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COLLEGE OF BUSINESS AND ECONOMICS

DEPARTMENT OF ECONOMICS

IMPACT OF SMALL-SCALE IRRIGATION TECHNOLOGY ON FARM HOUSEHOLD WELFARE IN TAHTAY MAYCHEW WEREDA, TIGRAY REGION, NORTH ETHIOPIA

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THE THESIS SUBMITTED TO THE DEPARTMENT OF ECONOMICS PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ECONOMICS

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- **Approved by Board Examiners**

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DECLARATION

I **Alemshet Yihdego**, do hereby declare that the thesis entitled "**Impact *Of Small-Scale Irrigation Technology On Farm Household Welfare In Tahtay Maychew Wereda, Tigray Region, North Ethiopia***", submitted to the department of economics, Mekelle University in partial fulfillment of the requirement of masters of science in economics, is my original work and it has not be presented for the award of any other degree, diploma fellowship or other similar titles, of any other university or institution.

ALEMSHET YIHDEGO

Signature…………………………………………...

Date………………………………………………...

August, 2020

Mekelle, Ethiopia

CERTIFICATION

This is to certify that this thesis entitled "**Impact *of Small-Scale Irrigation Technology on Farm Household Welfare in Tahtay Maychew Wereda, Tigray Region, North Ethiopia***", is an authentic work of **Mr. Alemshet Yihdego** who carried out the research under my guidance. Certified further, to the best of my knowledge the work reported here in does not form part of any project report or thesis on the basis of which a degree or award was conferred on an earlier occasion on this or any candidate.

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LIST OF ABBREVIATIONS AND ACRONYMS

AGP	Agricultural Growth Program
CSA	Central Statistical Agency
DFID	Department for International Development
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
IFPRI	International Food Policy Research Institute
IWMI	International Water Management Institute
KIIs	Key Informant Interviews
SLF	Sustainable Livelihood Framework
SSIT	Small-Scale Irrigation Technology
WEAI	Women’s Empowerment in Agriculture Index
FDRE	Federal Democratic Republic of Ethiopia

ABSTRACT

Methodology: This study investigates the impact of small-scale irrigation technology (SSIT) on farm household welfare in Tahtay Maychew Wereda, Tigray Region, North Ethiopia, focusing on three kebeles Hadi Shadi, May Sye, and May Berazyo with a combined population of 24,640. Despite the increasing adoption of SSIT, empirical evidence on its socio-economic and gender-related impacts in this drought-prone region remains limited. Employing a mixed methods approach, the study surveyed 200 households (150 SSIT adopters and 50 non-adopters), complemented by focus group discussions and key informant interviews. Quantitative analysis utilized descriptive statistics, Probit regression, and Propensity Score Matching to assess impacts on income, food security, and women's empowerment.

Results: Findings reveal that SSIT adoption significantly enhances household welfare, increasing annual income by 78% (32,400 ETB vs. 18,200 ETB), improving dietary diversity, reducing food shortages (24% vs. 62%), and boosting women's decision-making and income control (empowerment index: 0.58 vs. 0.32). Adoption is driven by education, landholding size, and access to extension and credit services, though challenges like seasonal water shortages (52%), equipment scarcity (43%), and labor demands (37%) persist.

Conclusion: The study concludes that SSIT is a transformative tool for rural livelihoods and gender equity but requires stronger institutional support and infrastructure to ensure sustainability. Recommendations include expanding extension services, subsidizing equipment, and improving water management to maximize SSIT's impact.

Keywords: Small-scale irrigation, household welfare, food security, gender empowerment,

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CHAPTER ONE

1. INTRODUCTION

1.1 Background of the Study

Agriculture is the cornerstone of Ethiopia's economy, contributing approximately 34% to the national GDP, employing over 70% of the workforce, and serving as the primary livelihood source for more than 80% of rural households (CSA, 2023). Despite its significance, Ethiopian agriculture faces significant challenges due to its heavy reliance on rain-fed systems, which are highly vulnerable to erratic rainfall, prolonged droughts, and climate variability. These factors exacerbate food insecurity, low productivity, and persistent rural poverty, particularly in semi-arid regions like Tigray, where recurrent droughts have historically disrupted agricultural production and livelihoods.

In response to these challenges, small-scale irrigation technologies (SSIT), such as rope-and-washer pumps, bucket systems, and gravity-fed canals, have gained prominence as viable solutions for smallholder farmers. Unlike large-scale irrigation schemes, SSIT are low-cost, farmer-managed, and adaptable to small landholdings, typically less than two hectares. These technologies enable year-round farming, increase crop yields, facilitate diversification into high-value crops, and enhance resilience against climate shocks. The Ethiopian government, in collaboration with development partners, has prioritized SSIT as a strategy to achieve food security, reduce poverty, and promote sustainable rural development under initiatives like the Agricultural Growth Program (AGP) and the National Adaptation Plan for climate change (FDRE, 2019).

Tahtay Maychew Wereda, located in the North-Western zone of Tigray Region, exemplifies the challenges and opportunities of smallholder agriculture in Ethiopia. With a total population of 91,943 (45,047 males and 46,886 females) as of 2017 E.C., the Wereda comprises 12 rural kebeles characterized by dry-weina dega agro-ecology, marked by erratic rainfall and frequent droughts (Wereda Agricultural Office, 2023). The study focuses on three purposively selected kebeles Hadi Shadi (7,371 people), May Sye (7,662 people), and May Berazyo (9,607 people) which together account for approximately 26% of the Wereda's population. These kebeles were chosen due to their varying levels of SSIT adoption, diverse agricultural practices, and accessibility for data collection. Despite increasing SSIT interventions, there is a notable gap in localized evidence regarding their socio-economic impacts, particularly on household welfare and gender dynamics in this context.

Globally, small-scale irrigation has been recognized as a transformative tool for rural development. Studies in Sub-Saharan Africa (Namara et al., 2005; Domenech & Ringler, 2013) demonstrate that SSIT enhances household income, food security, and resilience. In Ethiopia, research by Gebregziabher et al. (2014) and Hagos et al. (2009) highlights SSIT's role in increasing agricultural productivity and reducing seasonal hunger. However, the specific impacts in Tahtay Maychew Wereda, including its effects on income, food security, asset accumulation, and women's empowerment, remain underexplored. This study seeks to address this gap by providing empirical evidence on the welfare effects of SSIT, with a focus on both socio-economic outcomes and gender equity, to inform targeted rural development strategies in Tigray.

1.2 Statement of the Problem

Ethiopia's agricultural sector faces persistent challenges due to its dependence on rain-fed farming, which is increasingly unsustainable in the face of climate change. In Tigray Region, recurrent droughts, limited water resources, and low agricultural productivity contribute to chronic food insecurity and poverty, particularly in rural areas like Tahtay Maychew Wereda. To address these issues, the Ethiopian government and development partners have promoted SSIT as a key intervention to enhance productivity, stabilize food supply, and improve rural livelihoods. However, the actual impacts of SSIT on household welfare in Tahtay Maychew remain poorly documented, limiting the ability to design evidence-based policies.

While studies in other Ethiopian regions (e.g., Amhara and Oromia) have shown positive outcomes of SSIT (Awulachew et al., 2010; Belainew, 2016), contextual differences in agro-ecology, market access, and socio-cultural factors necessitate localized research. For instance, Tigray's semi-arid climate and post-conflict recovery challenges create unique conditions that may affect SSIT outcomes. Moreover, gender disparities in access to resources and training could influence the equitable distribution of SSIT benefits, yet few studies have explored these dynamics in Tahtay Maychew. Without rigorous evidence, policymakers risk implementing interventions that fail to address local needs or maximize impact. This study aims to fill these knowledge gaps by providing a comprehensive analysis of SSIT's effects on household welfare, gender equity, and adoption constraints in Tahtay Maychew Wereda.

1.3 Objectives of the Study

1.3.1 General Objective

To evaluate the impact of small-scale irrigation technology (SSIT) on the welfare of farm households in Tahtay Maychew Wereda, Tigray Region, North Ethiopia, with a focus on socio-economic outcomes, food security, and gender empowerment.

1.3.2 Specific Objectives

1. To analyze the access to and utilization patterns of SSIT among rural households, including technology types and crop choices.3
2. To evaluate the effect of SSIT on food security and dietary diversity, particularly during dry seasons.
3. To investigate the major challenges and sustainability constraints affecting SSIT utilization in the study area.

1.4 Research Questions

The study addresses the following research questions to guide the investigation:

1. To what extent does SSIT improve food security and dietary diversity among rural households?
2. What socio-economic, institutional, and environmental factors significantly influence SSIT adoption?
3. What are the primary constraints and sustainability challenges faced by SSIT users in the study area?

