

## Small-scale Irrigation: The Driver for Promoting Agricultural Production and Food Security (The Case of Tigray Regional State, Northern Ethiopia)

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### Abstract

Small-scale irrigation practices determine the level of food production and, to a great extent, the state of the food security. Considering its importance to the overall growth of the agriculture sector, the Government of Ethiopia gives special emphasis to enhance agricultural production through the promotion of small-scale irrigation schemes. This paper looks at the role of small-scale irrigation in promoting agricultural production and food security. It pays particular attention to the results of small-scale irrigation practices, issues that enhance or impede small-scale irrigation capacities and explore complementary strategies that enhance the development of small-scale irrigation. We use descriptive and regression analysis to examine the relationship between small-scale irrigation and agricultural production. Relying on a survey result and observations, we conclude that, small-scale irrigation schemes could significantly improve agricultural production and the status of food security.

**Keywords:** Ethiopia; Agricultural production; Food security; Small-scale irrigation; Crop

### Introduction

A doubling in global food demand projected for the next 50 years poses huge challenges for the sustainability both of food production and of terrestrial and aquatic ecosystems and the services they provide to society. Developments in agriculture over the last 30 years have brought significant increases in global production, partly as a result of expansion of cropland, partly through changes in technologies over time [1].

Agricultural productivity is very much affected due to variability of rainfall and drought [2]. By supporting the idea of Bhattarai, Warren and Khogali described that the rainfall in Ethiopia has erratic nature and the consequent moisture stress is a major limitation to raising agricultural production [3]. Von Braun and others also argue that farmers in poor areas have suffered from chronic poverty and severe food insecurity being vulnerable to climatic changes and dependent on variable rainfall. This is mainly attributed to a low level of agricultural productivity characterized by persistent rural poverty, and increasing population pressure has often resulted in a vicious circle of poverty and environmental degradation [4].

As many of the low productivity areas have untapped water resources, irrigation development is being suggested as a key strategy to enhance agricultural productivity and to stimulate economic development [2]. To lift and keep millions out of poverty requires that smallholder agriculture be productive and profitable and bring agricultural transformation by which individual farms shift from highly diversified, subsistence-oriented production towards more specialized production oriented towards the market or other systems of exchange. Hussain and Smith in the contemporary literature argued that irrigated farming is recognized as central in increasing land productivity, enhancing food security, earning higher and more stable incomes and increasing prospects for multiple cropping and crop diversification [5,6]. In some places, cereal production is more than doubled between 1995 and 2001 due to the combined effect of expansion of irrigation and the use of high-yielding varieties and fertilizers [7]. It was also claimed that Ethiopia cannot assure food security for its population with rain-fed agriculture alone and without a substantive contribution of irrigation [8]. A review of several empirical studies made by Hussain

and Hanjira indicated that there is a strong linkage between irrigation development and poverty reduction through increasing productivity, livelihood diversification as well as creating employment opportunities and income [7].

The history of water harvesting in Ethiopia dated back as early as the pre Axumit period (560 BC). It was a time when rainwater was harvested and stored in ponds for agricultural and water supply purposes. Anthropologists [9] have documented evidences from the remains of ponds that were once used for irrigation during this period. FAO [10] also reported that water harvesting irrigation is an ancient practice in Ethiopia, as an integral part of Ethiopian agriculture, dating back several centuries.

The current Ethiopian government considers water as an entry point for development. It identified as an important policy instrument to stimulate economic growth and rural development in general and in ensuring food security in partical [11]. Irrigation schemes are essential policy options chosen by the government to eradicate poverty and secure food security in Ethiopia and it has a great impact on the livelihood of rural community where agriculture is the bedrock of their life [12]. Research result of Carter and Danert indicated that there are two major classifications of small-scale irrigation, the modern scheme and the traditional scheme. The development of modern small-scale irrigation started since the mid-1980s [13]. They have relatively permanent structure and improved water control system, and are mostly constructed by either the government or non-governmental organizations (NGOs). The traditional one is constructed by the local community.

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According to Lakew [14], the types of water harvesting technologies used by farmers are shallow wells, household level structural storage ponds, community ponds and spring water through traditional irrigation. With regard to opportunities and problems of agriculture sector in Ethiopia, Haile [15] described that there is huge potential of agricultural resource; however, the agriculture sector of the country has increasingly been unable to provide adequate food for the rapidly growing population. Sileshi [16] also argued that water resource management in agriculture is a critical contributor to the economic and social development of Ethiopia. However, he also explained that irrigation is not a simple silver bullet: first, it can only work if other components of the agricultural system are also effective (e.g., seeds, extension); second, all the tools in the toolkit will be required to construct a viable solution.

