factors.

5.2. Impact of Irrigation on Smallholder

Research findings from KII also explained the challenges of irrigation. Most of the organizations explained that the challenge was technical and material gaps. The materials are automation rain gauge, soil moisture sensor, and water flow instruments. Likewise, the technical gaps are irrigation water use management and identifying pests and disease types. In addition, they lack well-trained experts in designing, constructing, and maintaining irrigation schemes.

Additionally, there was also a follow-up problem. It was due to the scheme's construction and development by different organizations. To end with, the KII was given suggestions like updated scientific technologies to irrigation water management and materials, which help to improve the irrigation water use efficiency in small-scale irrigation schemes. Further, it needs market shade and stores to preserve and establish a market cooperative.

The findings of this paper are similar to those of other scholars [2,8,12,14,37,38] who claim that weak local institutions cause irrigation schemes to fail. In Ethiopia, there were no inadequate police and regulations on water fees, water rights, water conflict resolutions, and incentives for collaborations [8]. It should then improve institutional mechanisms to enforce it through law [37,39]. Studies [13,14,31] suggest that to sustain irrigated agriculture, agronomic methods should be improved, postharvest technology should be implemented, and watershed management should be combined with irrigation development. According to [2], additional research on water productivity in agriculture should be conducted; similar to the KII findings, organizations should support training and experiments on water productivity. Refs. [32,36] Recommends giving attention to poor people, especially women, there is a poor economic background for agricultural inputs.

Small-scale irrigation is one of the variable solutions to secure household food needs in the country [3,14,32,34,40]. For instance, increasing the yield of crops improves food security, reduces unemployment, and reduces urbanization pressure. [16] also indicated that irrigation under the scheme has brought economic prosperity to the farmers and promotes maximum yield per hectare. Participation in irrigation had a significant impact on annual income. For example, annual income was twice that of non-irrigation users [41].

6. Conclusions

The analysis indicated contrasting results with respect to the interaction of the three different factors (socioeconomic, biophysical, and institutional) for characterizing and evaluating small-scale irrigation areas and respective smallholder farmers considered in this study.

The survey and statistical analysis revealed several cause–effect relationships among socioeconomic, biophysical, and institutional drivers, constraints, and opportunities. A major example is a relationship found between farmer income and irrigation scheme types. A rather counterintuitive finding was that traditional small diversions led to higher farmer income, well-being, and satisfaction than modern diversions and smallholder irrigation practices downstream of small dams and reservoirs.

The institutional factor of free crop choice (or not in the case of dam-based irrigation) was a major cause here. In the small-scale irrigation pilot study area using the modern diversion technique, crop selection is a farmer's choice (vegetables and cereals). Here, a combination of biophysical elements (lower elevation downstream the Zamra catchment on different lithologies and local drier and hotter microclimate, including locational aspects (distance from the larger road network, markets) could explain much about income and overall satisfaction. With respect to dam-based smallholder irrigation practices located in the upper parts of the Zamra catchment. The dam users didn't have flexibility in irrigation timing based on the crop type compared to other irrigation schemes. Moreover, a shortage of irrigation water, a lack of improved seeds, pests and diseases, and there was siltation in the dams. However, access to credit was better than the other irrigation schemes. In the dam, most of the time, the crops were grown cereals. The production from the dam was lower than the traditional diversion but more than the modern diversion.

This highlights the need to consider an integrated and multidisciplinary analysis of small-scale irrigation and farming to elucidate factors and elements that can lead to better choices for all stakeholders (farmers, irrigation institutions, government, and private) for improving the livelihood of smallholders in semiarid and mountainous regions. Additional research on water productivity in agriculture should be conducted. Moreover, alternative mechanisms must be implemented to update technologies in irrigation water management and materials, which help to improve the irrigation water use efficiency in small-scale irrigation schemes. For instance, automation rain gauge should be placed at the scheme level, and satellite data, water flow instruments, and a crop calendar are required.

Author Contributions: A.A.M. collected the data, analyzed the result, and wrote the draft article. Supervision: C.M.M., B.H.P.M. and D.T. Writing, reviewing, and editing the manuscript: A.A.M., C.M.M. and B.H.P.M. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the Dutch organization for internationalization in education (Nuffic), the University of Twente, the Faculty of Geo-information Science and Earth Observation (ITC), and the Ministry of Science and Higher Education of Ethiopia (MoSHE) under the Ethiopian Educational Network to Support Agricultural Transformation (EENSAT) project (CF13198, 2016).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data will be made available on DANS (Data Archiving and Networking service) of the University of Twente, Enschede, The Netherlands.

