Addis Ababa University, Ethiopian Journal of Business and Economics, EJBE Vol.: 12, No.: 2,
Doi: *https://dx.doi.org/10.4314/ejbe/v12i2.5* p-**ISSN:** ***2311-9772*** **e-ISSN:** ***2410-2393***
Available online: http://ejol.aau.edu.et/index.php/ejbe and https://www.ajol.info/index.php/ejbe

Impact of the Koga Irrigation Project on the Livelihood Improvement of the Rural Community in Mecha District, Amhara Region, Ethiopia

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Abstract

Koga is one of the large-scale irrigation projects constructed to improve agricultural production. Therefore, the study was aimed at investigating the contribution of the Koga irrigation project to the improvement of household livelihoods. The study used a mixed approach to data collection. Sample households were identified using a systematic random sampling technique. The samples were 270 and 241 for irrigation users and non-irrigation users, respectively. Average, percentage, and frequency were used to describe the demographic and socio-economic characteristics of the respondents. Independent t-test analyses were conducted to see the socio-economic impact of the irrigation project. Moreover, a logit regression model was used to identify the impact of the Koga irrigation project on the livelihood of the rural community. Crops annual production, productivity and consumption under irrigation was significantly ($P<0.01$) higher compared to rain-fed condition. Irrigation user farmers expend significantly ($P<0.05$) more cost for inputs compared to non-irrigation user farmers. The total net income generated from irrigation ranged from 36250.00-437995 ETB compared to 6550.00-188625.00 ETB from rain-fed. The majority of the respondents confirmed the presence of crop diversification and intensification in the project area of Koga irrigation. Generally, Propensity Score Matching (PSM) analysis indicated that the Koga irrigation project has had an impact on the livelihood of the rural community due to high crop productivity, diversification, and intensification. It is concluded that the expansion of medium and large-scale irrigation projects is necessary to enhance the livelihood of the rural community.

Keywords: Koga irrigation, Mecha district, rural community, livelihood

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Introduction

The purpose for which people engage in irrigation is to secure their basic needs and to earn income. But the activity is dependent greatly on access to land, labor, water, markets, knowledge, and capital, which are the main resources in the context of irrigated agriculture. Within any given culture, access to resources varies according to gender, age, wealth, caste, and ethnicity, which affects livelihood (FAO, 2001). The modern irrigation scheme affects livelihood and food indirectly through other infrastructures and institutions such as roads, drinking water, electricity, markets, agricultural offices, health centers, schools, etc. established following the construction of irrigation projects (Judt et al., 2008).

Associated with irrigation, cash crops are the main source of income. In recent years, the shift to cash crop production from subsistence farming due to irrigation has helped farmers generate a constant and higher income. Currently, people spend more money on food purchases, housing, education, and medical expenses (Judt et al., 2008). Irrigation projects have been shown to improve farmers' productivity substantially and help alleviate poverty (Garbero and Songsermsawas, 2016). Irrigation projects are effective at increasing high-value crop production. The impact of irrigation projects is more effective when it is integrated with market and market access interventions to allow farmers to maximize the benefits from increased production (Garbero and Songsermsawas, 2016). Generally, irrigated agriculture is becoming more important to meet the demands of food security, employment, rural transformation, and poverty reduction. In Ethiopia, the increase in agricultural productivity has enabled households to generate more income, build resilience, and transform their livelihood. Hence, small-scale irrigation is a policy priority in the country for rural poverty alleviation, climate change adaptation, and economic growth (Tadege, 2007).

Small-scale irrigation enhances agricultural productivity, serves as a source of diversified options to access food, creates employment opportunities, provides a means to cope with the effects of climate variability, and increases household assets (Feleke et al., 2019). The Koga irrigation and watershed management project are anticipated to intensify agricultural production and productivity among smallholder farmers in the Koga River Valley. The project is intended to achieve poverty reduction and enhance food security among the targeted farming groups. Agricultural production can be improved through intensive cropping systems that are supported with appropriate irrigation management systems to mitigate the adverse effects of drought and the limitations posed by land shortage (ADF, 2001). The World Bank proposed the Koga Irrigation Project to construct a dam and an irrigation and drainage system to irrigate 7,000 ha of land (ADF, 2001).

Any impact study estimates the difference in mean outcomes between the treatment group (project participants) and the comparison group (non-participants). The results of Adebayo et al. (2018) indicated that use of irrigation technologies had a positive impact on crop yield, household income, and household food security. The annual income of irrigator households was 78,12,099 ETB before and after using irrigation, compared to non-irrigators, who have an average annual income of 3,146.75 ETB (Mengistie and Kidane, 2016). The results of Nonvide (2020) from Benin also showed a positive impact of irrigation on food consumption. Feleke et al. (2020) also confirmed that participation in irrigation significantly and positively affects the amount of household income.

Irrigated agriculture is important to stimulate sustainable economic growth, and it is the cornerstone for food security and poverty reduction (Judt et al., 2008). Therefore, the government of Ethiopia has established Koga irrigation schemes with the aim of enhancing the livelihood of the rural community. However, it is not well known to what extent farm households using irrigation are better off than those who depend on rainfall (Ebissa, 2014). According to Koyachew et al. (2018), Koga irrigation has a positive impact on multidimensional household poverty reduction. However, the incidence of poverty among the sample households, regardless of access to irrigation, is still higher. This implies access to irrigation should be accompanied by institutional supports and complementary production inputs.

In this regard, Hussain and Wijerathna (2004) found that investments in irrigation do not directly reduce poverty in a significant way unless accompanied by other complementary interventions such as proper maintenance, equal distribution of available water, and improved cultivation technology. Generally, irrigation development is a priority for agricultural transformation, but poor practices in irrigation management discourage efforts to improve livelihoods and expose people to environmental risks like soil salinity and acidity (Dawit et al., 2021). Meanwhile, limited research studies were conducted on the impact of the Koga Irrigation Project. Majority of them were focused on food security by Temesgen (2022), multidimensional poverty reduction by

Koyachew et al. (2018), the environmental impact of the Koga irrigation project by Gizachew (2013), and social impact by Eguavoen and Tesfai (2012). Unfortunately, these studies were also unable to compare irrigation and non-irrigation users' responses to the project. Furthermore, there may be a methodological gap related to sample size and an econometric model to study the impact of the Koga irrigation project in particular and other small, medium, and large-scale irrigation projects generally. Hence, the current study aimed to assess the impact of the Koga irrigation project on household livelihoods in the study area.

Related Literature Review

Impact of Irrigation on Crop Diversity and Intensity:

The findings of Lafevor and Pitts (2022) show irrigation is a strong positive predictor of crop species richness and evenness diversity across all regions. The effects of irrigation on evenness and diversity are five times greater in low-diversity regions than in high-diversity regions. With implications for agricultural water policy in Mexico, this study illustrates the potential benefits of sustainable irrigation expansion in water-rich but irrigation-poor farming regions. Specifically, by enhancing crop species diversity, carefully targeted irrigation expansion can support the transition to sustainable intensification.