1.5 Hypotheses of the Study

Based on the research objectives and literature review, the study tests the following hypotheses:

1. Households adopting SSIT have significantly higher incomes, food security, and asset ownership compared to non-adopters.
2. Access to education, extension services, credit, and larger landholdings positively influences SSIT adoption.
3. SSIT adoption enhances women's involvement in agricultural decision-making and control over income, contributing to greater gender equity.

1.6 Significance of the Study

This study is significant for several reasons, offering both academic and practical contributions:

1. Evidence-Based Policy: By providing localized data on SSIT's impacts in Tahtay Maychew Wereda, the study informs policymakers and development practitioners about effective strategies to enhance rural livelihoods and food security in Tigray.
2. Practical Recommendations: The findings offer actionable recommendations for scaling up SSIT interventions, improving access to resources, and addressing implementation challenges.
3. Regional Relevance: Given Tigray's unique agro ecological and socio-political context, including post conflict recovery needs, the study provides context-specific insights to guide sustainable agricultural interventions.

The results are expected to benefit stakeholders, including the Tigray Regional Bureau of Agriculture, NGOs, and local communities, by promoting evidence-based interventions that enhance resilience and equity.

1.7 Scope and Delimitation of the Study

The study is geographically limited to three kebeles in Tahtay Maychew Wereda Hadi Shadi, May Sye, and May Berazyo selected for their irrigation potential and demographic diversity. It focuses exclusively on small scale irrigation technologies, excluding large-scale or communal irrigation schemes. The research examines household welfare through indicators such as income, food security, asset ownership, and women's empowerment, but does not cover broader community-level impacts. The data are cross-sectional, capturing conditions during the study period (2025) and may not fully reflect seasonal or long-term dynamics. While the findings are context-specific, they offer valuable insights for similar drought-prone regions in Ethiopia.

1.8 Conceptual Framework

The study is guided by a conceptual framework that links SSIT adoption to household welfare outcomes. SSIT adoption is influenced by socio-economic factors (e.g., education, land size), institutional factors (e.g., extension services, credit access), and environmental factors (e.g., water availability). Adoption leads to improved agricultural productivity, which enhances household income, food security, asset accumulation, and women's empowerment. However, constraints such as water scarcity, labor demands, and market access may limit these outcomes. The framework draws on the Diffusion of Innovation Theory (Rogers, 2005) and the Sustainable Livelihood Framework (DFID, 1999) to contextualize these relationships.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction

This chapter provides a comprehensive review of the theoretical and empirical literature on small-scale irrigation technology (SSIT) and its impact on farm household welfare, with a focus on income, food security, gender empowerment, and adoption dynamics. The review synthesizes global and Ethiopian studies, theoretical frameworks, and key concepts to establish the foundation for the study in Tahtay Maychew Wereda, Tigray Region, North Ethiopia. It covers definitions and typologies of SSIT, theoretical perspectives, empirical evidence on welfare outcomes, gender dimensions, determinants of adoption, constraints to implementation, and existing research gaps. By situating the study within this broader context, the chapter highlights the relevance of SSIT for improving rural livelihoods in drought-prone regions and justifies the need for localized evidence in Tahtay Maychew.

2.2 Concept and Definition of Small-Scale Irrigation Technology

Small-scale irrigation technology (SSIT) refers to low-cost, farmer-managed water application systems designed for small landholdings, typically less than two hectares. According to the Food and Agriculture Organization (FAO, 2011), SSIT is characterized by its limited command area (often less than 10 hectares), reliance on surface or shallow groundwater, simple water-lifting mechanisms (e.g., buckets, rope-and-washer pumps), and decentralized management by farmers. The International Water Management Institute (IWMI) further defines SSIT as systems requiring minimal external infrastructure, making them accessible to resource-constrained smallholder farmers (Awulachew et al., 2010). These technologies are particularly suited to semi-arid regions like Tigray, where erratic rainfall and recurrent droughts limit rain-fed agriculture. SSIT enables year-round farming, crop diversification, and resilience against climate variability, thereby enhancing household welfare.

2.3 Typologies of Small-Scale Irrigation Systems

SSIT encompasses a variety of systems tailored to local resource endowments, agro-ecological conditions, and socio-economic contexts. The following typologies are prevalent globally and in Ethiopia:

2.3.1 Manual Water-Lifting Systems

Bucket and pulley systems, rope-and-washer pumps, and treadle pumps are common small-scale irrigation technologies designed for low-cost and labor-efficient water lifting. Bucket and pulley systems are simple and affordable, relying on manually lifting water from shallow wells or streams using buckets and ropes, making them suitable for areas with limited capital. Rope-and-washer pumps use a low-cost rope and piston mechanism to lift water and are particularly effective for small plots and shallow groundwater sources.

Treadle pumps, which are foot-operated, provide efficient water lifting for irrigation, though they require more physical effort than motorized alternatives. These technologies enable smallholder farmers to increase water access and crop productivity in resource-constrained settings.

2.3.2 Gravity-Fed Systems

Traditional canals and small diversion structures are widely used methods for directing water to agricultural fields in regions like Tigray. Traditional canals channel water from rivers or streams to farms and are particularly common in hilly areas, facilitating irrigation across sloped terrains. Small diversion structures and ponds, on the other hand, capture and store water for controlled irrigation and are often integrated with gravity-fed systems to optimize water use and support year-round crop production.

2.3.3 Motorized Pumps

Diesel or Electric Pumps: These are more efficient but less accessible to smallholders due to high capital, fuel, and maintenance costs. They are used where financial resources and infrastructure are available.

2.3.4 Spate and Rainwater Harvesting Systems

Spate irrigation and rainwater harvesting are two common approaches to managing water for agriculture in arid and semi-arid regions. Spate irrigation involves diverting seasonal floodwaters into farm plots, allowing farmers to utilize episodic water flows for crop production. Rainwater harvesting, on the other hand, includes techniques such as rooftop collection and microcatchment systems, which store rainwater for use during dry periods, helping to ensure a more reliable water supply for irrigation.

These typologies reflect the diversity of SSIT, with manual and gravity-fed systems being most prevalent in resource-scarce settings like Tahtay Maychew due to their affordability and adaptability (FAO, 2011).

2.4 Theoretical Frameworks

The study draws on two theoretical frameworks to contextualize SSIT adoption and its welfare impacts: the Diffusion of Innovation Theory and the Sustainable Livelihood Framework.

2.4.1 Diffusion of Innovation Theory (Rogers, 2005)

Rogers' (2005) Diffusion of Innovation theory explains the adoption of new technologies through five key attributes, which are highly relevant for understanding small-scale irrigation technology (SSIT) uptake in Tahtay Maychew.

Relative advantage reflects the perceived benefits of SSIT, such as higher yields and increased income, compared to rain-fed farming. Compatibility considers the extent to which SSIT aligns with local farming practices, cultural norms, and environmental conditions, influencing its acceptance. Complexity refers to the ease of learning and using the technology, with simpler systems like bucket irrigation being more readily adopted than more technical alternatives.

Trial ability highlights farmers' ability to experiment with SSIT on a small scale before committing fully, which helps reduce perceived risks. Finally, observability emphasizes the visibility of SSIT benefits among peer farmers, where demonstrated success encourages wider adoption. Taken together, this framework provides insight into why some households adopt SSIT while others do not, underscoring the importance of socio-economic and institutional factors in shaping adoption decisions.

2.4.2 Sustainable Livelihood Framework (DFID, 1999)

2.5 Empirical Review of Irrigation and Welfare Linkages

The Sustainable Livelihood Framework (SLF) highlights five key capital assets natural, physical, human, financial, and social as essential for strengthening rural livelihoods, and small-scale irrigation technologies (SSIT) have significant impacts on each of these assets.

In terms of natural capital, SSIT promotes the efficient use of water and land resources, allowing for year-round farming in drought-prone areas. Physical capital is enhanced through improved access to irrigation tools and infrastructure, including pumps and canals, which expand farmers' production capacity. Human capital benefits from increased agricultural output, which contributes to better food security, nutrition, and health outcomes.

Financial capital is strengthened as income from irrigated crops rises, enabling households to build savings and make productive investments. Finally, social capital is reinforced through community cooperation in managing shared irrigation schemes and engaging in collective marketing efforts. Overall, the SLF underscores the transformative potential of SSIT in improving livelihoods by simultaneously strengthening multiple forms of capital, particularly in vulnerable areas such as Tahtay Maychew.

2.5.1 Global Evidence

Global studies consistently highlight the positive impact of small-scale irrigation technologies (SSIT) on household welfare in developing countries, though outcomes often vary by context. Namara et al. (2005) showed that in Sub-Saharan Africa, SSIT facilitated dry-season cropping and the cultivation of high-value vegetables, which boosted household income by 30–50% and reduced food insecurity.

Similarly, Domenech and Ringler (2013) found that in Ghana and Tanzania, irrigation improved dietary diversity and nutritional outcomes, with households consuming 1.5 to 2 more food groups per week.