Assessment report of Ministry of Agriculture, Natural Resources Management Directorate [17] indicated that irrigation development, particularly the smallholders has significant importance to raise production and productivity to achieve food self-sufficiency and ensure food security at household level in particular and the country at large. The same report also indicates that the major production constraints impeding development in the irrigation sub-sector among others are:

(i) predominantly primitive nature of the overall existing production systems, (ii) shortage of agricultural inputs and credit systems, (iii) limited access to improved irrigation technologies and inadequate research support, (iv) lack of trained manpower and frequent staff turnover, and (v) unstable institutional set up and inadequate extension services and limited availability of capital.

To see the positive effect of small-scale irrigation on agricultural production and food security, therefore, it is important to understand how small-scale irrigation farmers are doing the irrigation activities and what factors impede them from achieving the optimum level of agricultural outputs. Therefore, this paper tries to assess the results of small-scale irrigation practices in promoting agricultural production and its impact in the improvement of the livelihood of the farmers.

The specific research objectives are formulated as follows:

- Understand the role of small-scale irrigation on agricultural production and food security of rural household farmers.
- Identify issues that enhance or impede small-scale irrigation capacities in the target areas.
- Explore and propose complementary strategies that enhance the development of smallholder irrigation throughout the region.

## Materials and Methods

### Description of the study area

Tigray regional state is found in the northern part of Ethiopia extending from 12°15' to 14°50'N and from 36°27' to 39°59'E. It covers a little more than 80 000 km<sup>2</sup>, most of which are highlands between 1500 and 3900 m.a.s.l. As per the projection of the Central Statistical Agency, Federal Democratic Republic of Ethiopia [18], the population of Tigray Regional State is 4,960,003 and from this population about 75.8% is living in rural area.

Tigray region is highly vulnerable to recurrent drought and famine. Rainfall distribution in the region is characterized by high temporal and spatial variability, with annual precipitation ranging from 450 to 980 mm [19]. Moisture deficiency is the most critical problem identified in the study of production systems in the region [20]. Agriculture is the

main economic activity that is employed by the majority of farmers in the study areas. Smallholder mixed crop livestock farming is the dominant mode of production in the districts. The system is oriented towards providing subsistence requirements for the farm household.

The target *woredas* are the potential areas whereby small-scale irrigation activities are undertaken by farming communities. In these *woredas*, a lot of conservation activities have been undertaken in the previous years and small-scale irrigation is practiced using micro dams, shallow wells, private ponds, community bond, check dams and diversions. In the target *tabias* farmers produce a mixture of cereals, vegetables, fruits and pulses by using small scale irrigation scheme as well as using rain-fed. Based on the information collected from the five target *tabias*, a total of 2648.4ha was used for irrigation activities in 2013/14 harvesting period. The major crops grown in the area includes teff, barley, wheat, sorghum, maize, faba bean, finger millet, chickpea and others. Different vegetables such as tomato, potato, onion, pepper, lettuce, carrot, garlic and fruits grow in the area using irrigation both at the rainy and dry seasons.

### Definition of dependent and independent variables

The dependent variable of this study is agricultural production of the small-scale irrigation scheme in the target *tabias* (*tabia* is the lowest administrative hierarchy below *woreda*/district). There are quite variety of factors which can affect agricultural production, both positively and negatively. It is very difficult to enumerate and discuss all the factors that affect agricultural production. However, for the purpose of the research at hand, some of the major factors affecting agricultural production are considered. Based on the economic theory and results of previous empirical studies, each variable is defined with its hypothesis as indicated below.

**Sex:** This study hypothesized that female headed households are less likely to participate in the small-scale irrigation scheme as compared to males [21].

**Age:** Older people have relatively greater experience of farming activities and better access to land than younger heads [22].

**Household Size:** A negative correlation between household size and food security is expected as food requirements increase in relation to the number of persons in a household [23].

**Education:** Educational attainment could lead to awareness of the possible advantages of modernizing agriculture by means of technological inputs; enable them to read instructions on fertilizer packs and diversification of household incomes which, in turn, would enhance households' food supply [24].

**Irrigation farmland size:** Under subsistence agriculture, holding size is expected to play a significant role in influencing farm households' food security [24].

**Availability of water for irrigation activities:** The potential to improve yields depends strongly the practice of irrigation schemes [21].

**Application of inputs:** Fertilization of farmland can boost agricultural production and influence the food security status of a household.

**Application of technologies (motor and treadle pumps):** The use of motorized water pump and treadle pump as part of water lifting technology and other water lifting technologies, have increased agricultural production [25].

**Farm Income:** Net farm income is the single most watched

indicator of farm sector well-being, as it captures and reflects the entirety of economic activity across the range of production processes, input expenses, and marketing conditions that have persisted during a specific time period [26]. In our hypothesis, we assume that irrigation activities enhance agricultural production and thus increase revenue earned by farmer household.