Acknowledgments: The contribution of Mahari Asfaw and Regional, District, and Kebele agricultural experts, Non-government organizations, and the farmers around the Zamra catchment is also properly acknowledged for their dedicated support and cooperation during the study.

Conflicts of Interest: The authors declare that they have no conflict of interest.

Appendix A

Figure A1. Road infrastructure in modern diversion photo taken by A.A.M. on 28 August 2020.

Figure A2. Poor canal maintenance at the Shilant-2 dam; the photo was taken by A.A.M. on 21 August 2019.

Table A1. Production of each irrigation scheme with market and credit service analysis.

Dependent Variable: Production (Quintal)						
Sources of Irrigation Water	Challenges to Marketing	Access to Credit	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Traditional Diversion	Price fluctuation	Yes	32.375	4.400	23.702	41.048
		No	20.538	3.452	13.735	27.342
	Transport problem	Yes	39.000	12.446	14.469	63.531
		No	15.000	8.800	−2.346	32.346

Table A1. *Cont.*

Dependent Variable: Production (Quintal)						
Sources of Irrigation Water	**Challenges to Marketing**	**Access to Credit**	**Mean**	**Std. Error**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
	Distance to market	Yes	.[a]	.	.	.
		No	.[a]	.	.	.
	Lack of store/shade	Yes	15.000	12.446	−9.531	39.531
		No	.[a]	.	.	.
	No problem	Yes	15.600	5.566	4.629	26.571
		No	6.667	7.186	−7.496	20.830
Modern Diversion	Price fluctuation	Yes	.[a]	.	.	.
		No	.[a]	.	.	.
	Transport problem	Yes	.[a]	.	.	.
		No	16.000	12.446	−8.531	40.531
	Distance to market	Yes	.[a]	.	.	.
		No	8.000	12.446	−16.531	32.531
	Lack of store/shade	Yes	5.000	12.446	−19.531	29.531
		No	.[a]	.	.	.
	Price fluctuation, distance to market, and transport	Yes	13.409	2.653	8.179	18.639
		No	11.364	3.753	3.967	18.760
	Transport problem and distance to market	Yes	9.600	1.968	5.721	13.479
		No	10.932	1.876	7.234	14.630
Dam	Price fluctuation	Yes	22.270	2.046	18.237	26.303
		No	24.154	3.452	17.350	30.958
	Transport problem	Yes	.[a]	.	.	.
		No	12.250	6.223	−0.016	24.516
	Distance to market	Yes	20.000	8.800	2.654	37.346
		No	11.500	8.800	−5.846	28.846
	Lack of store/shade	Yes	20.000	12.446	−4.531	44.531
		No	.[a]	.	.	.
	No problem	Yes	15.692	3.452	8.889	22.496
		No	11.167	5.081	1.152	21.181
	Price fluctuation, distance to market, and transport	Yes	30.000	12.446	5.469	54.531
		No	4.000	12.446	−20.531	28.531
	Transport problem and distance to Market	Yes	.[a]	.	.	.
		No	5.000	12.446	−19.531	29.531
	None	Yes	14.333	7.186	0.170	28.496
		No	12.200	5.566	1.229	23.171

[a] This level combination of factors is not observed; thus, the corresponding population marginal mean is not estimable.

Table A2. Irrigation schemes compare production with access to irrigation and frequency of advisory service.