Moreover, Alaofè et al. (2016) examined how Benin's crop output diversity and nutritional diversity were affected by solar-powered drip irrigation utilizing solar market gardens (SMGs). Also, it was shown that 57% of the women spent extra money on food, 54% on health care, and 25% on education. This study has demonstrated that crop diversity and intensification by solar-powered drip irrigation have the potential to enhance nutritional status. The research finds that increased irrigation facilities and a diversified crop basket both boost cropping intensity for the years 1990–1991 to 2014–2015 using secondary data and panel data regression approaches (Paria et al., 2021). The improvement in the rural poor's standard of living is mostly attributable to increases in agricultural production. One of the methods for agricultural intensification that will be used in developing nations is irrigation development (Angood, et.al., 2002). By gains in agricultural intensification for the larger economy of rural livelihoods, irrigated agriculture can reduce poverty (Smith, 2004). Irrigation boosts agricultural output, provides a variety of food options, job opportunities, and a way to deal with the effects of climate change while also increasing household assets (Feleke et al., 2019).

The Impacts of Irrigation Projects on Agricultural Productivity

According to Hussain and Wijerathna (2004), irrigation has a strong augmenting impact. The value of crop production under irrigation is about twice that of rain-fed agriculture. Dillon (2008) employed propensity score matching and difference in difference techniques with two rounds of panel data (1998 and 2006) to analyze the impacts of irrigation in Mali. The author found significant positive increases in agricultural production, consumption, and caloric and protein intakes for households with access to irrigation. According to Hussain and Wijerathna (2004), the value of crop productivity per hectare under irrigation is about twice that of rain-fed land.

The study conducted by Jabbar et al. (2000) indicated that irrigation may not directly improve poverty unless it is accompanied by other complementary interventions. Using the yield estimation method of measurement, Jabbar et al. (2000) have argued that although irrigation development was found to contribute to some livelihood strategies, it did not lead farmers to adopt improved technologies, and hence yields or welfare indicators were not increased as expected. Many farmers continue to use traditional technologies even when irrigation is available, which limits the productivity impact of irrigation. These results are not conclusive, but they suggest that more research on the impacts of irrigation investments is fundamental to increasing crop productivity. Consistently, Jabbar et al. (2000) and Street (2000) have found a negative and/or weak relationship between irrigation and agricultural productivity.

The Impacts of Irrigation Projects on Income of the Beneficiaries

Numerous study results show that household income and consumption are much higher in irrigated settings than rain-fed settings, and a 50% gap is common (Dillon, 2008). Case studies undertaken by Meliko and Oni (2011), Solomon and Ketema (2015), and Asrat and Anteneh (2019) were some examples that highlighted the positive impacts of irrigation on poverty by using an income proxy and the FGT model. Meliko and Oni (2011) found that poverty incidence, depth, and severity were higher among non-irrigated households in South Africa. Similarly, based on descriptive statistics, the FGT poverty indices Heckman's selectivity model and methods of data analysis by Solomon and Ketema (2015) have found that the incidence, depth, and severity of poverty were significantly lower among those farm households with access to irrigation in the Ambo district of western Ethiopia. Tesfaye et al. (2005) also revealed that poverty incidence was significantly lower among households with higher irrigated areas.

Even if access to irrigation moves up the mean income, farmers have different capacities for making better use of the available irrigation water, and therefore irrigation widens the income gap. Senaratna et al. (2014) also showed that irrigation access has a positive effect on income through livelihood choices in Sri Lanka. Nkhata, Jumbe, & Mwabumba (2014) found that irrigation had a positive impact on annual agricultural income, and the impact was different among the Similarly Gebregziabher and Namara (2007) and Getnet et al. (2016) indicated that the average income of irrigating households was found to be above the regional average income, whereas it was 50% less than the regional average for non-irrigating households. Both Nkhata et al. (2014) and Gebregziabher and Namara (2007) argued that significant income improvement is accompanied by poverty reduction among farmers with access to irrigation in the study area. Hagos et al. (2009) argued that the net gross margin income from irrigation is more than twice as high as the gross margin from rain-fed agriculture. The bulk of the contribution to the national economy comes from the smallholder-managed irrigation schemes, most importantly from the traditional schemes. However, the contribution of irrigation to national income is still very small.

The study undertaken in Tanzania confirmed that despite current operational and technical problems facing irrigation schemes, the schemes have significantly contributed to both food security and cash income. In villages where the irrigation practice was dominant, the villages were able to produce a four-month food surplus and a cash income. This scenario shows that irrigation, if well advocated, has the potential to alleviate poverty and ensure year-round food security (Masuruli, 2004). According to the study undertaken on three irrigation schemes in Tigray, Ethiopia, the annual income of irrigation users has increased by about 31-61%. The improvement has resulted mainly from sales of cash crops produced using irrigation. In addition, the study shows that the development of the irrigation schemes has helped the farmers reduce the risk of drought by fostering livestock and crop production and diversifying income sources (Behailu, Abdulkadir, Mezgebu, & Yasin, 2005). The study of Alaofè et al. (2016) also revealed that about 57% of the women spent their additional income on food, 54% on health care, and

25% on education. These studies have shown that irrigation has the potential to improve nutritional status through direct consumption and increased income.

The Impacts of Irrigation Projects on Beneficiaries' Consumption

Irrigation had a positive impact on crop production, consumption, and revenue generation, all of which together indicated an improvement in food security. The sensitivity analysis test shows that the impact results estimated by this study were insensitive to unobserved selection bias, which shows it is a real impact of the irrigation (Jambo, Alemu, and Tasew, 2021). The overall study results of Hussain and Wijerathna (2004) revealed that irrigation has a contribution to household consumption, but the magnitude of the impacts varies greatly across systems and depends on other factors. Bhattarai and Narayanamoorthy (2003) clearly demonstrate the role of irrigation in increasing household consumption and reducing rural poverty. The study by Hussain and Wijerathna (2004) revealed that households' income and expenditure levels were higher in areas with access to irrigation infrastructure than those areas having no such option. Households' expenditure was 24% higher in areas with irrigation than in areas having no access to irrigation in Sri Lanka. Similarly, in Pakistan, the study indicated that access to irrigation infrastructure reduced the incidence of chronic poverty.