### Sampling procedure and data collection

This study was conducted based on the survey undertaken during December 2014 in three potential irrigation *woredas* of Tigray region, Northern Ethiopia. The sample households were selected by utilizing a three-stage stratified sampling procedure as the major method of sampling. During the first stage, three *woredas* were purposely selected, namely Kilte Awlaelo, Ahferom and Tahtay Maichew *woredas* from the eastern and central zone of Tigray regional state. Those *woredas* with better small-scale irrigation interventions were taken into consideration in the selection of *woredas*. Similarly, at the second stage, in consultation with *Woredas* Agriculture and Rural Development offices, five *tabias* (two *tabias* from Kilte Awlaelo *Woreda*, two *tabias* from Ahferom *Woreda* and one *tabia* from Tahtay Maichew *Woreda*) were purposely chosen. The study *tabias* were chosen based on the performance of small-scale irrigation activities, accessibility to the irrigation sites and the presence of a large number of ponds, shallow wells and diversion beneficiaries. At the third stage, household lists that are involved in small-scale irrigation scheme in the selected *tabias* were obtained from *tabia* administration. From the total number of households that are using small-scale irrigations in the selected study areas, 20 beneficiaries were taken from each *tabia* by systematic random sampling.

Based on the multistage sampling process mentioned above, a total of 100 households were selected by systemic random sampling technique. The summary of the number of households selected from each study area is presented in Table 1.

To carry out this study, both primary and secondary data sources were employed. The primary data were collected by employing triangulation method such as key informant interview using semi-structured checklist, focus group discussion, expert interview; semi structured household questionnaire and observation of events in the irrigation scheme. Secondary information that could supplement the primary data were collected from published and unpublished documents obtained from different sources. These included country policy statements, strategies regulations, reports and past case study papers on small-scale irrigation practices.

Issues covered during the data collection were demographic features, socio-economic situation of sampled households, irrigation practices, irrigated land, crops grown, the livelihood impact of irrigation activities, opportunities and challenges of irrigation activities, and areas of attention for the expansion and development of irrigation schemes. Discussions were also held with irrigation experts at the *woredas* Offices of Agriculture and Rural Development. Secondary data

Woredas	Tabias	Frequency
Kilte Awlaelo	Abraha Atsbiha	20
	Mesanu	20
Ahferom	Endamariam	20
	Laelay Megara Tsemri	20
Tahtay Maichew	May Siye	20
	Total	100

Source: survey result, 2015

Table 1: Summary of sample respondents by Woredas and tabias.

was also collected from respective *woreda* Offices of Agriculture and Rural Development.

### Data analysis

The data generated through household questionnaire was analyzed by employing the Statistical Package for Social Science (SPSS version 20) and MINITAB version 14. To analyze the data collected, descriptive methods such as frequency, percentage, average, and standard deviation were used. The Pearson correlation ( $r$ ) was used to measure the linear association between the dependent and independent variable. It describes the strength of the relationship between the two variables. The coefficient of determination ( $r^2$ ) was also used to define the percent of the variation in the values of the dependent variable that can be explained by variations in the value of the independent variables. In this regard,  $r^2$  explains the variability in the dependent variable explained by the variability in the independent variable. Multiple regressions was also used to allow additional factors to enter the analysis separately so that the effect of each independent variable can be estimated. It is valuable for quantifying the impact of various simultaneous influences upon a single dependent variable. F-Test was also used to examine whether the two populations have the same variance while the t-test and analysis of variance (ANOVA) was used to compare group means. A t-test was used to examine the mean difference between different continuous variables.

## Results and Discussion

### Descriptive analysis

Needless to mention that agricultural production is determined by various household attributes. Of these attributes, demographic and socio-economic characteristics are the ones. Hence, this section will discuss household characteristics like sex, age, family size, education status, household access to productive resources, etc. which determine agricultural production of sample respondents. The survey also includes other independent variables that determine agricultural production of the farmers such as cultivated land, available active labour force, availability of water resources such as ponds, diversions, utilization of inputs, trends of agricultural production, and other related activities. The descriptive analysis and the overall relationship of the dependent and independent variables are discussed as follows.