Dependent Variable: Production (Quintal)						
Sources of Irrigation Water	**Frequency of Advisory Service**	**Sufficient Irrigation Water**	**Mean**	**Std. Error**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Traditional Diversion	Daily	Yes	10.000	12.487	−14.611	34.611
		No	.[a]	.	.	.
	Monthly	Yes	9.600	5.584	−1.407	20.607
		No	10.000	12.487	−14.611	34.611
	Weakly	Yes	28.333	4.162	20.130	36.537
		No	31.500	8.830	14.097	48.903
	Bi-weekly	Yes	33.200	5.584	22.193	44.207
		No	10.000	12.487	−14.611	34.611
	unconditional	Yes	17.429	4.720	8.126	26.731
		No	12.000	8.830	−5.403	29.403
Modern Diversion	Daily	Yes	19.000	8.830	1.597	36.403
		No	.[a]	.	.	.
	Monthly	Yes	9.750	1.882	6.040	13.460
		No	8.667	3.224	2.312	15.021
	Weakly	Yes	9.917	2.549	4.893	14.940
		No	5.500	8.830	−11.903	22.903
	Bi-weekly	Yes	13.727	2.662	8.480	18.974
		No	7.750	6.244	−4.556	20.056
	Unconditional	Yes	19.286	4.720	9.983	28.588
		No	.[a]	.	.	.
Dam	Daily	Yes	.[a]	.	.	.
		No	.[a]	.	.	.
	Monthly	Yes	20.783	2.604	15.651	25.914
		No	23.250	4.415	14.549	31.951
	Weakly	Yes	18.750	3.122	12.597	24.903
		No	16.750	3.605	9.645	23.855
	Bi-weekly	Yes	19.615	3.463	12.789	26.441
		No	12.167	5.098	2.119	22.214
	Unconditional	Yes	16.833	5.098	6.786	26.881
		No	18.000	5.584	6.993	29.007

[a] This level combination of factors is not observed; thus, the corresponding population marginal mean is not estimable.

References

1. Awulachew, S.B.; Merrey, D.; Kamara, A.; van Koppen, B.; Penning de Vries, F.; Boelee, E. *Experiences and Opportunities for Promoting Small-Scale/Micro Irrigation and Rainwater Harvesting for Food Security in Ethiopia*; International Water Management Institute: Addis Abeba, Ethiopia, 2005.
2. Behailu, M.; Haile, M. Water Harvesting in Northern Ethiopia: Environmental, Health and Socio-Economic Impacts | Mendeley. Available online: https://www.mendeley.com/search/?page=1&query=Water%20harvesting%20in%20northern%20Ethiopia%3A%20environmental%2C%20health%20and%20socio-economic%20impacts&sortBy=relevance (accessed on 10 December 2022).