In terms of the role of micro-irrigation for income generation in Asia, Regassa (2005) revealed that micro-irrigation had a widespread impact on rural consumption, helping smallholder families to increase their net income by an average of USD 100.00 per year. The numerical results of the study show that household income and consumption are much higher in irrigated settings than rain-fed settings, and a 50 percent point gap is common. The same study suggests that irrigation significantly contributes to reducing the worst kinds of poverty. This study concludes that in areas where communities and households depend on agriculture for their livelihood, access to irrigation is a necessary but not sufficient condition for consumption.

A study conducted to assess the impacts of small irrigation on agricultural production and consumption in marginal areas of Punjab, Pakistan, showed that consumption estimates in irrigated agriculture were higher than overall estimates in the country. The poverty head count index was 29.14% and 37.3% in the irrigated land and rain-fed categories of the farmers, respectively (Hussain & Wijerathna, 2004). The study carried out by Hussain and Wijerathna

(2004) indicated that irrigation significantly reduces poverty. Dillon et al. (2008) found significant positive increases in consumption, agricultural production, and calorie and protein intakes for households with access to irrigation.

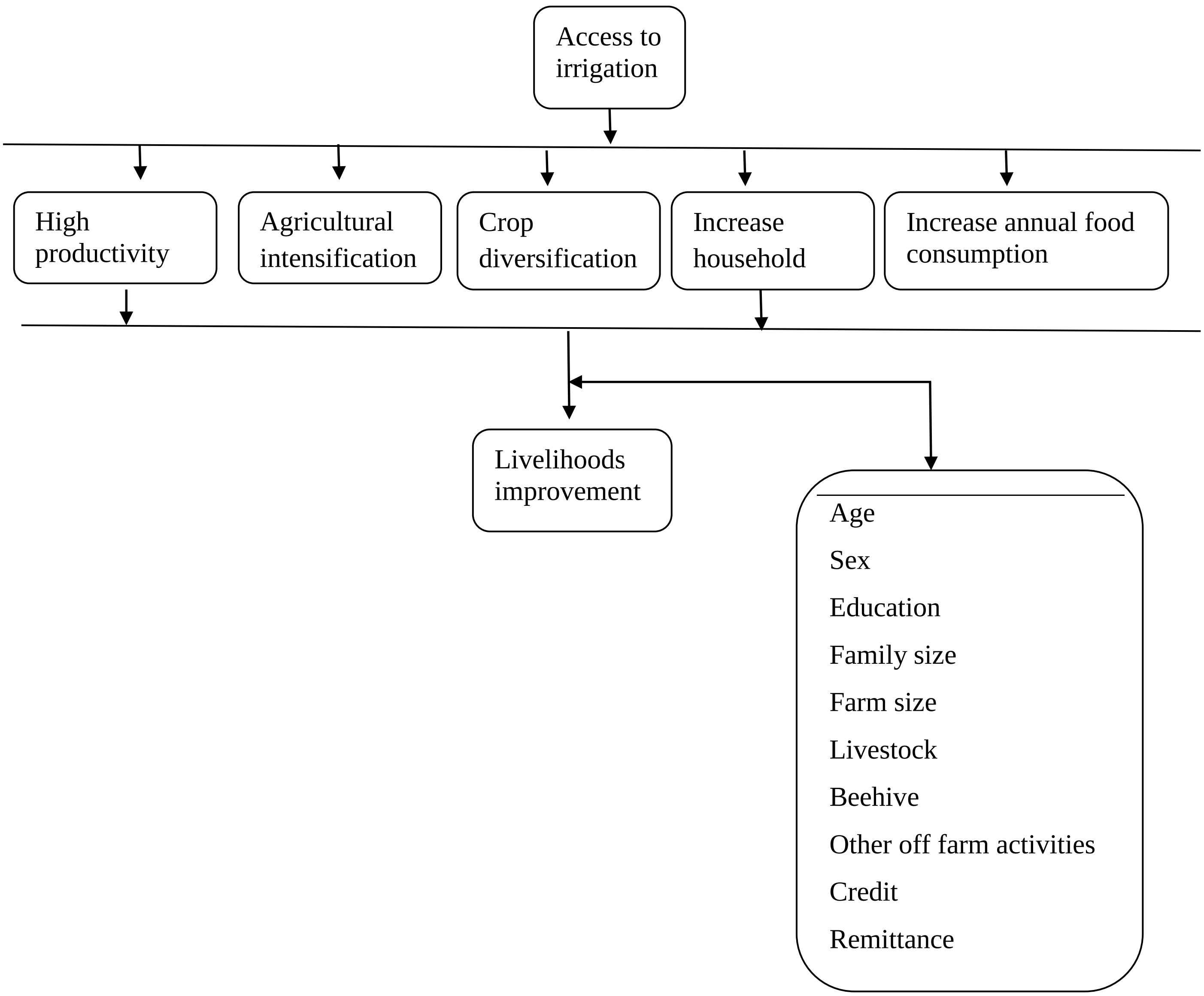
The Impact of Irrigation to Livelihood Improvement

As Smith (2004) indicated, there are four major interrelated mechanisms through which irrigated agriculture can reduce poverty: (1) Improvements in the levels and security of productivity, employment, and incomes for irrigating farm households and farm labor; (2) linkages in the rural economy; (3) increased opportunities for rural livelihood diversification; and (4) multiple uses of water supplied by irrigation infrastructure. First and most directly, irrigation can raise the incomes of those farmers with access to irrigated land. Water control in agriculture may boost productivity and incomes by ensuring adequate water throughout the growing season, contributing to higher yields and quality (higher farm-gate prices) by eliminating water deficits and providing at least a measure of drought protection; securing a crop where rainfall is inadequate or too variable; allowing a second or even a third crop by making water available in the dry season; allowing new crops or varieties for which market opportunities exist; improving timeliness and/or crop duration, allowing area expansion and/or increased cropping intensities; enabling farmers to adapt timing of production to market demand and higher prices; taking advantage of good weather conditions or avoiding adverse weather; and raising farm household and hired labor productivity through A further benefit arising for landowners may be the appreciation of the value of land that has access to irrigation, often enhancing access to credit and social standing and influence within the community.

Irrigation can contribute to improving rural livelihoods, but it is often subject to criticisms of inefficiency in water use, high capital and recurrent costs, lack of sustainability, and association with inequity in the distribution of both land and water (Angood et al., 2002). On the other hand, Judt et al. (2008) clarified that the modern irrigation scheme did not affect the livelihood and food situation directly but indirectly through other modernizations that came with and after the construction of the modern main canal, e.g., roads, merchants, agricultural offices, health centers, drinking water points, schools, electricity, etc. The findings of Senaratna Sellamuttu et al. (2014) show that irrigation access has a positive effect on income through livelihood choices. Small-scale irrigation is becoming the main mechanism in livelihood enhancement discourse, especially in recent times when the rainfall pattern is becoming erratic in the country (Alemu and Dessale, 2022). (Hussain & Wijerathna, 2004) also stated that irrigated agriculture provides livelihoods to hundreds of millions of rural people in general.