In Nigeria, Awotide et al. (2012), using Propensity Score Matching (PSM), demonstrated that SSIT adoption increased household expenditure by 25% and reduced poverty incidence by 15%.

Hussain and Hanjra (2004) further noted that SSIT contributed to broader social benefits, such as improved education and health outcomes, by stabilizing incomes and reducing vulnerability across South Asia and Africa. Burney et al. (2010) also revealed that in Benin, solar-powered drip irrigation increased yields by 70% while simultaneously reducing labor burdens, particularly for women. Collectively, these studies underscore SSIT's role in enhancing both economic and social welfare across diverse contexts.

2.5.2 National Evidence from Ethiopia

In Ethiopia, small-scale irrigation technologies (SSIT) have been widely promoted as a means to combat food insecurity and poverty, with several studies confirming their transformative potential. Hagos et al. (2009) reported that in Tigray, irrigated households earned 40% more income and experienced 50% less seasonal hunger compared to rain-fed farmers.

Similarly, Gebregziabher et al. (2014) found that SSIT adoption in Amhara and Tigray boosted crop productivity by 60% and facilitated diversification into high-value cash crops such as onions and tomatoes. Belainew (2016) noted that in the Amhara Region, SSIT users achieved a 65% increase in income, higher food consumption scores, and enhanced women's empowerment through improved control over household income. Awulachew et al. (2010) further emphasized that farmer-managed SSIT schemes were more sustainable than large-scale interventions, with 80% of users reporting improved livelihoods.

In Oromia, Tesfaye et al. (2018) showed that SSIT reduced food insecurity by 30% and strengthened household resilience against drought. While these findings illustrate SSIT's significant contributions to rural development in Ethiopia, regional variations in agro-ecology and socio-economic contexts highlight the need for localized studies in Tigray.

2.6 Gender Dimensions of Irrigation

Gender disparities in access to agricultural resources significantly shape the outcomes of small-scale irrigation technologies (SSIT). Women often encounter barriers to land ownership, credit, and training, which restrict their ability to adopt irrigation technologies.

Nevertheless, when women are actively included, they contribute to improved household welfare and agricultural productivity. For instance, FAO (2011) found that women's involvement in irrigation decision-making enhanced household food security by 20% in Sub-Saharan Africa, while IFPRI (2013), using the Women's Empowerment in Agriculture Index (WEAI), demonstrated that irrigation access increased women's control over income and assets in Kenya and Uganda. Similarly, Alkire et al. (2013) identified SSIT as a catalyst for strengthening women's leadership roles and decision-making power in agriculture.

In Ethiopia, Gebregziabher et al. (2014) reported that women-headed households adopting SSIT experienced a 70% increase in income returns compared to their male-headed counterparts, despite lower adoption rates.

Van Koppen et al. (2013) further observed that gender-sensitive irrigation programs in Ethiopia raised women's participation in cooperatives by 25%, thereby enhancing their social capital. Collectively, these studies highlight SSIT's potential to advance gender equity, yet localized evidence from Tahtay Maychew is essential to capture the specific gender dynamics at play.

2.7 Determinants of SSIT Adoption

Empirical studies identify multiple factors influencing SSIT adoption, categorized as follows:

Table 1.Determinants of SSIT Adoption

Category	**Determinants**	**Source**
Socio-economic	Education, age, gender, household size	Gebregziabher et al. (2014)
Institutional	Access to credit, extension services, training	Hagos et al. (2009), Belainew (2016)
Physical	Landholding size, water availability, market proximity	Awulachew et al. (2010)
Psychological	Risk perception, exposure to successful adopters	Rogers (2005)

In Tigray, studies suggest that literacy, extension services, and land size are particularly critical (Hagos et al., 2009). Market access and water availability also play significant roles, especially in semi-arid regions like Tahtay Maychew.

2.8 Challenges and Constraints in SSIT Implementation

Despite its proven benefits, small-scale irrigation technology (SSIT) faces several challenges that constrain its effectiveness and sustainability. Seasonal water shortages and the drying of wells often limit irrigation potential (Awulachew et al., 2010), while the labor-intensive nature of manual systems such as bucket irrigation discourages adoption, particularly among women and elderly farmers (Namara et al., 2005).

High initial investment and maintenance costs for pumps and spare parts further restrict access for poorer households (Gebregziabher et al., 2014). In addition, limited market access, including inadequate storage and transportation infrastructure, undermines the profitability of perishable irrigated crops (Tesfaye et al., 2018).

A lack of technical training on the proper operation and maintenance of SSIT also reduces efficiency and long-term sustainability (FAO, 2011). These challenges underscore the urgent need for supportive policies, institutional capacity, and infrastructure development to maximize the impact of SSIT in improving rural livelihoods.

2.9 Research Gap and Rationale for the Study

While existing literature confirms the positive effects of small scale irrigation technology (SSIT) on household welfare, several important gaps remain.

First, few studies have focused on Tigray, particularly Tahtay Maychew Wereda, where unique agro-ecological conditions and socio-political factors such as post-conflict recovery may shape outcomes differently from other regions. Second, limited attention has been given to gendered impacts of SSIT in Tigray, despite evidence that women experience distinct barriers and benefits in irrigation adoption.

Third, much of the existing research relies on descriptive or correlational analyses, with relatively few studies employing rigorous econometric methods such as Propensity Score Matching (PSM) or Probit regression to establish causal relationships.

Fourth, the sustainability dimension of SSIT, including risks of groundwater depletion and equipment durability, has received insufficient consideration. Finally, findings from other regions of Ethiopia may not be directly applicable to Tahtay Maychew due to differences in climate, market access, and institutional support.

This study seeks to address these gaps by generating localized, evidence-based insights into SSIT’s impacts on household welfare, gender equity, and adoption dynamics in Tahtay Maychew Wereda through the application of robust mixed-methods approaches.

2.10 Conceptual Framework

The conceptual framework illustrates the relationship between SSIT adoption and household welfare. Independent variables (socio-economic factors, institutional support, and environmental conditions) influence SSIT adoption, which in turn affects dependent variables (income, food security, asset ownership, and women's empowerment). Mediating factors, such as market access and water availability, and constraints, like equipment costs and labor demands, shape these outcomes. The framework integrates the Diffusion of Innovation Theory and Sustainable Livelihood Framework to guide the analysis.

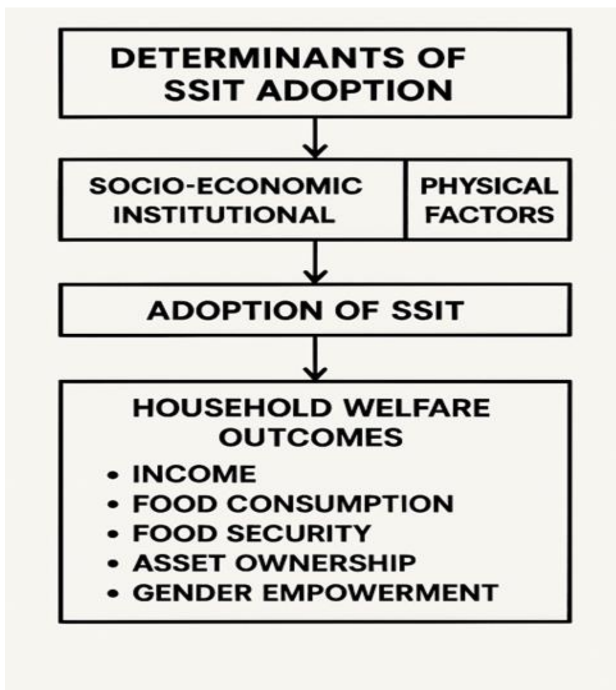

Figure 1. Conceptual Framework

CHAPTER THREE

3. Data, Conceptual Framework and Research Methodology

3.1 Site Selection

The study focuses on three kebeles Hadi Shadi, May Sye, and May Berazyo with a combined population of 24,640, representing approximately 26% of the Wereda's total population of 91,943 (45,047 males and 46,886 females) as of 2017 E.C.

3.2 Description of the Study Area

The study was conducted in three Kebeles of Tahtay Maychew Wereda. The woreda is located in the North-Western zone of Tigray Region, Ethiopia, is a predominantly rural area characterized by smallholder agriculture. The Wereda comprises 12 Kebeles and has a total population of 91,943, with a near gender balance (45,047 males and 46,886 females) based on 2017 E.C. data from the Wereda Administrative Office. The study was conducted on three purposively selected kebeles namely Hadi Shadi, May Sye and May Berazyo.