3. Hagos, E. Development and Management of Irrigation Lands in Tigray, Ethiopia. Ph.D. Thesis, Wageningen University, Wageningen, The Netherlands, UNESCO-IHE, Delft, The Netherlands, 2005; pp. 1–12.
4. Haregeweyn, N.; Poesen, J.; Nyssen, J.; de Wit, J.; Haile, M.; Govers, G.; Deckers, S. Reservoirs in Tigray (Northern Ethiopia): Characteristics and Sediment Deposition Problems. *Land Degrad. Dev.* **2006**, *17*, 211–230. [CrossRef]
5. Teka, D.; van Wesemael, B.; Vanacker, V.; Poesen, J.; Hallet, V.; Taye, G.; Deckers, J.; Haregeweyn, N. Evaluating the Performance of Reservoirs in Semi-Arid Catchments of Tigray: Tradeoff between Water Harvesting and Soil and Water Conservation. *Catena* **2013**, *110*, 146–154. [CrossRef]
6. Teka, D. Multi-Scale Analysis of Surface Runoff and Water-Harvesting Dams in a Semi-Arid Region: A Case Study in Tigray (Ethiopia). Ph.D. Thesis, UCL-Université Catholique de Louvain, Ottignies-Louvain-la-Neuve, Belgium, 2014.
7. Yohannes, D.F.; Ritsema, C.J.; Solomon, H.; Froebrich, J.; van Dam, J.C. Irrigation Water Management: Farmers' Practices, Perceptions and Adaptations at Gumselassa Irrigation Scheme, North Ethiopia. *Agric. Water Manag.* **2017**, *191*, 16–28. [CrossRef]
8. Awulachew, S.; Erkossa, T.; Namara, R.E. Irrigation Potential in Ethiopia: Constraints and Opportunities for Enhancing the System. *Gates Open Res.* **2010**, *3*, 22. [CrossRef]
9. Ashu, E. The Impact of Small Scale Irrigation on the Income and Food Security Among Small-Scale Farmers in Ethiopia: A Review. *Am. J. Environ. Resour. Econ.* **2022**, *7*, 53–59.
10. Adela, F.A.; Aurbacher, J.; Abebe, G.K. Small-Scale Irrigation Scheme Governance—Poverty Nexus: Evidence from Ethiopia. *Food Secur.* **2019**, *11*, 897–913. [CrossRef]
11. Abe, A. Utilization of Community Managed Irrigation Scheme in Bale Zone: The Case of Agarfa Woreda, Oromia Regional State, South East Ethiopia. *J. Equity Sci. Sustain. Dev. (JESSD)* **2019**, *3*, 39–50.
12. Sisay, B.; Fekadu, B. Small-Scale Irrigation and Household Income Linkage: Evidence from Deder District, Ethiopia. *Afr. J. Agric. Res.* **2013**, *8*, 4441–4451. [CrossRef]
13. Awulachew, S.B.; Ayana, M. Performance OF Irrigation: An Assessment at Different Scales in Ethiopia. *Exp. Agric.* **2011**, *47*, 57–69. [CrossRef]
14. Amede, T. Technical and Institutional Attributes Constraining the Performance of Small-Scale Irrigation in Ethiopia. *Water Resour. Rural. Dev.* **2015**, *6*, 78–91. [CrossRef]
15. Belay, A.M.; Assefa, T.; Belay, S.A.; Yimam, A. Evaluating the Performance of Small-Scale Irrigation Schemes in Sub Humid Ethiopian Highlands; a Case Study in Mugie and Fesas. *Irrig. Drain.* **2022**. [CrossRef]
16. Olaniran, J.A.; Adetutu, O.; Oloruntuga, I.; Ojo, O.I. Evaluation of Small Farmer Managed Irrigation Schemes in Some Fadama Communities of Oyo State, Nigeria. *Ann. Fac. Eng. Hunedoara* **2019**, *17*, 89–96.
17. Yihdego, A.G.; Gebru, A.A.; Gelaye, M.T. The Impact of Small—Scale Irrigation on Income of Rural Farm Households: Evidence from Ahferom Woreda in Tigray, Ethiopia. *Int. J. Bus. Econ. Res.* **2015**, *4*, 217. [CrossRef]
18. Mupaso, N.; Nyamutowa, C.; Masunda, S.; Chipunza, N.; Mugabe, D. Characterisation of Smallholder Irrigation Schemes in Chirumanzu District, Zimbabwe. *J. Agric. Sci.* **2014**, *6*, 189–199. [CrossRef]
19. Bekele, A.E. Five Key Constraints to Small Scale Irrigation Development in Ethiopia: Socio-Economic View. *Glob. Adv. Res. J.* **2014**, *3*, 441–444.
20. Libseka, H.; Welde, K.; Degef, K. Assessment of Constraints and Opportunities of Small-Scale Irrigation Practices in South Tigray, Ethiopia. *J. Environ. Earth Sci.* **2015**, *5*, 96–100.
21. Gebregziabher, G.; Namara, R.E.; Holden, S. Technical Efficiency of Irrigated and Rain-Fed Smallholder Agriculture in Tigray, Ethiopia: A Comparative Stochastic Frontier Production Function Analysis. *Q. J. Int. Agric.* **2012**, *51*, 203–226.
22. Embaye, T.A.G.; Kahsay, G.H.; Abadi, N.; Kebede, M.M.; Dessie, D.T. Evaluation of Water Harvesting Structures on Agricultural Productivity: The Case of Tigray Region, Ethiopia. *Sustain. Water. Resour. Manag.* **2020**, *6*, 78. [CrossRef]
23. Dejene, S.; Teshome, W.; Makombe, G.; Awulachew, S.B.; Prasad, K. Institutions, Management Practices and Challenges of Small-Scale Irrigation Systems in Ethiopia: A Case Study of Two Modern Smallholders Irrigation Systems in Western Oromia, Ethiopia. 2008; 298–322.
24. Mutambara, S.; Darkoh, M.B.K.; Atlhopheng, J.R. A Comparative Review of Water Management Sustainability Challenges in Smallholder Irrigation Schemes in Africa and Asia. *Agric. Water Manag.* **2016**, *171*, 63–72. [CrossRef]
25. Ataklti, Y.T. Assessing the Potential of Geonetcast Earth Observation and in Situ Data for Drought Early Warning and Monitoring in Tigray, Ethiopia. Master's Thesis, University of Twente, Enschede, The Netherlands, 2012.
26. WaPOR, F. FAO's Portal to Monitor Water Productivity through Open Access of Remotely Sensed Derived Data. Available online: https://wapor.apps.fao.org/home/WAPOR_2/1 (accessed on 10 December 2022).
27. Limon, G.; Fournié, G.; Lewis, E.G.; Dominguez-Salas, P.; Leyton-Michovich, D.; Gonzales-Gustavson, E.A.; Gonzalez, A.E.; Cabezas, A.H.; Pinto, J.; Rushton, J.; et al. Using Mixed Methods to Assess Food Security and Coping Strategies: A Case Study among Smallholders in the Andean Region. *Food Secur.* **2017**, *9*, 1019–1040. [CrossRef]
28. Braun, V.; Clarke, V. Qualitative Research in Psychology Using Thematic Analysis in Psychology Using Thematic Analysis in Psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101. [CrossRef]
29. Hancock, D.R.; Algozzine, B. *Doing Case Study Research: A Practical Guide for Beginning Researchers*, 3rd ed.; Teachers College Press: Columbia, NY, USA, 2017.
30. Central Statistical Agency (CSA). The Federal Democratic Republic of Ethiopia Central Statistical Agency Report on Area and Production of Major Crops. *Stat. Bull.* **2016**, *1*, 584.