Figure 1

Conceptual Framework



Source: - Own design based on literature

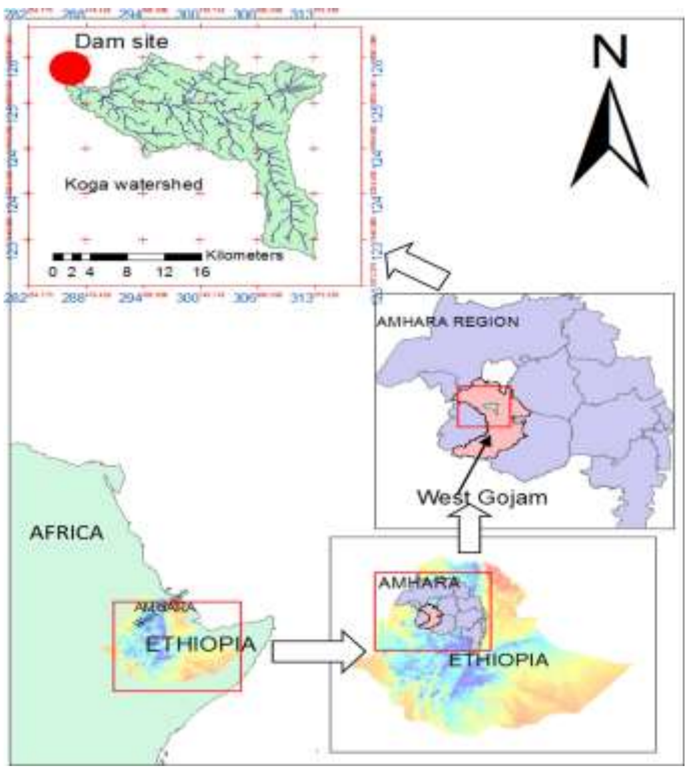
Method of the Study

Description of Koga Irrigation

The Koga irrigation dam is currently under construction on the Gilgel Abay river, the main inflow to Lake Tana, which is the source of the Abay River (Figure 1). The dam is the centerpiece of the Koga Irrigation and Watershed Management Project. The water to be stored in the reservoir created is to be used by 7,000 ha of smallholder farmers (Gebre et al., 2008). It is located in Mecha Woreda, West Gojjam Zone. The scheme has a well-organized and coordinated irrigation system with infrastructure that includes a 19.7 km primary canal, 42.3 km secondary canals, 117 km tertiary canals, 783 km quaternary canals, and 12-night storage structures to deliver water to each plot of land (Getnet et al., 2016).

Figure 2

Map of Koga Irrigation Project



Source: - Adapted from Asres, 2016

Research Design

A descriptive research design was used to describe the characteristics of the irrigated and non-irrigated households in detail. annual earnings (incomes), productivity of the irrigated and non-irrigated lands, technologies, intensification and diversification of agricultural production, input application, and other income sources out of irrigation. A quasi-experimental design was also used to study the impact of the project intervention on the livelihoods of the community. Hence, a mixed-mode approach was used by combining the features of quantitative and qualitative methods of data collection.

Sampling Techniques

The project has a total of 12 blocks. Among these five blocks, such as Kudmi, Chihona, Ambomesk Enguti, and Tagel Wodfit, samples were selected using a simple random sampling technique that was determined by a sample size determination formula developed by Yamane (1965) formula developed by Yamane (1965). The sample households of five irrigated blocks and four non-irrigated adjacent kebeles were also selected using a simple random sampling technique.

Sampling Method

The sample population was classified into two groups: irrigation and non-irrigation households. Sample households from the Koga irrigation project were identified using a systematic random sampling technique from the irrigation beneficiary households list. The project command area encompassed nine rural kebeles with about 14,000 households, of which 10031 households are irrigation beneficiaries in 12 blocks. Therefore, on average, each block has 835 beneficiary households. Hence, the overall sampling frame from the three randomly selected kebeles was 835 households from irrigated groups, 608 households from non-irrigation groups, and 12 irrigation blocks. The simplified formula proposed by Yamane (1965) with a 95% confidence level was used to determine the sample sizes for the finite study population.

$$n = \frac{N}{1 + N(e^2)}$$

Where: n = the sample size, N = the population size, e = the level of precision (e=0.05 and 0.1 to determine the interviewee household and irrigation blocks, respectively)

Therefore, based on the above formula, the sample sizes of irrigation users and non-irrigation users were 270 and 241 households, respectively. Among these, survey questionnaires 233 and 212 from irrigation users and non-irrigation users, respectively, were valid and used for data analysis. Furthermore, 5 sample blocks for the interviewee's households were selected randomly.

Methods of Data Collection

In this study, quantitative primary data was collected from sampled households. The conventional household survey method was used to collect quantitative information. A carefully designed questionnaire consisting of interrelated questions was employed and administered by trained enumerators. Sample household heads were the unit of analysis from whom quantitative data was collected.

Methods of Data Analysis

Quantitative data analyses were conducted using simple and relevant statistical methods such as average, percentage, and frequency distribution. In order to see the socio-economic impact of irrigation schemes, comparative analyses were made between irrigation and non-irrigation households using an independent t-test with equal variance. A propensity score match (PSM) with a logit regression model was conducted to identify the impact of irrigation on the livelihood of the rural community based on the determined variables in Figure 2.

Result and Discussion

Demographic Characteristics of the Respondents

The average age of the respondents was between 40 and 41, with a minimum of 21 and 28 and a maximum of 60 years for irrigation users and non-users, respectively. This indicates the population of the study area was in the young age category. It implies that the study area is characterized by an active working age group, which creates high pressure on the production factors such as water and land (UN, 2016). The average family size of the households was 4.2 and 4.44, with a minimum of 1 and a maximum of 8 and 10 for irrigation users and non-users, respectively. The CSA data also indicates the average family size of the areas was 5.1 in 2019 (CSA, 2020). Regarding the educational status of the respondents, the average was grade 4 and 3, with a minimum of no formal education and a maximum of 12th and 10th for irrigation users and non-users, respectively (Table 1). Education helps the farming community accept agricultural technologies and rationally allocate existing limited farm resources to achieve farming objectives and goals (Odinwa et al., 2015). Arega (2006) also confirmed that education is an important variable affecting the use of inputs positively and significantly.