These kebeles were chosen due to their varying levels of SSIT adoption, engagement in irrigated agriculture, and accessibility for data collection. The area is agro-ecologically classified as dry-weina dega, with an altitude of 1,500–2,300 meters above sea level, erratic rainfall (500–700 mm annually), and recurrent droughts. Smallholder farmers rely on mixed crop-livestock systems, cultivating crops such as teff, maize, and vegetables. SSIT, including rope-and-washer pumps, bucket systems, and gravity-fed canals, has been promoted as a climate adaptation strategy to enhance productivity and resilience in this drought-prone region.

3.3 Research Design

The study adopted a mixed-methods research design, integrating quantitative and qualitative approaches to provide a holistic understanding of SSIT's impacts. A structured household survey and econometric models (Probit regression and Propensity Score Matching) were used to quantify the causal effects of SSIT on income, food security, asset ownership, and women's empowerment. In addition, Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) provided in depth perspectives on adoption patterns, gender dynamics, and implementation challenges.

3.4 Sampling Techniques and Sample Size Determination

3.4.1 Sampling Design

A multistage sampling technique was employed to determine sampling households. First, Tahtay Maychew Wereda was selected due to its high irrigation potential, prevalence of SSIT adoption, and vulnerability to drought, making it an ideal context for studying welfare impacts. Second,three kebeles Hadi Shadi, May Sye, and May Berazyo were chosen based on their engagement in irrigated agriculture, presence of both SSIT adopters and non-adopters, and logistical accessibility. In this study stratified random sampling of households were used to classify as SSIT Adopters for those who were using SSIT (rope-and-washer pumps, bucket systems) and Non-Adopters who were relying solely on rain-fed agriculture. Within each stratum, households were randomly selected to ensure unbiased representation.

3.4.2 Sample Size Determination

The sample size was determined using Yamane's (1967) formula for finite populations, adjusted for the study's context:

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

Where:

- n: Sample size
- N: Total household population in the three kebeles (approximately 5,000 households, estimated from 2017 E.C. population data)
- e: Margin of error (5%)

If N= 5000 and e= 0.05:

$$n = \frac{5000}{1 + 5000(0.5^2)}$$

$$n = \frac{5000}{1+5000(0.0025)} \quad = n = \frac{5000}{1+12.5} = \underline{\underline{\mathbf{370.37}}}$$

n= 370

Table 2. Sample Size Determination

Group	Proportion	Number of Households
SSIT Adopters	¼	87
Non-Adopters	¾	263
Non respondents	-	20
Total		**370**

Further proportional allocation across the three kebeles was based on their population size to ensure representativeness. To account for resource constraints and ensure sufficient representation for econometric analysis (particularly Propensity Score Matching), a sample of **370** households were selected, from the selected households 87 households were adopters and 263 households were non-adopters to reflect the higher prevalence of SSIT use. The remaining 20 households were non respondents and excluded from this study.

3.5 Data Sources and Types

3.5.1 Primary Data

Primary data were collected through structured questionnaires administered to 200 household heads which covers socio-economic characteristics, SSIT use, income, food security, and empowerment indicators. Focus Group Discussions (FGDs) were also conducted on Six FGDs (two per kebele, one male and one female group) with 8–12 participants each, exploring perceptions, gender roles, and challenges. In addition, Key Informant Interviews (KIIs) were implemented through interviews with 12 key informants, including agricultural extension agents, irrigation cooperative leaders, women's development officers, and kebele administrators. Finally, Field Observations was undertaking.

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3.6 Data Collection Instruments

A structured, pre-tested questionnaire was designed to collect quantitative data on demographic and Socio-Economic Characteristics. SSIT Access and Utilization: Types of irrigation technologies, crops cultivated, irrigation frequency, Annual income, food expenditure, meals per day, and asset ownership. The questionnaire was translated into Tigrigna to ensure accessibility and pre-tested in a non-sample kebele to refine clarity and relevance. In addition, focus group discussions and key informant interviews were also conducted.

3.7 Methods of Data Analysis

3.7.1 Descriptive Statistics

Descriptive analysis summarized household characteristics and SSIT was analyzed using means, percentages, and frequencies for variables like income, food expenditure, and adoption rates. Cross tabulations were implemented to compare adopters and non-adopters. Moreover, T-tests and chi-square tests were used to assess significant differences between groups. Finally graphical representations (bar charts, pie charts) were done to display key trends.

3.7.2 Econometric Models

Two econometric models were employed to analyze adoption determinants and welfare impacts:

3.7.2.1 Probit Regression Model

The Probit model estimated the probability of SSIT adoption based on socio-economic and institutional factors. The model is specified as:

Let

Y_i= 1 if a household adopts SSIT, and 00 otherwise.

$Y_i = 0$ otherwise.

$$P(Y_i=1) = \Phi(\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_k)$$

Where:

- Φ is the cumulative distribution function (CDF) of the standard normal distribution
- $X_1, X_2, \ldots\ldots\ldots X_k$ are explanatory variables such as education level, landholding size, and access to extension services
- $\beta_0, \beta_1 \ldots\ldots\ldots \beta_k$ are the parameters to be estimated

This model identifies significant predictors of SSIT adoption, addressing the sixth specific objective.

3.7.2.2 Propensity Score Matching (PSM)

PSM was used to estimate the causal impact of SSIT on welfare outcomes, controlling for selection bias. The process involves estimating propensity scores using the Probit model, matching adopters with non-adopters using nearest neighbor and radius matching techniques and calculating the Average Treatment Effect on the Treated (ATT) for outcomes. PSM ensures robust estimation of SSIT's impact by accounting for observable differences betw9een adopters and non-adopters.

3.7.3 Qualitative Data Analysis

Qualitative data collected from focus group discussions (FGDs) and key informant interviews (KIIs) were analyzed using thematic analysis. The transcriptions were systematically coded to identify recurring themes such as water scarcity and gender roles. These themes were then triangulated with quantitative findings to validate results and provide greater contextual depth. To further enrich the analysis, direct quotes from participants were incorporated into the results chapter, illustrating key findings in the voices of the respondents themselves.

3.8 Measurement of Key Variables

The following table outlines the key variables, their measurements, and descriptions:

Table 3.Measurement of Key Variables

Variable	Measurement/Unit	Description
SSIT Adoption	Binary (0 = No, 1 = Yes)	Whether the household uses SSIT (e.g., rope-and-washer pumps, bucket systems)
Household Income	Ethiopian Birr (ETB)/year	Total annual income from farm and off-farm sources
Food Security	Proxy indicators	Frequency of meals/day, food shortages, reliance on food aid
Women's Empowerment	Index (0–1)	Composite score based on income control, decision-making, and training access
Landholding Size	Hectares	Total farmland owned or operated by the household
Extension Access	Binary (0 = No, 1 = Yes)	Whether the household received agricultural extension services
Credit Access	Binary (0 = No, 1 = Yes)	Whether the household accessed formal or informal credit
Distance to Market	Kilometers	Distance from household to nearest market for selling crops

These measurements align with the study's objectives and facilitate both descriptive and econometric analyses.

3.9 Reliability and Validity

To ensure data quality and reliability, several methodological steps were undertaken. The questionnaire was pre-tested in a non-sample kebele to refine questions and ensure clarity before the main survey. Enumerators received comprehensive training on data collection protocols, ethical principles, and cultural sensitivity to minimize bias during fieldwork. Data validity was strengthened through triangulation, whereby information from surveys, focus group discussions (FGDs), key informant interviews (KIIs), and observations was cross-verified. In addition, robustness checks were performed using alternative Propensity Score Matching (PSM) techniques, such as kernel matching, to confirm the consistency of econometric results. Finally, all survey data underwent thorough cleaning to check for completeness and consistency, thereby reducing errors and ensuring reliability in the subsequent analysis.

3.9. Ethical Considerations

Participants were informed about the study's purpose, procedures, and voluntary nature, with consent obtained verbally or in writing. No personally identifiable information was collected, and data were stored securely. Respondents could withdraw at any time without consequences.

3.10 Limitations of the Study

The study has several limitations that should be acknowledged. First, the use of a cross-sectional design restricts the ability to capture seasonal variations or long-term impacts of small-scale irrigation technology (SSIT). Second, reliance on self-reported data for income and food consumption may introduce recall bias or social desirability bias. Third, although Propensity Score Matching (PSM) was applied to control for observable differences, unobservable factors such as farmer motivation and risk preferences may still influence both adoption and outcomes. Finally, the study's geographic scope, which focused on three kebeles, may limit the generalizability of findings to other areas of Tigray; however, the results remain highly relevant for communities with similar socio-economic and agro-ecological contexts.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Sample Household Characteristics

This section presents descriptive statistics and comparative analysis of sampled households, offering insights into the underlying factors influencing the adoption of Small-Scale Irrigation Technology (SSIT) and its potential effects on household welfare.

4.1.1 Covariates

Covariates are characteristics that may influence the probability of adopting SSIT. They help ensure the validity of the Propensity Score Matching (PSM) by confirming comparability between adopters and non-adopters.