**Agricultural production of the sample respondents:** The agricultural products produced by the sample respondents in 2013/14 were classified into three categories namely vegetables (onion, tomato, potato and others), fruits (avocado, mango, orange, banana, etc.) and cereal crops (maize, wheat, sorghum, *teff*, etc). Based on the information from the respective *Woredas* Office of Agriculture and Rural Development, the total area covered by small-scale irrigation scheme was about 62.42 ha. From this total amount about 35.77 ha (57.3%) was covered by vegetables with total production of 265,268 kg (7416 kg per ha) and sales volume of Birr 1,209,780.00 (Birr 4.56 per kg). Also, the total area covered by fruits was about 9.4 ha (15.06%) with a total fruit production of 8096 kg (8600 kg per ha) and sales volume of Birr 44,440.00 (Birr 5.49 per kg). The total area covered by crops was about 17.25 ha (27.63%) while the total production was 53310 kg (3090.4 kg per ha). (1USD is equivalent to 20.5Birr as of January 2015) (Figure 1).

**Spatial distribution of respondents and agricultural production:** In 2013/2014 harvest period, about 27% of the respondents of were producing less than 1000 kg, 32% of the respondents were producing above 1000 kg but less than 5000 km while 20% of the respondents





Figure 1: Products of small-scale irrigation, Abraha Atsbiha, Kilte Awlaelo.

Total yield in kg in 2013/2014	Tabia Abraha Atsbiha	Tabia Mesanu	Tabia Endamariam	Tabia Laelay Megara Tsemri	Tabia May Siye	Total
No response	0	6	6	9	0	21
Up to 1000 kg	2	2	9	5	9	27
From 1001 kg up to 2000 kg	1	4	4	5	6	20
From 2001 kg up to 5000 kg	2	4	0	1	5	12
From 5001 kg up to 10000 kg	10	2	0	0	0	12
Above 10000 kg	5	2	1	0	0	8
<b>Total</b>	<b>20</b>	<b>20</b>	<b>20</b>	<b>20</b>	<b>20</b>	<b>100</b>

Source: Survey result, 2015

Table 2: Total yield in kg in 2013/2014 harvesting period by tabia.

Total yield in kg in 2013/2014	Sex of the head of the household					
	Male		Female		Total	
	Number	Percent	Number	Percent	Number	Percent
No response	19	21.11	2	20	21	21
Up to 1000 kg	25	27.78	2	20	27	27
From 1001 kg up to 2000 kg	16	17.78	4	40	20	20
From 2001 kg up to 5000 kg	10	11.11	2	20	12	12
From 5001 kg up to 10000 kg	12	13.33	0	0	12	12
Above 10000 kg	8	8.89	0	0	8	8
<b>Total</b>	<b>90</b>	<b>100</b>	<b>10</b>	<b>100</b>	<b>100</b>	<b>100</b>

Source: Survey result, 2015

Table 3: Total yield in kg in 2013/14 by sex.

were producing more than 5000 kg. In this regard, the respondents of Abraha Atsbiha tabia were more productive as compared to other tabias (Table 2).

**Sex of the respondents vs. agricultural production:** Out of the total sampled household members, 90% respondents constitute male headed households and the remaining 10% respondents are female headed households. The survey result also revealed that about 88% of the respondents are married, 8% are single and the remaining 4% are either separated or widowed (Table 3).

When we compare the agricultural production by taking sex as a variable, we can see that about 80% female respondents are producing less than 2000 kg while that 66.67% of men respondents are producing similarly less than 2000 kg. On the other side, no female

was producing more than 5000 kg while 22.22% of male respondents were producing more than 5000 kg in 2013/14. From the given data Table 2, it is observed that there is higher percentage of production for men headed households than women headed households. This low level of agricultural production of female headed households can be attributed to the low level of input utilization by female respondents. In this regard, about 55.56% of female respondents were utilizing less than 50 kg of inputs in 2013/14 while that of male respondents is 31.51%. On the other side, about 50.68% of male respondents were applying inputs between 51 kg to 100 kg while only about 22.22% of female respondents are applying inputs within this range. Moreover, from the survey result we can also observe that women have less accessibility to irrigation land as compared to men. In this regard, about 44.44% of women respondents are having less than 0.25 ha of irrigation land while that of male is about 15.49%.

When we measure the strength of the linear association between sex and agricultural production through Pearson correlation, it is moderate with p-value of 0.512. Hence the relation between sex and agricultural production is not very much significant and female headed households are likely to participate in the small-scale irrigation scheme like that of males.

**Age of the respondents vs. agricultural production:** Our hypothesis stated that the higher the age of the household head, the more stable the economy of the farm household; because older people have relatively richer experience of farming activities and better access to land than younger heads. When we see the age structure of the sample respondents, it is observed that 23% of the respondents are within the range of 18 to 35 years of age while 70% of the respondents are representing the age group of 36 to 65, and the remaining 7% is above 65 years of age. The average age of the household members in the study sample was observed to be 46.26 years with the standard deviation of 12.22. When we measure the strength of the linear association between age and agricultural production through Pearson correlation, it is very poor with p-value of 0.059 which is against our hypothesis. Hence the relation between age of the respondents and agricultural production is very poor and this could be attributed as a result of better access to education, input utilization and technologies of the young respondents as compared to older respondents.