Table 1

The Proportion of Irrigation-User and None-User Respondents for Quantitative Parameters

Variable	Mean		Std. Dev.		Minimum		Maximum	
	Irrigation-users	Non-users	Irrigation-users	Non-users	Irrigation-users	Non-users	Irrigation-users	Non-users
Age	39.87	41.41	8.41	6.70	21	28	60	60
Family size	4.24	4.44	1.57	1.32	1	1	8	10
Educational level	3.592	2.61	3.384	2.845	0	0	12	10

Source: Stata Output

About 24 and 17% were female, while 76 and 83% were male, for irrigation users and non-users, respectively. Regarding the marital status of the respondents, 86, 7, 5, and 2% were married, widowed, unmarried, or divorced, respectively, for irrigation users, while 92, 6, and 3% were married, widowed, or divorced, respectively, for non-irrigated farmers (Table 2).

Table 2

The Proportion of Irrigation-User and None-User Respondents for Quantitative Categorical Parameters

Variable	Frequency Irrigation-users	Non-users	Percent Irrigation-users	Non-users
Sex				
female	56	36	24.03	16.98
male	177	176	75.97	83.02
Marital status				
divorce	5	6	2.15	2.83
married	200	194	85.84	91.51
unmarried	12	0	5.15	0
widow	16	12	6.87	5.66

Source: - Stata Output

Socioeconomic Characteristics of the Respondents

Access to Infrastructure

As indicated in Table 3.3, the mean length of road to access the main asphalt road is 3.01 and 7.46 km, with the minimum distance of 0.30 and 4.00 km and the maximum distance of 8.00 and 11.00 km for irrigation users and non-users, respectively. The mean length of the areas to access local markets is 4.78 and 9.79 km, with a minimum distance of 10.00 and 13km and a maximum distance of 13.00km for irrigation users and non-users, respectively. Regarding access to irrigation, the field of the respondents is easily accessible to irrigation water for producing irrigated crops. In this regard, the farthest farms were 2km from the secondary and territory irrigation channels. Farmers travel between 1.5 and 2.7 km in average, with a minimum travel of 0.4 and 1.0km and a maximum travel of 5 km, to extension services.

The present study identified that irrigation user farmers are significantly ($P<0.01$) more accessible to infrastructures and services compared to non-irrigation user farmers (Table 3). This condition makes a capability to use improved agricultural technologies and to supply their products to the market easily. Sapkota, (2014) confirmed that road density is highly significant to increase the income index of the rural community.

Table 3

Access to Roads, Market, Extension and Irrigation Services

Variable	Mean		Std. Dev.		Minimum		Maximum		Significance level	
	Users	None	Users	None	Users	None	Users	None	t-value	p-value
Asphalt (km)	3.01	7.46	1.91	1.65	0.30	4.00	8.00	11.00	26.17	0.000***
Market (km)	4.78	9.79	2.08	1.66	0.50	6.00	10.00	13.00	27.79	0.000***
Irrigation (km)	0.98	-	0.40	-	0 .10	-	2.10	-	-	-
Extension (km)	1.47	2.66	0 .80	0.91	0 .40	1.00	5.00	5.00	14.65	0.000***

Source: Stata Output

Land Ownership

Land ownership plays a significant role in enhancing the production and productivity of crop production both under irrigation and rain-fed conditions (Koirala et al., 2016; Singirankabo and Ertsen, 2020). In this regard, more than 89% of farmers in Koga irrigation areas have their own land to produce agricultural products. The availability of the soil to supply essential plant nutrients is important to produce crops with a minimum supply of artificial fertilizers. Although the irrigation command area is characterized by medium-to-fine textured, red-brownish colored soil with low soil PH and low nutrient availability, mainly nitrogen (ERIAS, 2017), most irrigation users and non-irrigation users agreed that the fertility status of the Koga irrigation is fertile, followed by moderately fertile (Table 4).

Table.4

Land Ownership and Fertility Status of The Soil

Variable	Frequency		percent	
	Irrigation users	Non-users	Irrigation users	Non-users
Land ownership				
no	19	24	8.15	11.32
yes	214	188	91.85	88.68
Fertility status				
fertile	114	84	48.93	39.62
moderate	101	88	43.35	41.51
poor	18	40	7.73	18.87

Source: - Stata Output

Market Related Issues

Although there was a substantial market problem in the study areas, irrigation user farmers produce crops to generate income, while most irrigation non-user farmers produce crops for home consumption. Among the existing market problems, the low product price adjusted by merchants and brokers has affected the ability to fully exploit the potential of irrigated crop production. Irrigation-user farmers in the study area sold the irrigated crop products at the farm gate, while the final destination of crop products produced under rain-fed conditions is the nearby local markets. Modern transport facilities play a great role in enabling the farming community to use improved agricultural technologies and to supply their products to the market, especially easily perishable horticultural commodities (Bonsu, 2014). But both irrigation user and non-user farmers have transported farm inputs and products by horse and donkey pull carts dominantly in Koga irrigation areas (Table 5). The key determinants in accessing the market are availability of transportation, mode of transportation, and quality of road infrastructure (Aheeyar et al., 2015).

Table 5

Market Related Issues and Transportation Facilities in The Study Area

Variable		Frequency		Percent	
		Irrigation-users	Non-users	Irrigation-users	Non-users
Do you produce for market					
	no	0	117	0	55.19
	yes	233	95	100	44.81
Market problem					
	no	76	62	32.62	29.25
	yes	157	150	67.38	70.75
Market problem type					
	no problem	76	62	32.62	29.25
	far market	11	11	4.72	5.19
	low price	140	129	60.09	60.85
	transport	6	10	2.58	4.72
Market destiny					
	farm gate	138	-	59.23	-
	distant	-	28	-	13.21
	local	95	184	40.77	86.79
Transport facility					
	cart	152	154	65.24	72.64
	labor	37	42	15.88	19.81
	vehicle	44	16	18.88	7.55

Source: - Stata Output

Extension Services

Provision of extension services to smallholder farmers is one of the missions of agricultural offices in the endeavor of transforming an agriculturally-led economy into an industrially-led economy in a country (Berhane et al., 2018). In this perspective, the majority of both irrigation users and non-user farmers have received extension services. Professional advice followed by demonstrations of improved production technologies and theoretical and practical training were among the extension services provided in the study areas (Table 6).

Table 6

Extension Services and Types of Services Received

Variable	Frequency		percent	
	Irrigation-users	Non-users	Irrigation-users	Non-users
Extension services				
no	50	54	21.46	25.47
yes	183	158	78.54	74.53
Type of service				
no	50	54	21.46	25.47
advice	125	129	53.65	60.85
demonstration	25	16	10.73	7.55
training	33	13	14.16	6.13

Source: - Stata Output

Credit Services

Credit service is vital to the purchase of improved technologies and inputs, particularly for irrigation and agriculture in general. Credit to agriculture has a positive influence on agricultural productivity (Yego et al., 2018). Unfortunately, in the study area, most of the farmers did not access credit services. The main reason not to take credit was the interest rate paid on the principal. They replied that microfinance (the Amhara Credit Service Institute) was the only source of credit in the areas (Table 7).