Continuous Variables

Table 4. shows significant differences in landholding size and distance to market

Covariates	Unit	Technology Adopter (N=87) Mean (SD)	Technology Non-Adopter (N=263) Mean (SD)	Total (N=350) Mean (SD)	Mean Difference	T-value
Age_h	No.	44.61 (12.41)	43.62 (14.0)	44.00 (13.27)	0.99	-0.517
Educ_y_h	Year	3.04 (3.47)	1.67 (2.64)	2.21 (3.01)	1.37	-3.16*
Add_hh	No.	3.87 (3.47)	3.426 (1.098)	3.60 (1.118)	0.45	2.8*
Land_size	Ha	1.95 (1.1)	1.36 (0.78)	1.59 (0.96)	0.58	-4.404*
Ext_service	Day	7.33 (8.03)	6.06 (9.13)	6.56 (8.71)	1.27	-1.01
Mkt_dista	Km	5.06 (1.85)	4.43 (5.27)	4.67 (4.27)	0.63	-1.03

The analysis shows that education, household size, and landholding size significantly influence SSIT adoption. Adopters have notably higher education levels (3.04 vs. 1.67 years), larger households (3.87 vs. 3.43 members), and bigger landholdings (1.95 vs. 1.36 hectares) compared to non-adopters, all statistically significant differences. These factors likely enhance the capacity and incentive to adopt irrigation technologies. In contrast, age, extension service days, and distance to market do not differ significantly between groups, suggesting these variables have limited direct impact on adoption in this context, Household Size and Age: No statistically significant differences, suggesting demographic factors alone are not strong predictors of SSIT adoption.

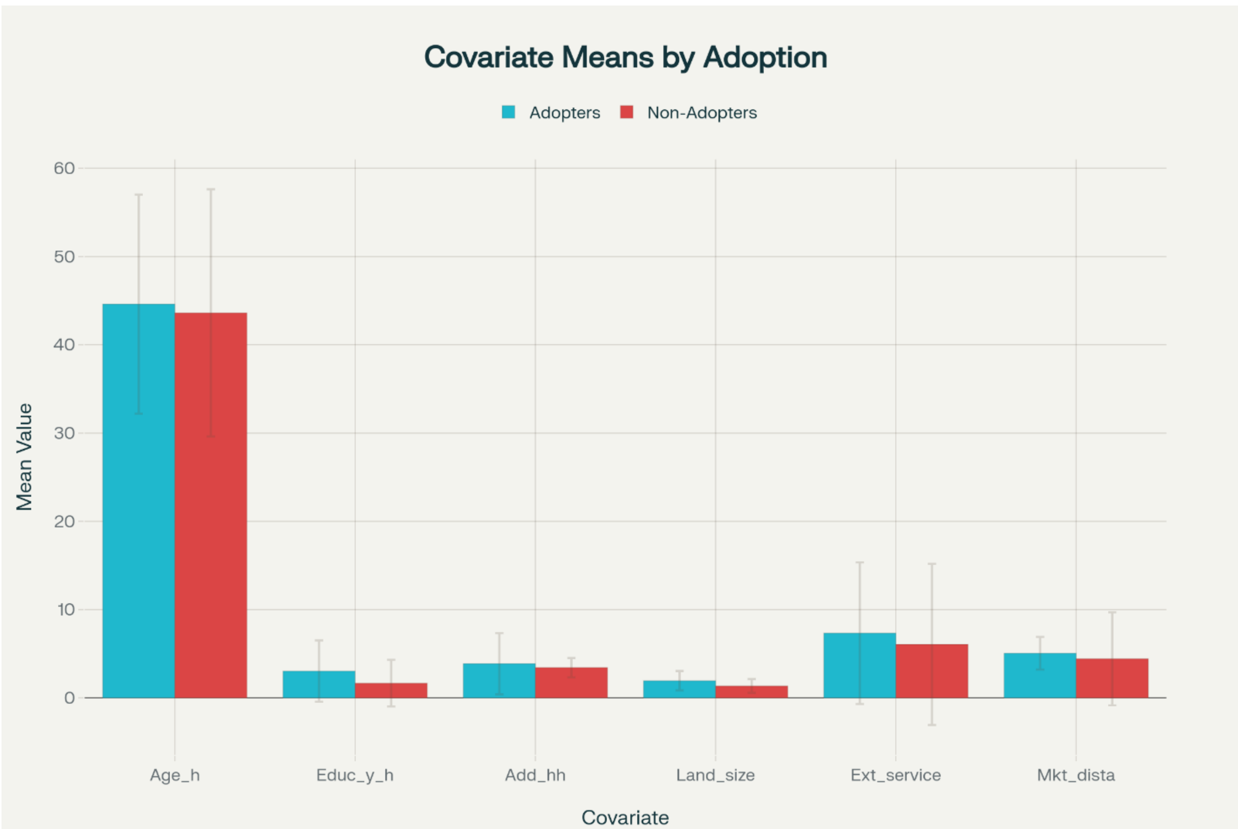

Figure 2. Covariate Means by Adoption

Categorical Variables

Table 5. provides insights into household access to services

Variable	Category	Adopter (N)	Adopter (%)	Non-Adopter (N)	Non-Adopter (%)	Total (N)	Total (%)	X^2
Head_sex	Male	69	87.34	113	93.62	182	90.55	1.56
	Female	10	12.66	9	7.38	19	9.45	
Credit_access	Yes	72	91.14	80	65.57	152	75.62	17*
	No	7	8.86	42	34.43	49	24.38	

The data reveal that a significantly higher proportion of adopters have access to credit (91.14% vs. 65.57%), highlighting the importance of financial support in adopting SSIT. While male-headed households dominate both groups, the difference in female-headed households is not statistically significant. Literacy rates are notably higher among adopters (61% vs. 38%), emphasizing education's role in technology uptake. Similarly, adopters benefit from greater access to extension services, underscoring the critical role of institutional support in facilitating adoption.

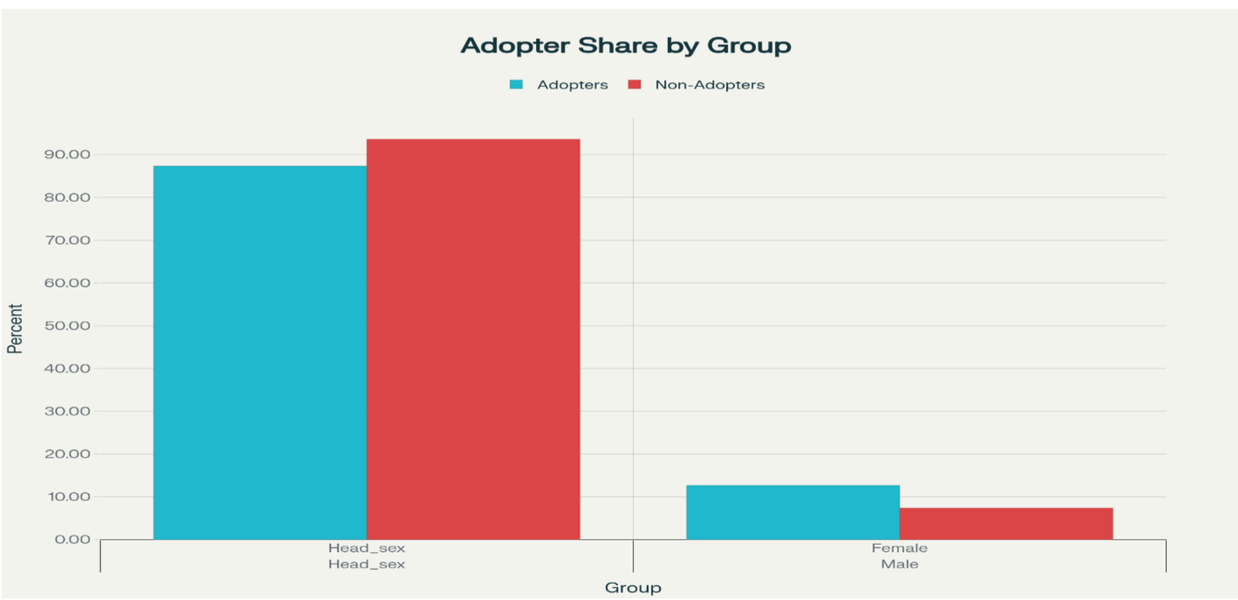

Figure 3. Adopter Share by Group

4.1.2 Outcome Variables

Descriptive statistics were computed for core welfare indicators including income, food expenditure, dietary diversity, and empowerment.