**Household size vs. agricultural production:** Household size was considered as one of the potential variables that could affect agricultural production negatively. About 10% of the total sample households have a maximum of two family size whereas 53% of the households have the family size that ranges from three to six. The rest 37% of the sample have more than six family sizes. The largest family size of the sample households was found to be 10 and the smallest was 1. On the other hand, the average family size of the sample households is estimated to be 5.63 with the standard deviation of 2.4 and this is similar to the national average of 5 persons (CSA, 1994).

When we measure the strength of the linear association between total household size and agricultural production using Pearson correlation, it is 0.912. Hence, there is very high significant relationship between family size and agricultural production.

**Educational status of respondents vs. agricultural production:** In our hypothesis, education was considered as one of the factors which influence the agricultural production status and food security of households positively. Educational status of the respondents shows that about 35% of the respondents are illiterate while 6%, 31% and 18% have attended religious learning, primary school first cycle (Grade

1 to 4) and primary school second cycle (Grade 5 to 8) respectively. About 9% of the respondents have joined secondary school (Grade 9-12). Only one respondent is diploma holder in general agriculture. The survey also assessed the number of children attending schools at a household level. Accordingly, about 21% of the respondents do not send their children to schools while 18%, 42% and 16% are sending 1 to 2, 3 to 4 and 5 to 6 children to school respectively. Only 3% of the respondents send above 6 children to schools. When we assess the relationship between education and agricultural production, 15 of the illiterate farmers were producing above 2000 kg while 17 of the educated farmers were producing above 2000 kg (the average agricultural production per household is about 3267 kg with standard deviation of 55.88). When we measure the strength of the linear association between education status of respondents and agricultural production using Pearson correlation, it is weak with p-value of 0.107. This might imply that sample respondents with lower educational attainment were using technological inputs and fertilizer to boost their agricultural yields.

**Availability of irrigation land vs. agricultural production:** The total irrigation farmland is normally defined as the cultivated own land plus any land operated/owned by other farmers but cultivated with some arrangements such as sharecropping for grain, cash or crop residue. With regard to the irrigated land size among the respondents, about 56% of the respondents are having less than 0.5 ha, 17%, 24% and 3% of the respondents are having irrigation land from 0.51 up to 1 ha, above 1 ha but less than 2 ha and above 2 ha respectively. In this regard, the mean irrigated land size in the study area for 2013/14 harvest period was 0.6242 ha with standard deviation of 0.6102. When we measure the strength of the linear association between the size of the irrigated land and agricultural production through Pearson correlation, it is strong and positive with p-value of 0.000 (significant at 0.01 level, 2-tailed). Therefore, there is very high significant relationship between irrigation farmland and agricultural production, which supports our hypothesis that irrigated lands account for a substantial portion of increased yields.

**Availability of water for irrigation activities vs. agricultural production:** In our hypothesis we stated that the potential to improve yields depends strongly the practice of irrigation schemes. In this regard, the researchers tried to see availability of water from different corners such as the availability of water sources, investment in ponds, and distance to water points, adequacy of water for irrigation activities frequency of utilization water (access to water) and experience in irrigation activities.

With regard to the ownership of ponds, about 61% of the respondents have their own ponds as a source of water for irrigation activities. The remaining 39% of the respondents do not own ponds but utilize various sources of water such as river, diversions for their irrigation activities. In relation to the adequacy of water for irrigation, about 60% of the respondents also agreed that there was adequate water for irrigation activities. In this regard, a question was raised to respondents in relation to the availability of irrigation water during 2013/14. About 41% of the respondents reply that there was water throughout the year, 9%, 16% and 2% of the respondents confirmed that there was water for 7 to 9 months, for 3 to 6 months and below three months respectively. Based on the information from the respondents, the average availability of water during 2013/14 was 9.058 months with standard deviation of 3.077.

With regard to access to water (frequency of using water per week) indicated in Table 3 above, about 70% of the respondents get access to

Variables	Correlation	Total yield in kg
Source of irrigation water	Pearson Correlation	-.193
	Sig. (2-tailed)	.054
	N	100
Frequency of using irrigation	Pearson Correlation	-.032
	Sig. (2-tailed)	.755
	N	100
Distance to pond in minutes	Pearson Correlation	.416**
	Sig. (2-tailed)	.000
	N	100
Total cost for the construction of pond	Pearson Correlation	.200*
	Sig. (2-tailed)	.046
	N	100
The availability of water ponds	Pearson Correlation	.425**
	Sig. (2-tailed)	.000
	N	100
For how many years you have been using the ponds (experience in using ponds)?	Pearson Correlation	.318**
	Sig. (2-tailed)	.001
	N	100
How long did your pond hold water last year (availability of water during harvesting period)?	Pearson Correlation	.404**
	Sig. (2-tailed)	.000
	N	100
**Correlation is significant at the 0.01 level (2-tailed).		
*Correlation is significant at the 0.05 level (2-tailed).		