Table 7

Credit Access

Variable	Frequency Irrigation-users	Non-users	percent Irrigation-users	Non-users
Credit				
no	166	151	71.67	71.23
yes	67	61	28.33	28.77
Credit source				
no credit	166	59	71.67	71.23
family	3	2	1.29	0.94
friend	5	3	2.15	1.42
micro	59	56	25.32	26.42
Reason not credit				
credit beneficiary	67	61	29.18	28.77
access	58	30	24.89	14.15
collateral	11	7	4.72	3.30
interest rate	96	114	41.20	53.77

Source: - Stata Output

As illustrated in Table 8 the credit taken by irrigation user and non-user farmers were not significant (P>0.05). It indicates that credit was not a co-factor for the difference observed between irrigation users and non-user farmers in terms of income and consumption.

Table 8

Credit Amount Taken in Koga Irrigation Project Areas

Variable	Mean		Std. Dev.		Minimum		Maximum		Significance	
	Users	None	Users	None	Users	None	Users	None	t-value	p-value
Credit amount	4071.07	4349.05	7053.50	8032.54	0	0	27000	50000	0.38	0.69^{ns}

Source: - Stata Output

Farm Size

Land is one of the production factors (Semin and Namyatova, 2019; Metzemakers and Louw, 2005). Due to high population growth in the country, the land holding share is decreasing over time. Hence, enhancing the productivity of the agricultural lands by using modern irrigation technologies and inputs is vital. The farm size of the study area ranged from zero (production with rental land) to 3 hectares for irrigation users, while it ranged from 0.25 to 2 hectares for non-irrigation users. Moreover, the difference in farm size between irrigation users and non-users was significant ($P < 0.01$). It implies that farm size is a factor in the variation observed among irrigation users and non-users in terms of annual production, consumption, and income (Table 9). Farm size is an important variable affecting the use of inputs both positively and significantly (Arega, 2006). Regarding the land holdings of the study area, Molla et al. (2019) reported that the average land holding in Mecha district was 1.5 ha per household and ranged from 0 to 3 ha.

Table 9

Land Holding, Under Irrigation and Rain Fed Condition

Variable	Mean		Std. Dev.		Minimum		Maximum		Significance	
	Users	None	Users	None	Users	None	Users	None	t-value	p-value
Farm size (ha)	0 .86	0 .77	0.41	0 .37	0.00	0.25	3.00	2.00	2.20	0.03*

Source: - Stata Output

Other Agricultural Productions in Koga Irrigation Project Areas

According to Anang (2019), engagement in other agricultural production and off-farm work has a robust and positive impact on crop productivity. In the Koga irrigation project area, farmers received reasonable income from livestock, eucalyptus tree plantations (for non-irrigation user farmers), beekeeping, and other off-farm activities (Table 10). Although there is no comparative analysis of tree planting instead of annual crop production, non-irrigation user farmers have been planting up to 0.5 ha of land for eucalyptus trees for firewood, charcoal, and construction purposes.

Table 10

Benefits from Other Agricultural Practices and Off-Farm Activities

Variable	Mean		Std. Dev.		Minimum		Maximum	
	Users	None	Users	None	Users	None	Users	None
Tree (ha)	-	0.66	-	0.14	-	0	-	0.5
Tree value	-	6471.69	-	13733.25	-	0	-	50000
Livestock value	6096.99	7328.30	10335.37	15214.56	0	0	50000	75000
Off-farm value	848.06	1025.23	2683.54	3691.95	0	0	15000	24000
Remittance	692.64	1561.32	5002.25	7926.85	0	0	50000	60000
Beekeeping	393.13	1277.83	1742.36	5442.17	0	0	10450	41000

Source: - Stata Output

Input Costs of Irrigation and Rain-fed Production

According to Arega (2006), the price of output was found to be an important variable affecting the use of inputs positively and significantly. McArthur and McCord (2017) indicated the clear role of fertilizer, improved seeds, and water in boosting yields. As a result, farmers in the Koga project area incur significant input costs for both irrigation and rain-fed conditions. Although farmers expend considerable input costs, irrigation-user farmers expend significantly ($P< 0.05$) more for fertilizer, pesticides, improved seed, and labor compared to non-irrigation-user farmers in the Koga project areas (Table 11). In the face of increasing global food prices, importing agricultural products is becoming more challenging. This condition necessitates a significant increase in water and land productivity via investment in both irrigated and rain-fed agriculture (Tilahun et al., 2011). Irrigated agriculture is more efficient in terms of economics. This may be attributed to the use of other complementary crop management technologies such as fertilizers and the use of improved crop varieties (Tilahun et al., 2011).

Table 11

Cost of Inputs

Variable	Mean		Std. Dev.		Minimum		Maximum		Significance	
	Users	None	Users	None	Users	None	Users	None	t-value	p-value
Fertilizer	9296.77	4945.66	2922.72	1233.62	2600	2300	17200	8500	20.10	0.000**
Pesticides	1876.81	752.02	689.215	353.51	400	150	4560	1750	21.34	0.000**
Seed	4133.51	912.31	2300.77	905.01	150	0	14000	4500	19.08	0.000**
Labor	3909.93	2023.40	1729.09	1150.98	600	0	11400	4500	13.41	0.000**

Source: - Stata Output

Farmers' Motivation to Use Irrigation

Farmers' motivation for producing under irrigation varies greatly, according to their perception. Most of the farmers use irrigation for the economic benefit of irrigated crops, while others do so due to the availability of their farm land in the command areas of the Koga irrigation project. In the study area, the major irrigation production problem that farmers persistently faced was crop damage due to plant disease and insect pests (Table 12). According to Mango et al. (2018), access to irrigation and reliable water sources have a significant influence on the adoption of small-scale irrigation farming.

Table 12

Major Irrigation Issues in The Study Area

Variable	Frequency Irrigation users	percent Irrigation users
Irrigation motivation		
command area	96	41.20
economic purpose	137	58.80
Irrigation problem		
no	133	57.08
yes	100	42.92
Which problem faced		
no	133	57.08
logging	2	0.86
pest	78	33.48
water shortage	21	9.01

Source: - Stata Output

Irrigation Experience and Irrigation Frequency

Farmers in the study area have been engaged for a long period of time under irrigation as well as under rain-fed conditions. According to Ainembabazi and Mugisha (2014), it is useful for the adoption of agricultural technologies. Farmers in the study area received irrigation every 12 days, with a minimum irrigation frequency of 7 days and a maximum frequency of 21 days (Table 13). According to USDA (1997), determination of irrigation water requirements requires a measurement or estimate of the rate of crop water use. But the water distribution in Koga irrigation is not based on the specific requirements of each irrigated crop. This condition affects the productivity of the crops.