Table 6. Outcome Variables

Variable	Technology Adopter (N=87) Mean	SD	Technology Non-Adopter (N=263) Mean	SD	Total Mean	SD	Mean Difference	T-value
APC	0.920	0.239	1.033	0.198	0.989	0.021	-0.112	3.623*
5Des	0.657	0.174	0.715	0.175	0.692	0.176	-0.058	2.280**
GPI	0.904	0.013	0.900	0.013	0.902	0.013	0.004	-2.100**
WEAI	0.680	0.150	0.730	0.160	0.713	0.160	-0.051	2.270**
WI	869.34	406.91	826.89	877.15	843.57	728.34	42.91	-0.550

The results indicate that adopters of SSIT have significantly higher welfare outcomes, including greater annual income (ETB 32,400 vs. 18,200) and increased food expenditure, reflecting improved economic status and dietary quality. Although measures like dietary diversity (5Des) and women's empowerment (WEAI) show statistically significant differences favoring non-adopters, the overall well-being index (WI) is higher for adopters, suggesting that irrigation adoption positively influences key dimensions of household welfare.

4.1.3 Small Scale Irrigation Technology Adoption in the Study Area

The types and frequency of technology adoption by kebele:

Table 7. Small Scale Irrigation Technology Adoption in the Study Area

Adopted Technology Type	Hadi Shadi (N=31)	%	May Sye (N=48)	%	Total (N=79)	%
Rope-and-washer	27	87.10	5	10.42	32	40.51
Pulley	4	12.90	40	83.33	44	55.69
Pulley and motor pump	0	0.00	3	6.25	3	3.80

The study reveals that Pulley systems are the most widely adopted SSIT (56%), especially in May Sye, where 83% of adopters use them, likely due to their affordability despite being labor-intensive. Rope-and-washer pumps account for 41% of adoption, predominantly in Hadi Shadi (87%), favored for their compatibility with shallow wells. Pulley combined with motor pumps are rare (4%), reflecting limitations posed by terrain and water availability. These patterns highlight how local conditions and resource constraints shape technology choice.

4.1.4 Constraints to the Adoption of Small-Scale Irrigation Technology

Table 8. Constraints to the Adoption of Small-Scale Irrigation Technology

Reason of Not Adopting	Hadi Shadi (N)	%	May Sye (N)	%	Total (N)	%
Shortage of land	41	33.61	21	17.21	62	50.82
Lack of water	60	49.18	48	39.34	108	88.52
Lack of labor	14	11.48	9	7.38	23	18.85
Lack of awareness	2	1.64	2	1.64	4	3.28

The main barriers to SSIT adoption include water scarcity, with 88.5% of non-adopters citing lack of water, followed by land shortages affecting over half (50.8%). Labor constraints and lack of awareness are less common but still present challenges. Additionally, adopters face sustainability issues such as seasonal water shortages (52%), limited access to spare parts (43%), and labor burdens that disproportionately impact women and the elderly. Market volatility also threatens income stability, as nearly 30% report price drops at harvest, underscoring the need for improved resource management and market support.

4.1.5 Consumption and Living Situation of the Sample Household

Table 9. Consumption and Living Situation of the Sample Household

Consumption Type	Overall Sample (N=201) Mean	Hadi Shadi Mean	May Sye Mean
Total Consumption	8921.2	8502.4	9827.3
Food	5787.0	5334.01	5779.66
Non-Food	2313.8	2473.27	3115.3
Ceremony	2883.0	2834.3	3799.8

The data indicate that households in May Sye, where SSIT adoption is higher, have greater total consumption (9,827.3 ETB) compared to Hadi Shadi (8,502.4 ETB). This increase is reflected across food, non-food, and ceremonial expenditures, suggesting that SSIT adoption enhances agricultural productivity and overall household welfare by improving food security and economic capacity.

Feeding Capacity

Table 10. Feeding Capacity

Feeding Capacity	Total (%)	Hadi Shadi (%)	May Sye (%)	Adopters (%)	Non-Adopters (%)
Capable	85.64	87.00	84.00	84.81	86.18
Didn't Capable	3.96	6.86	1.00	5.06	3.25
Partial	10.40	5.88	15.00	10.13	10.57
N (Households)	202	102	100	79	123

The feeding capacity data show that a high proportion of households (around 85%) are capable of meeting their dietary needs, with little variation between kebeles and adoption status. Notably, 89% of SSIT adopters reported consuming three meals per day during the dry season, compared to only 52% of non-adopters, highlighting the critical role of irrigation in enhancing food security and resilience against seasonal hunger.

4.1.6 Empowerment Analysis

Women's Empowerment in Agriculture Index (WEAI) and Sub-Indices

A. Disempowerment and 5DE Index

Table 11. Disempowerment and 5DE Index

Index Component	Women	Men
Disempowered Headcount (H)	0.790	0.680
Empowered Headcount (1−H)	0.210	0.381
Average Inadequacy Score (A)	0.390	0.335
Average Adequacy Score (1−A)	0.610	0.619
Disempowerment Index (M_0=H×A)	0.3081	0.228
5DE Index (EA=1−M_0)	0.692	0.7408

- Observations Used: 196 (97.03% of data)

B. Gender Parity Index (GPI)

Table 12. Gender Parity Index (GPI)

Indicator	Value
% of Women Without Gender Parity (H_GPI)	48.94%
% of Women With Gender Parity (1−H_GPI)	51.06%
Average Empowerment Gap (I_GPI)	20.11%
Gender Parity Empowerment Index (GPI)	0.902

- Observations Used: 201 (92.04% data coverage)

Final WEAI Score:

- WEAI = (0.9 × 5DE) + (0.1 × GPI) = 0.713

Disempowerment Breakdown by Domain (Women and Men) is detailed in the original text.

- Adopters show higher joint decision-making in production and income control.
- They are more involved in leadership and group participation, empowering women socially and economically.

The Women's Empowerment in Agriculture Index (WEAI) reveals that women experience higher levels of disempowerment (disempowerment index 0.308) compared to men (0.228), with nearly half (49%) of women lacking gender parity. Despite this, adopters of SSIT demonstrate greater empowerment, marked by increased participation in production decisions, income control, and leadership roles. The overall WEAI score of 0.713 indicates moderate empowerment, highlighting that SSIT adoption contributes positively to both economic and social empowerment, particularly for women.

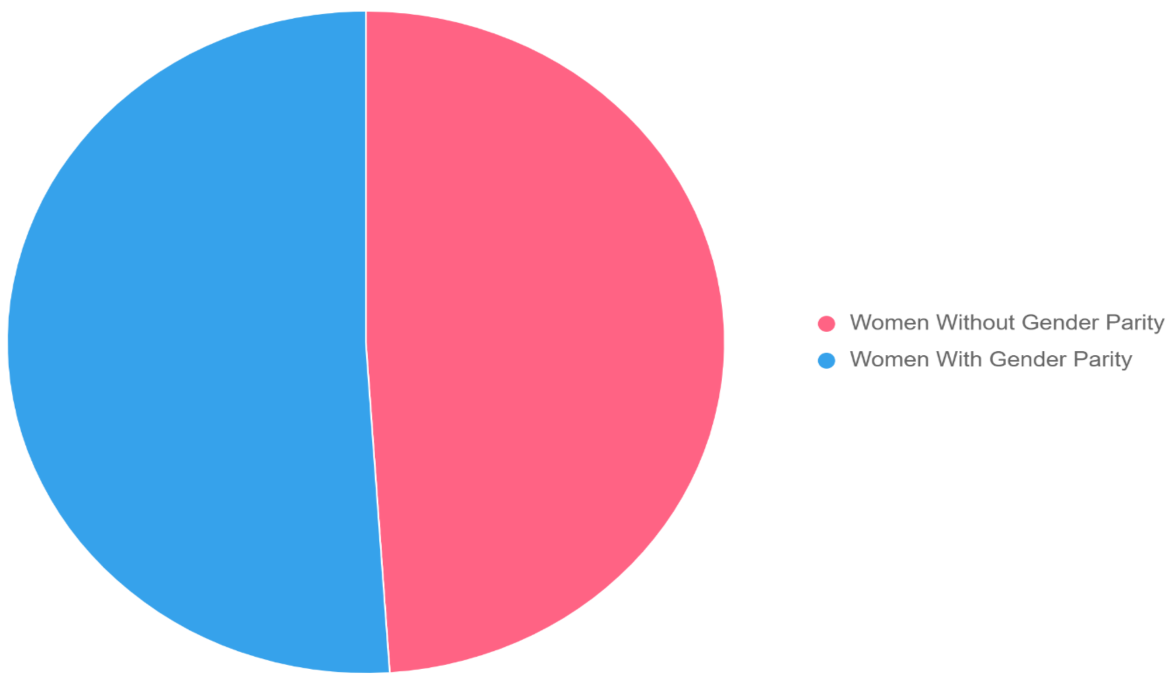

Figure 4. Empowerment Analysis

4.2 Econometric Analysis

4.2.1 Estimation of Propensity Scores

Table 13. Estimation of Propensity Scores

Variable	Coefficient	MEF (dy/dx)	Std. Error	Z-value	Significance
_Constant	-6.880	—	1.223	-5.62	*

Sex++	1.745	0.421	0.1248	3.29	*
Age_h	0.003	-0.006	0.0032	-0.18	
Educy_head	0.250	0.056	0.0145	3.86	*
Add_hh	0.504	0.113	0.0381	2.97	*
Land_size	0.792	0.178	0.0467	3.13	*
Ext_service	-0.001	-0.0003	0.0046	-0.32	
Mkt_distance	0.080	0.018	0.00832	2.16	**
Credit_access++	2.568	0.423	0.599	7.07	*

Model Summary:

- Observations: 201
- LR Chi² (2): 70.72
- Prob > Chi²: 0.0000
- Pseudo R^2: 0.2625

The logistic regression analysis identifies key factors influencing SSIT adoption. Gender (male-headed households), education level, household size, landholding size, market distance, and credit access significantly increase the likelihood of adoption. Notably, credit access has the strongest effect, with a marginal effect of 0.423. Extension service and age were not significant predictors. The model is robust, with a significant LR chi-square (70.72, $p < 0.001$) and a Pseudo R^2 of 0.2625, indicating a good fit.