Source: survey result, 2015

**Table 4:** Strengths of linear association of water related variables to agricultural production.

the water once per week, while 19%, 8% and 1% of the respondents get access to irrigation water twice per week, three times per week (once per two day) and on daily basis respectively (Table 4).

The strength of the linear association between water related variables and agricultural production through Pearson correlation was analyzed and its result is found to be as indicated in Table 3.

From the table, we can see that investment in construction of ponds to be significant at 0.05 level (2-tailed) while the linear relationship for the variables distance to pond in minutes, the availability of water ponds, experience in using ponds and availability of water during harvesting period are significant at 0.01 level (2-tailed). Hence, there is very high significant relationship between access to irrigation water and agricultural production.

**Application of agricultural inputs vs. agricultural production:** Our hypothesis was fertilization of farmland can boost agricultural production and influence the food security status of a household. The application of inputs for agricultural activities was assessed on the basis of whether a household uses fertilizer or not. Accordingly, more than 83% of the respondents were using agricultural inputs for their farming activities during 2013/14 harvesting period. The major types of inputs used in the study area were DAP, UREA and improved seed. When we assess the rate of utilization of inputs, we can see that about 28% of the respondents were utilizing less than 50 kg, 39% of the respondents from 51 kg up to 100 kg, 13% of the respondents from 100 kg to 200 kg and 2% above 200 kg. The average utilization of inputs is 77.72 kg with standard deviation of 70.12 and its average cost is Birr 1056.00 with standard deviation of 1036. When we look up on the strength of the linear association between the fertilizer used and agricultural production through Pearson correlation, it is strong and positive with

p-value of 0.000 (significant at 0.01 level, 2-tailed) which is in line with the previous research result of intensive high-yield agriculture is dependent on addition of fertilizers [27] (Figure 2).

**Utilization of irrigation technologies vs. agricultural production:**

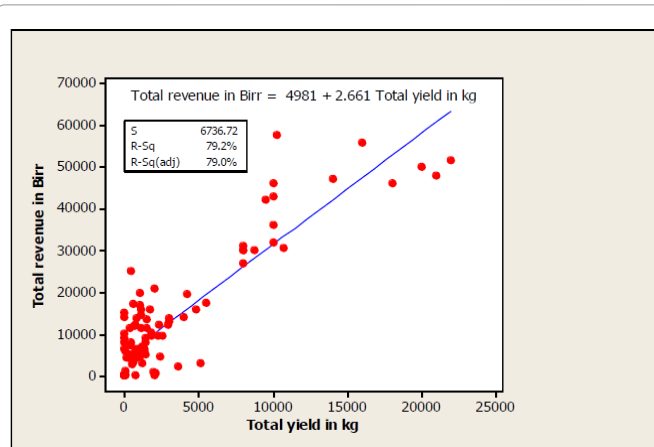
In our hypothesis we assume that the use of motorized water pump and treadle pump as part of water lifting technology and other water lifting technologies have increased agricultural productivity of farmers. In our research, about 58% of the respondents own motor pumps while 11% of the respondent rent pumps for irrigation activities and the remaining 31% neither own nor rent pumps. The average price of pump is Birr 8803.00 with standard deviation of 4797 (Figures 3 and 4).

When we measure the strength of the linear association between the use of irrigation technologies and agricultural production through Pearson correlation, it is strong and positive with p-value of 0.004 (significant at 0.01 level, 2-tailed). This result indicates that as household farmers increase their investment in the purchase irrigation technologies, agricultural production increases which leads to better access to food and thereby improved standard of living which is similar to the research results of Nata and Bheemalingeswara [25].

**Agricultural production vs. total revenue:** Randy [26] identified that net farm income is the most watched indicator of farm sector well-

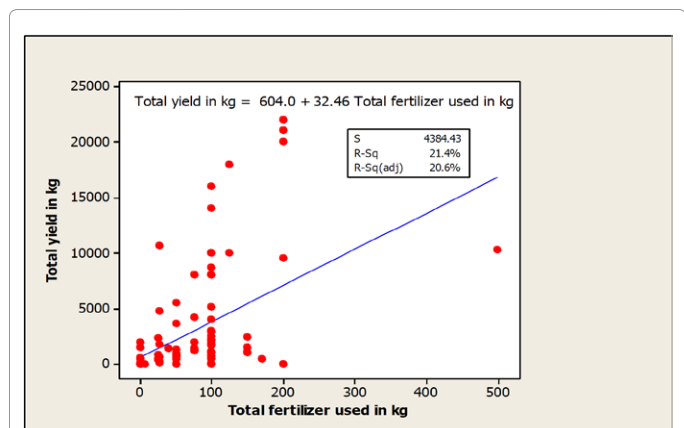


Figure 4: Treadle pump from ponds, Mesanu.