Table 13

Farming Experience and Frequency of Production

Variable	Mean		Std. Dev.		Minimum		Maximum	
	Users	None	Users	None	Users	None	Users	None
Irrigation production	11.605	-	5.720379	-	1	-	29	-
Rain-fed production	-	13.702	-	6.35	-	4	-	31
Irrigation frequency	12.545	-	4.52	-	7	-	21	-

Source: - Stata Output

The Contribution of Irrigation for Livelihood Improvement

Crop Diversification and Intensification

In fact, crop diversification and intensification are associated with the commencement of medium and large irrigation projects in a given area. Crop diversification and intensification boost land efficiency and productivity. In this regard, the majority of the respondents confirmed the presence of crop diversification and intensification in the project area of Koga irrigation (Table 14). Irrigation has a strong and significant impact on cropping intensities. Irrigation has a high positive effect on yield performance, production volume, and intensity of crop production (Babovic and Milic, 2009). The beneficiaries gain higher crop yields through the diversification of crops cultivated (Garbero and Songsermsawas, 2016). Farmers utilize groundwater irrigation to assure that at least two of these crops are sequenced on the same field within the same year. Such double cropping has had a significant and positive influence on regional agricultural productivity (Krupnik et al., 2017). In the Koga irrigation areas, the majority of the irrigation user farmers reported that they have produced irrigated crops twice in the past year, while non-irrigation users only once (Table 14).

Table 14

Frequency of Crop Production in Koga Project Areas

Variable	Irrigation-users		Non-users	
	Frequency	percent	Frequency	percent
Crop intensification				
1-time per year	12	5.15	155	73.11
2-times per year	204	87.55	57	26.89
3-times per year	17	7.30	-	-
Crop diversity				
no	46	19.74	-	-
yes	187	80.26	-	-

Source: - Stata Output

Crop Productivity

Crop productivity (yield) is a function of the genotype of the crop, the environment, and management (Cooper et al., 2021; Sadras et al., 2015). The productivity of a given crop managed under irrigation with the application of optimum water and under rain-fed conditions with limited or excess water as other factors that are constant are quite different (Makombe et al., 2007). According to Bennett and Harms (2011), water is one of the main yield-limiting factors.

With this argument, crop production and productivity under irrigation were significantly ($P< 0.01$) higher compared to the production and productivity of the crop under the rain-fed condition in the Koga areas (Table 15).

Table 15

Crop Production and Productivity Under Irrigation and Rain-Fed Condition

Variable	Mean		Std. Dev.		Minimum		Maximum		Significance	
	Users	None	Users	None	Users	None	Users	None	t-value	p-value
Productivity ($Q\ ha^{-1}$)	66.57	37.57	8.93	6.82	45	20	100	55	38.18	0.000^{**}
Production (Q)	96.99	29.77	43.13	16.87	30	7.5	257.5	96.25	21.25	0.000^{**}

Source: - Stata Output

The null hypothesis of the study was that there is no difference between irrigation users and non-users in terms of crop productivity. As indicated in Table 16, there was a mean difference of 2.9 t of productivity between irrigation users and non-users. It implies that crop productivity due to irrigation was higher by 2.9 t compared to non-users. The two-paired sample t-test with equal variance analysis showed that crop productivity was significantly ($P<005$) enhanced due to irrigation. Moreover, the t-calculated value of 38.18 is greater than the t-tabulated value of 1.96 at a 95% confidence interval. Therefore, there was crop productivity enhancement due to the Koga irrigation project. The increment in yield due to irrigation was confirmed by Meredith et al. (2017), who found that plant biomass or yield increased relative to the amount of water consumed. Specifically, Okada et al. (2018) confirmed that in response to irrigation expansion, maize production in Europe will increase.

Table 16

The Effect of Irrigation on Crops Productivity at Koga Irrigation Project

Group	Observation	Mean	Std. Err.	Std. Dev.	Df	t-value	P-value
Non-users	212	37.58	0.47	6.82			
Users	233	66.58	0.59	8.93			
Combined	445	52.76	0.78	51.56	443	38.18	0.000^{**}
Difference		29.00	0.76	-			

Source: - Stata Output

The propensity score match (PSM) analysis presented in Table 17 illustrated that the overall (ATE) crop productivity difference between irrigation users and non-user farmers and the actual (ATET) crop productivity difference obtained only due to irrigation were significantly different ($P< 0.05$). In the current study, the overall (ATE) crop productivity difference between irrigation users and non-user farmers and the actual (ATET) crop productivity difference obtained only due to irrigation exceeded 1.15% only. Irrigation has a strong and significant impact on crop productivity, with the dominant effects on cropping intensities (Jin et al., 2012). Dhehibi et al. (2016) suggest that farmers could increase the production of these crops by applying water more efficiently.

Table 17

Average Treatment Effect (ATE) And Average Treatment Effect of The Treatment (ATET) on Crop Productivity

Effect	Coefficient	Statistics	Z-value	P-value
ATE	29.69	0.05	35.04	0.000**
ATET	29.35	0.05	32.66	0.000**

Source: - Stata Output

Annual Income

Irrigated agriculture is more efficient in terms of economics (Tilahun et al., 2011). In this regard, the total net benefit of irrigation user farmers was significantly (P 0.01) higher than the net benefit generated from rain-fed agriculture. The total net income generated from irrigation ranged from 36250.00 to 437995 ETB as compared to 6550.00 to 188625.00 ETB from rain-fed in the study areas (Table 18). It was also confirmed by Hagos et al. (2009) that irrigation generated an average income of US$ 323 ha-1 under smallholder-managed irrigation systems, compared to an average income of US$147 ha-1 for rain-fed systems. Babovic (2009) also confirmed that the profitability of field crop production increases from 3% in dry farming to 18.4% in irrigation. The average income is equivalent to Tshs. 133,078 per season for irrigation production as compared to Tshs. 92,500 for rain-fed production, which was lower by 30% in Tanzania (Masuruli, 2004).

Table 18

Net Income Under Irrigation and Rain-Fed Condition

Variable	Mean		Std. Dev.		Minimum		Maximum		Significance	
	Users	None	Users	None	Users	None	Users	None	t-value	p-value
INI	83406.72	-	42972.74	-	9880	-	232125	-	28.25	0.000**
RNI	67310.48	55052.15	39475.95	33924.41	0	6550	270450	188625	3.49	0.001**
TNI	150717.2	55052.15	74914.77	33924.41	36250	6550	437995	188625	17.06	0.000**

INI; Irrigation net income, RNI; rain-fed net income and TNI; total net income

Source: - Stata Output

The null hypothesis of the study was that there is no difference between irrigation users and non-users in terms of annual income generation. As indicated in Table 19, there was a mean difference of 95665.05 ETB in annual income between irrigation users and non-users. It means that irrigation users' income generation capacity was 95665.05 ETB higher than non-irrigation users. The two-paired sample t-test with equal variance analysis showed that income generation was significantly (P< 005) increased due to irrigation. Moreover, the t-calculated value of 17.06 is greater than the t-tabulated value of 1.96 at a 95% confidence interval. Therefore, there was income growth due to the Koga irrigation project. The current finding is in line with Gadisa et al.'s (2019) finding that participation in irrigation significantly affected household income and irrigator households get more gross income of BRL 22,161 than non-irrigator households.