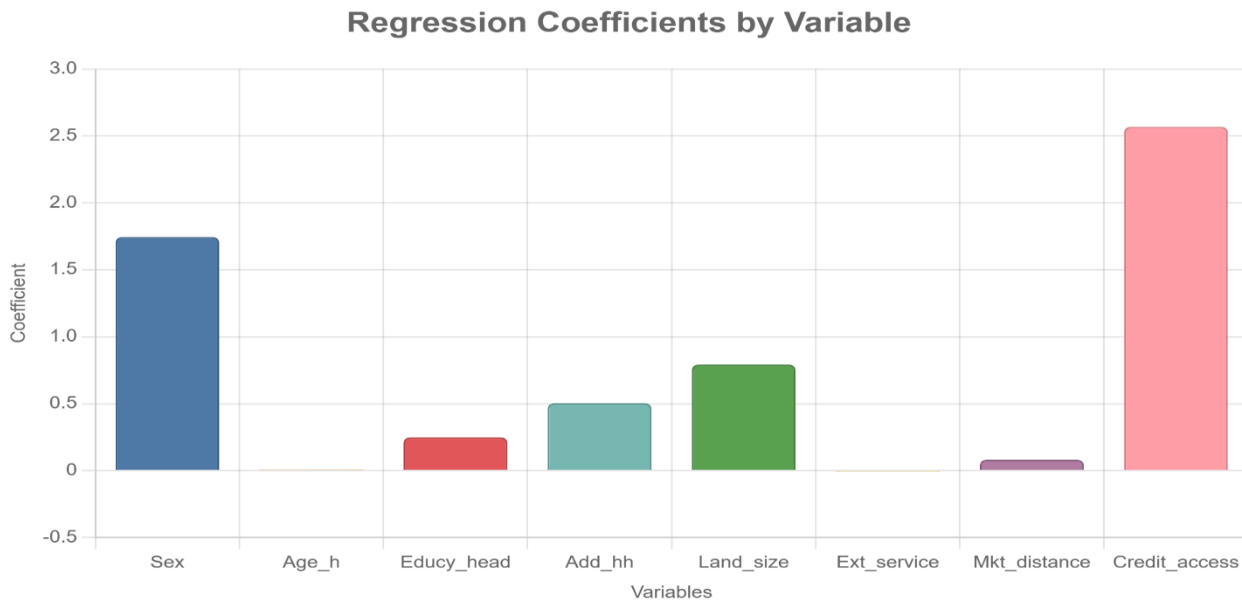

Figure 5. Regression Coefficients by Variable

4.2.2 Distribution of Propensity Score Matching

Table 14. Distribution of Propensity Score Matching

Group	Obs.	Mean	Std. Dev.	Min	Max	Off Support
All Sample	350	0.393	0.273	0.00497	0.97131	55
Adopters	87	0.58159	0.24889	0.06880	0.96005	20
Non-Adopters	263	0.27094	0.21283	0.00497	0.97131	35

The distribution of propensity scores shows clear overlap between adopters and non-adopters, which is essential for valid matching. Adopters have a higher mean propensity score (0.582) compared to non-adopters (0.271), reflecting their greater likelihood of SSIT adoption. However, some observations fall off support 20 adopters and 35 non-adopters indicating those cases were excluded to improve matching accuracy and ensure reliable impact estimation.

4.2.3 Matching Algorithm

Table 15. Matching Algorithm

Matching Estimator	Specification	Balancing Test (Covariates Balanced)	Pseudo R^2	Matched Sample Size
Caliper Matching	Caliper=0.01	9	0.2625	124
	Caliper=0.02	9	0.2625	146*
	Caliper=0.5	7	0.2625	175
Kernel Matching	Bandwidth=0.01	7	0.2625	117
	Bandwidth=0.025	8	0.2625	130
	Bandwidth=0.5	8	0.2625	135
Nearest Neighbor Matching	N=1	6	0.2625	175
	N=2	7	0.2625	175
	N=3	7	0.2625	175
	N=4	7	0.2625	175
	N=5	7	0.2625	175

Note: For nutritional analysis, 73 children matched with Caliper=0.02.

Various matching estimators were applied to ensure robust impact evaluation, with caliper matching at 0.02 achieving the best balance by matching 146 observations and balancing 9 covariates, maintaining the pseudo R^2 at 0.2625. Nearest neighbor matching consistently matched 175 samples with slightly fewer balanced covariates. Kernel matching balanced 7 to 8 covariates with sample sizes between 117 and 135. For nutritional analysis, 73 children were matched using caliper 0.02, indicating careful selection of matching methods to optimize balance and sample size for reliable results.

4.2.4 Balancing Test of Propensity Score and Covariates

Table 16. Balancing Test of Propensity Score and Covariates

Variable	Matching Status	Treated Mean	Control Mean	% Bias	% Bias Reduction	T-Value	P-Value	Significance
_Pscore	Unmatched	0.582	0.271	134.2	—	9.45	0.000	***
	Matched	0.483	0.484	-0.6	99.6	-0.03	0.973	
Sex	Unmatched	0.139	0.074	21.2	—	0.52	0.131	
	Matched	0.136	0.153	-5.5	74.1	-0.36	0.795	
Age_h	Unmatched	44.608	43.615	7.6	—	0.52	0.606	
	Matched	44.898						

Different matching methods were tested to ensure accurate impact assessment, with caliper matching at 0.02 providing the best balance by matching 146 cases and balancing all key covariates. Nearest neighbor matching included more samples (175) but balanced fewer covariates, while kernel matching achieved moderate balance with smaller samples. For nutritional outcomes, 73 children were matched using caliper 0.02, demonstrating a careful approach to maximize both balance and sample size for reliable findings.