Sources: Survey result, 2015

Figure 5: Relationship of total yield in kg to total revenue in Birr.



Sources: Survey result, 2015

Figure 2: Relationship of fertilizer used in kg to total yield in kg.



Figure 3: Motorized river diversion, Mesanu.

being, as it captures and reflects the entirety of economic activity across the range of production processes, input expenses, and marketing conditions that have persisted during a specific time period. During the survey, about 64% of the respondents confirmed that irrigation activities are improving their agricultural production and their income from the sale of agricultural products which leads to improved standard of living of their families. The average income from the sale of agricultural products for the year 2013/14 was Birr 13301.00.

In this regard, the survey result indicated that those farmers who are producing more agricultural products through small-scale irrigation are becoming better-off and they are increasing their income (revenue) from the sale of agricultural products and this leads them to improve their standard of living (Figure 5).

This was further confirmed during the discussion with the respondents. Some of the major results identified in relation to the contribution of small-scale irrigation to agricultural production and thereby food security include increased agricultural production and better food security, getting additional income, access to improved nutritional values (vegetables and fruits), improved feeding habit, improved access of water for drinking livestock development and



sanitation, purchase of oxen and cows, pay credit and save money, purchase of household goods, building of houses in towns, cover educational cost for their children and the likes. These all indicate that small-scale irrigation activities are promoting the livelihood of the farmers.

### Summary of regression results

The joint effect of a group of independent variables on promoting agricultural production is studied by framing the multiple regression equation of the variable “Y” on the other independent variables. The following model with 6 independent variables was used in the model specification. In classical regression model, each estimate gives the partial effect of a coefficient with the effects of other X variables being controlled.

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6$$

Where: Y=Agricultural production in kg

a = Intercept (constant)

b<sub>1</sub> to b<sub>6</sub>= Regression coefficients

Based on the regression analysis, the following results were found. Total yield in quintal = 1.750

0.410 age of the head of household

0.172 schools attended by the head of the household

0.070 Investment (purchase value) of pump

+0.268 total inputs used in kg

+0.090 total irrigated land in ha

+1.030 revenue generated from the sale of agricultural products (Table 5).

From the table of regression analysis (Table 5) we can see that the variables age of the head of the household, schools attended by the head of the household, investment (purchase value) of pump, total inputs used in kg, total irrigated land in ha and revenue generated

from the sale of agricultural products showed a significant impact on agricultural production.

**Coefficient of determination result (r<sup>2</sup>):** The coefficient of determination (r<sup>2</sup>) is 91.9%. This denotes that about 91.9% of the total variation of the dependent variable (agricultural production) is explained by the independent variables included in the multiple regressions. Therefore, one must look at other variables beyond the listed independent variables in order to find out the reasons for the increase in agricultural production. Hence, the actual reason for the increase in agricultural production in the farm sector can be the factors such as fertility of soil, ownership of oxen, extension service, mixed cropping, crop rotation, properly application of quality agricultural inputs and others.

The F ratio is also found significant. From the value of “t” statistic corresponding to the regression coefficients, some variables are found to be significant such as age of the head of the household, schools attended by the head of the household, investment (purchase value) of pump, total inputs used in kg, total irrigated land in ha and revenue generated from the sale of agricultural products.

### Major problems of small-scale irrigation and possible intervention areas

The major small scale irrigation problems identified during the survey include financial constraints especially for the purchase of motor pumps, shortage of agricultural inputs specially improved seed and pesticides, high cost of irrigation, shortage of water pump technologies, spare parts and gabions, technical problems such as maintenance of motor pumps, insufficient market information and market networks, shortage of ponds and diversion, infrastructure specially road and storage, theft of fruits, diseases and pests such as rust, root ruts, ball worm, blights, powdery mildew, gummosis and water borne diseases, inefficient management of resources such as water, land and labour. As per the discussion with *wereda* irrigation experts the major problems of the irrigation are shortage of motorized pumps, insufficient diversion infrastructure, shortage of improved seed, dependency syndrome on government and on donors (farmers want construction of diversion