Table 19

The Effect of Irrigation on Annual Income generation capacity

Group	Observation	Mean	Std. Err.	Std. Dev.	Df	t-value	P-value
Non-users	212	55052.15	2329.93	33924.41			
Users	233	150717.20	4907.83	74914.77			
Combined	445	105141.9	3600.07	75943.6	443	17.06	0.000**
Difference		95665.05	5605.03	-	-	-	-

** highly significant at 0.05 probability level.

Source: - Stata Output

The propensity score match (PSM) analysis in Table 20 illustrated that the overall (ATE) annual household income difference between irrigation users and non-user farmers and the actual (ATET) annual household income due to irrigation only was significantly (P<0.05). The overall (ATE) annual household consumption difference between irrigation users and non-user farmers was 92765.44 ETB, while the actual (ATET) household income difference obtained due to irrigation only was 88684.62 ETB. It implies that the value of 4080.82 ETB obtained from the difference between ATE and ATET was not due to irrigation but to other factors such as age, education level, farm size, credit, livestock, non-farm activities, remittance, beekeeping, and additional investment. Similarly, Alemu and Dessale (2022) found that small-scale irrigation has had a positive impact on household income compared to non-irrigators, which contributes to an average annual income of 72,701,49 ETB. That was about 16,157.06 ETB in annual average income for non-irrigators. Irrigation has significant and positive impacts on farm incomes, which is a necessary condition for the successful transformation of smallholder agriculture in Africa (Akudugu et al., 2021).

Table 20

Average Treatment Effect (ATE) And Average Treatment Effect of The Treatment (ATET) On the Household Income

Effect	Coefficient	Statistics	Z-value	P-value
ATE	92765.44	0.05	17.65	0.000**
ATET	88684.62	0.05	17.10	0.000**

**, highly significant at 0.05 probability level.

Source: - Stata Output

Household food Consumption

In fact, the presence of higher production leads to the possibility of higher consumption and sales of agricultural products (FAO, 2017). In the Koga project area, irrigation user farmers significantly ($P<0.01$) consumed and sold more agricultural products compared to irrigation non-user farmers (Table 21). According to McArthur and McCord (2017), higher availability of staple foods promotes health and labor productivity across sectors. Irrigation enhances revenues and enables a switch from relying mainly on consuming their own produce to purchasing more food from the market (Garbero and Songsermsawas, 2016). Agricultural gross capital formation has a positive influence on agricultural productivity (Yego et al., 2018).

Table 21

Households Annual Consumption Under Irrigation and Rain Fed Condition

Variable	Mean		Std. Dev.		Minimum		Maximum		Significance	
	Users	None	Users	None	Users	None	Users	None	t-value	p-value
Consumption (Q)	18.78	12.51	7.78	3.31	0	5	38	21	10.86	0.000**
Sell (Q)	78.21	17.25	40.13	15.33	8	-2.5	227.5	82.25	20.77	0.000**

Source: - Stata Output

The null hypothesis of the study was that there is no difference between irrigation users and non-users in terms of annual consumption. As indicated in Table 22, there was a mean difference of 0.63 t of annual food consumption between irrigation users and non-users. It implies that the annual food consumption of irrigation user farmers was higher by 0.63 t compared to non-irrigation user farmers. The two-paired sample t-test with equal variance analysis showed that annual food consumption was significantly (P<005) higher due to irrigation. Moreover, the t-calculated value of 10.86 is greater than the t-tabulated value of 1.96 at a 95% confidence interval. Therefore, there was more food consumption due to the Koga irrigation project. Access to irrigation enabled the sample households to grow crops more than once a year to ensure increased and stable production, income, and consumption (Tesfaye et al., 2005).

Table 22

The Effect of Irrigation on Annual Food Consumption

Group	Observation	Mean	Std. Err.	Std. Dev.	Df	t-value	P-value
Non-users	212	12.51	0. 22	3.31			
Users	233	18.78	0. 50	7.78		10.86	0.000**
Combined	445	15.80	0 .32	6.83	443		
Difference		6.26	0 .58	-	-	-	-

**, highly significant at 0.05 probability level.

Source: - Stata Output

The overall (ATE) annual household consumption difference between irrigation users and non-user farmers and the actual (ATET) annual household consumption due to irrigation only was significantly (P<0.05). The overall (ATE) annual household consumption difference between irrigation users and non-user farmers was 7.46, while the actual (ATET) household consumption difference obtained due to irrigation only was 6.79. In the current study, the overall (ATE) annual household consumption difference between irrigation users and non-user farmers and the actual (ATET) annual household consumption difference obtained due to irrigation only exceeded 9.0% (Table 23). Irrigation users' per capita consumption expenditure and income were 16 percent and 35 percent, respectively, higher compared to non-irrigation users, a significant difference (Asrat et al., 2022). Irrigation has significant and positive impacts on food consumption, which is a necessary condition for the successful transformation of smallholder agriculture in Africa (Akudugu et al., 2021).

Table 23

Average Treatment Effect (ATE) And Average Treatment Effect on The Treatment (ATET) Of Irrigation on The Household Consumption

Effect	Coefficient	Statistics	Z-value	P-value
ATE	7.46	0.05	11.45	0.000**
ATET	6.79	0.05	11.36	0.000**

**, highly significant at 0.05 probability level.

Source: - Stata Output

Conclusion and Recommendation

Crop diversification and intensification are tangible due to the Koga irrigation project, which contributes to high crop productivity, annual income, and crop consumption. The income growth observed due to the Koga irrigation project could be directly associated with crop productivity enhancement. Generally, the covariates considered in the study, such as age, education level, farm size, credit, livestock, non-farm activities, remittance, beekeeping, and additional investment, affect the overall difference between irrigation users and nonusers' livelihoods. Both the descriptive and econometric analyses revealed that irrigation has a strong impact on annual crop productivity, crop diversification and intensification, annual income, and crop consumption in Koga irrigation areas. The result of the current study provides strong support for the continuation and advancement of investment in irrigation infrastructure in Ethiopia in general and in the Amhara region in particular for the improvement of the rural community livelihoods.

Acknowledgements

The authors acknowledge Yome Institute of Economic Development for the opportunity to conduct this research, Mecha District Agricultural Office and Adet Agricultural Research Center Koga research staffs

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