31. Mengistie, D.; Kidane, D. Assessment of the Impact of Small-Scale Irrigation on Household Livelihood Improvement at Gubalafto District, North Wollo, Ethiopia. *Agriculture* **2016**, *6*, 27. [CrossRef]
32. Dawit, D.; Balta, A. Review on Impact of Small Scale Irrigations in Household Food Security in Ethiopia. *J. Econ. Sustain. Dev.* **2015**, *6*, 62–70.
33. Chazovachii, B. The Impact of Small Scale Irrigation Schemes on Rural Livelihoods: The Case of Panganai Irrigation Scheme Bikita District Zimbabwe. *J. Sustain. Dev. Afr.* **2012**, *14*, 217–231.
34. Kassa, M.; Gebrehiwot, N.T.; Mesfin, K.A.; Nyssen, J. Small-Scale Irrigation: The Driver for Promoting Agricultural Production and Food Security (The Case of Tigray Regional State, Northern Ethiopia) Irrigation & Drainage Systems Engineering Small-Scale Irrigation: The Driver for Promoting Agricultural Production and Food Security (The Case of Tigray Regional State, Northern Ethiopia). *Irrig. Drain. Syst. Eng.* **2015**, *4*, 141. [CrossRef]
35. Yami, M. Sustaining Participation in Irrigation Systems of Ethiopia: What Have We Learned about Water User Associations? *Water Policy* **2013**, *15*, 961–984. [CrossRef]
36. Haile, G.G.; Asfaw, K.K. Irrigation in Ethiopia: A Review. *Acad. J. Agric. Res.* **2015**, *3*, 264–269.
37. Haileslassie, A.; Hagos, F.; Agide, Z.; Tesema, Z.E.; Hoekstra, D.; Langan, S.J. *Institutions for Irrigation Water Management in Ethiopia: Assessing Diversity and Service Delivery*; International Livestock Research Institute: Nairobi, Kenya, 2016.
38. Oates, N.; Hisberg, A.; Rodríguez Ros, J.; Solomon, H.; Ludi, E.; Marlet, S.; Jamin, J.Y. The Implications of State Intervention for Self-Governed Irrigation Schemes: Insights from Tigray, Ethiopia. *Irrig. Drain.* **2020**, *69*, 88–99. [CrossRef]
39. Checkol, G.; Alamirew, T. Technical and Institutional Evaluation of Geray Irrigation Scheme in West Gojjam Zone, Amhara Region, Ethiopia. *J. Spat. Hydrol.* **2008**, *8*, 3.
40. Iticha, M.D. Review on the Impact of Small Scale Irrigation Scheme on Household Income and Poverty Reduction in Ethiopia. *J. Resour. Dev. Manag.* **2019**, *57*. [CrossRef]
41. Astatike, A.A. Assessing the Impact of Small-Scale Irrigation Schemes on Household Income in Bahir Dar Zuria Woreda, Ethiopia. *J. Econ. Sustain. Dev.* **2016**, *7*, 82–88.