Model		Coefficients <sup>a</sup>				
		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.750	.441		3.970	.000
	Age of the head of the household	-.410	.127	-.138	-3.229	.002
	Schools attended by the head of the household	-.172	.044	-.166	-3.905	.000
	Investment (purchase value of pump)	-.070	.031	-.108	-2.229	.028
	Total inputs used in kg	.268	.074	.171	3.635	.000
	Total irrigated land in ha	.090	.034	.118	2.606	.011
	Revenue generated from the sale of agricultural products					
a. Dependent Variable: Total yield in kg						
Model		ANOVA <sup>a</sup>				
		Sum of squares	df	Mean square	F	Sig.
1	Regression	204.549	6	34.092	84.231	.000 <sup>b</sup>
	Residual	37.641	93	.405		
	Total	242.190	99			
Model Summary						
Model	R	R Square	Adjusted R Square	Standard error of the estimate		
1	.919a	6	0.835	0.636		

Source: survey result, 2015

Table 5: Results of multiple regression model.

and water harvesting technologies from the government and donor) rather than introducing such irrigation schemes and technologies, inefficient utilization of resources such as water and land, lack of knowledge and skills in irrigation activities, inappropriate utilization of inputs and the likes.

The respondents were requested to identify priority areas in solving the small-scale irrigation schemes. Accordingly, they highlighted the following issues as a point of attention from the concerned bodies. Improving access to and availability of inputs specially improved seeds and chemicals, improve access to credit and long-term loans, improve access or supply of pumps, spare parts and electric dynamo for water pumps, facilitating training and experience sharing, strengthening/organizing cooperatives of irrigation, utilize resources efficiently, produce market oriented products/ produce seeds (encouraging multiplying seeds by farmers), improving access to timely market information and market networking, strengthening value chain and supply of processing materials, improve conservation of soil and water, enclosure of irrigation area and reduce grazing.

The respondents were also requested to highlight the role of the government in promoting small-scale irrigation practices throughout the region. Some of the major issues raised by the respondents as the role of government include but not limited to supply of quality and variety of improved seeds for vegetables and fruits, fertilizers, pesticides and chemicals (in some cases subsidizing the supply of inputs), improving access or supply of pumps, spare parts and electric dynamo for water pumps, construction of additional diversions, common well or bore pond and check dams, regular maintenance of water structures, canals and diversions, introducing modern irrigation and water harvesting technologies, technical support including provision of training and extension service experience sharing to beneficiaries on irrigation activities, continuous follow up and supervision, arrangement of transpiration facilities (improve infrastructure facilities), promoting access to credit, promoting integrated farming including moisture conservation and watershed management, supply of construction materials such as cement, gabion and providing timely market information (market networking or linkage).

## Conclusions and Recommendations

The study covers the demographic and socio-economic factors that influence small-scale household irrigation in promoting agricultural production and livelihoods. In particular, it targets *woredas* whereby small-scale irrigation activities are undertaken by farming communities. In the target *tabias* farmers produce a mixture of cereals, vegetables, fruits and pulses by using small scale irrigation scheme as well as using rain-fed.

A total of 100 respondents were involved in the survey. From the survey, it was found that the average family size to be 5.59 with the standard deviation of 2.4 and the average irrigation land holding of the respondents is 0.6242 ha with standard deviation of 0.6102. Considering sex of the head of the household as a variable, the survey result revealed that female headed households produce less as compared to men. When we measure the strength of the linear association between different variables and agricultural production through Pearson correlation, variables such as availability of water ponds, distance to water points, availability of water in the harvesting period, utilization of inputs, access to technologies, total irrigated land are playing an important role in promoting agricultural production and there is positive and significant relationship to agricultural production. Similarly from the regression analysis we found that the variables age

of the head of the household, investment (purchase value) of pump, total inputs used in kg, total irrigated land in ha and revenue generated from the sale of agricultural products showed a positive and significant impact on agricultural production and thereby enhancing food security of the rural farmers.

The problems identified during the survey include financial constraints especially for the purchase of motor pumps, shortage of agricultural inputs specially improved seed and pesticides, high cost of irrigation, shortage of water pump technologies, spare parts and gabions, technical problems such as maintenance of motor pumps, insufficient market information and market networks, shortage inadequate ponds and diversion and lack of infrastructure facilities.

Relying on a survey result and observations, we conclude that, small-scale irrigation schemes could significantly improve agricultural production and food security. In order to improve and expand small-scale irrigation activities, it is necessary to solve the above mentioned problems through the involvement and joint effort of all stakeholders including the farming community, government, non-government organizations, private sector and also designing well-structured short-term and long-term plans and development programs to fill the capacity gaps. Moreover, attention should be given for the expansion of irrigation cooperatives so that farmers can join-hand in dealing with irrigation activities based on cooperative principles and values and solve their common problems through members' participation.

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