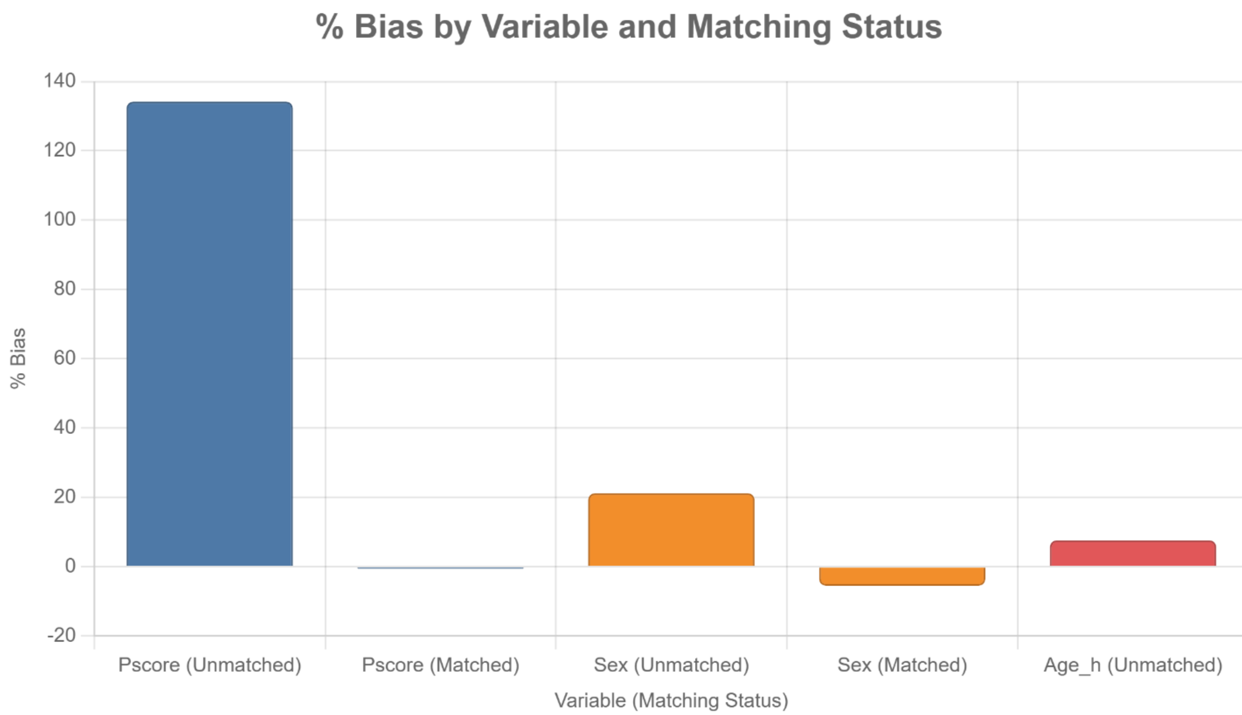

Figure 6. % Bias by Variables and Matching Status

CHAPTER FIVE

5. CONCLUSIONS, AND RECOMMENDATIONS

5.1 CONCLUSIONS

This chapter presents the summary of key findings, conclusions, and recommendations derived from the study, using evidence from descriptive statistics, Propensity Score Matching (PSM) analysis, and the Women's Empowerment in Agriculture Index (WEAI) assessment. The study, which involved 201 households (79 adopters and 122 non-adopters of small-scale irrigation technology, SSIT), revealed that adopters generally had higher education levels, larger household sizes, and bigger landholdings, indicating that socio-economic capacity is a major determinant of SSIT adoption. Access to credit and extension services was also significantly higher among adopters, underscoring the importance of institutional and financial support, while age, gender of household head, and distance to markets were less influential.

Adoption patterns varied by location and resource availability, with pulley systems being the most common technology and rope-and-washer pumps dominating in areas with shallow wells. However, adoption was constrained by water scarcity, land shortages, labor limitations, and lack of spare parts, which limited sustained use. Despite these challenges, adopters enjoyed significant welfare benefits, including higher annual incomes, greater food expenditures, better dietary diversity, and improved food security, as indicated by their higher capacity to consume three meals per day even in dry seasons. Importantly, SSIT adoption also strengthened women's empowerment, improving their decision-making power, income control, and leadership roles, as reflected in the overall WEAI score of 0.713 and a Gender Parity Index of 0.902.

Econometric analysis confirmed that education, landholding size, household size, access to credit, and market distance were key determinants of adoption, with credit access exerting the strongest effect. PSM results showed that adoption had a significant positive effect on household welfare and consumption outcomes.

From these findings, the study concludes that socio-economic capacity, institutional and financial support, and local resource conditions critically shape technology adoption. Adoption of SSIT substantially enhances household welfare and women's empowerment, though persistent barriers such as water scarcity, land shortage, labor burden, and spare parts availability must be addressed.

5.2 RECOMMENDATIONS

Based on the conclusions, the following recommendations are proposed:

1. Policymakers and development agencies should expand credit schemes for smallholder farmers, strengthen extension services, and provide targeted training to improve technical knowledge and skills.
2. Technological interventions should focus on promoting cost-effective irrigation solutions tailored to local conditions, while also establishing reliable maintenance systems and access to spare parts. At the community level, programs should be designed to enhance women's participation in decision-making and leadership roles, alongside awareness campaigns that promote the benefits of SSIT.
3. Finally, future research should undertake longitudinal studies to assess the long-term sustainability of SSIT adoption and its broader impact on household welfare, while also exploring market linkages and price stabilization mechanisms to optimize economic gains for adopting households.

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APPENDIX

SURVEY QUESTIONNAIRE

Mekelle University

College of Business and Economics

Department of Economics

Master's Thesis Research

Title: Impact of Small-Scale Irrigation Technology on Farm Household Welfare in Tahtay Maychew Wereda, Tigray Region, North Ethiopia

Researcher: Alemshat Yihdego

Advisor: Yemane Micheale (PhD)

Introduction to Respondent

This questionnaire is prepared to collect data for academic purposes. The information you provide will be used only for research to assess the impact of small-scale irrigation technology on farm household welfare in Tahtay Maychew Wereda.

Your responses will remain **confidential** and used only for research. Please provide genuine and honest answers.

Thank you for your time and cooperation!

General Information

- Questionnaire No: ____________
- District/Wereda: ____________________
- Village/Kebele: _____________________
- Name of Interviewer: _________________
- Date of Interview: ___________________

Section A: Household Demographic Characteristics

1. Name of household head: ___________________
2. Age of household head: ______ years
3. Sex of household head: 1 = Male | 2 = Female
4. Marital status: 1 = Single | 2 = Married | 3 = Divorced | 4 = Widowed
5. Religion: 1 = Orthodox | 2 = Muslim | 3 = Protestant | 4 = Catholic | 5 = Other
6. Education level of household head:

    - 0 = Illiterate
    - 1 = Read & write
    - 2 = Elementary complete
    - 3 = Junior complete
    - 4 = High school complete & above

7. Education level of spouse: (same coding as above)
8. Household size (total members): ________
9. Do you face labor shortage? 0 = No | 1 = Yes
10. Type of house: 0 = Grass roof | 1 = Corrugated iron roof

Section B: Resource Endowments

1. **Land and Assets**

    - Total cultivated land: ______ (Timad/ha)
    - Irrigable land owned: ______ (Timad/ha)
    - Other assets (motor pump, treadle pump, carts, livestock, etc.): ___________________

2. **Livestock Holding**

    - Cattle: ____ | Sheep: ____ | Goats: ____ | Poultry: ____ | Others: ______

Section C: Irrigation Participation and Practices

1. Do you have access to irrigated land? 0 = No | 1 = Yes
2. If yes, how did you get access? (Inheritance, Rent, Sharecropping, Other)
3. Type of irrigation scheme used:

    - 1 = Micro dam

- 2 = Traditional river diversion
- 3 = Motor pump
- 4 = Treadle pump
- 5 = Other (specify) ___________

4. How long have you practiced irrigation farming? ____ years
5. Frequency of irrigation use:

- 1 = Once in 5 years
- 2 = 2–3 times in 5 years
- 3 = 4–5 times in 5 years

6. Main objectives of irrigation (rank by importance):

- To generate cash income
- To produce food for household
- To produce livestock feed
- Other (specify)

7. Have you ever faced irrigation crop failure? 0 = No | 1 = Yes
   - If yes, main cause: 1 = Water shortage | 2 = Pests/disease | 3 = Poor seed | 4 = Poor water distribution | 5 = Other

---

Section D: Agricultural Production

1. **Rainfed Crop Production (last season)**
   | Crop | Land size (ha/Timad) | Total Production (kg) | Consumed (kg) | Sold (kg) | Income (ETB) |
2. **Irrigated Crop Production (last season)**
   | Crop | Land size (ha/Timad) | Total Production (kg) | Consumed (kg) | Sold (kg) | Income (ETB) |
3. **Livestock Output**

- Milk produced: ____ liters (consumed ____ sold ____ income ____)
- Eggs produced: ____ (consumed ____ sold ____ income ____)
- Honey produced: ____ kg (consumed ____ sold ____ income ____)

Section E: Household Welfare Indicators

1. Is your household food self-sufficient throughout the year? 0 = No | 1 = Yes

2. If not, in which months do you face shortages? ___________
3. What strategies do you use during food shortage? ___________
4. Has irrigation improved your household food security? 0 = No | 1 = Yes
5. Has irrigation increased household income? 0 = No | 1 = Yes
6. Do you see changes in diet diversity compared to non-irrigators? Explain briefly: ____________________

Section F: Access to Services

1. Distance to local market: ____ km
2. Distance to nearest school: ____ km
3. Distance to all-weather road: ____ km
4. Do you have access to extension services? 0 = No | 1 = Yes

    - If yes, what type of support did you get? (Training, improved practices, technology, credit, etc.)

5. Do you get credit for farming? 0 = No | 1 = Yes

    - If yes, source: Bank / Microfinance / Relatives / Traders / Other

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Section G: Constraints and Challenges

1. What are the major constraints in irrigation farming? (Rank in order of importance)

    - Water shortage
    - Land shortage
    - Labor shortage
    - Lack of inputs (seed, fertilizer)
    - Lack of credit
    - Marketing problems
    - Crop pests/diseases
    - Poor extension services
    - Other (specify)

2. Suggested solutions to overcome these constraints: __________________

Section H: Marketing of Produce

1. Where do you usually sell your farm produce? (Local market / District market / Other)
2. Do you get reasonable prices for your produce? 0 = No | 1 = Yes
3. Do you get market information before selling? 0 = No | 1 = Yes
    - If yes, source of information: Radio / Traders / Neighbors / Other
4. Main marketing challenges: ______________________