THE ROLE OF GENDER IN SMALL-SCALE IRRIGATION MANAGEMENT PRACTICES: THE CASE OF SMALLHOLDER IRRIGATED VEGETABLE PRODUCTION IN ZIWAY LAKE WATERSHED

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The Role of Gender in Small-Scale Irrigation Management Practices: The Case of Smallholder Irrigated Vegetable Production in Ziway Lake Watershed

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DECLARATION

I hereby declare that this Master Thesis entitled “**The Role of Gender in Small-Scale Irrigation Management Practices: The Case of Smallholder Irrigated Vegetable Production in Ziway Lake Watershed**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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RECOMMENDATION OF ADVISORS

we, the major and co-advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled "**The Role of Gender in Small-Scale Irrigation Management Practices: The Case of Smallholder Irrigated Vegetable Production in Ziway Lake Watershed**" repaired under my guidance by Tiringo Alie Zeleke submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Water Resource Engineering, Specialization in Irrigation Engineering.

Therefore, we recommend the submission of the revised version of the thesis to the department following the applicable procedures.

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APPROVAL SHEET

We the advisors of the thesis entitled "**The Role of Gender in Small-Scale Irrigation Management Practices: The Case of Smallholder Irrigated Vegetable Production in Ziway Lake Watershed**" by Tiringo Alie, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Tiringo Alie Zeleke have read and evaluated the thesis entitled "**The Role of Gender in Small-Scale Irrigation Management Practices: The Case of Smallholder Irrigated Vegetable Production in Ziway Lake Watershed**" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Water Resource Engineering, Specialization in Irrigation Engineering.

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Finally, approval and acceptance of the thesis are contingent upon the submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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ACRONYMS/ABBREVIATIONS

A.T.J.K	Adami Tulu Jido Kombolcha
Ec	Conveyance efficiency
ETB	Ethiopian birr
ET_o	Reference evapotranspiration
FGDs	Focus group discussions
FHHs	Female-headed householders
ha	Hectares
IMO	Irrigation management organization
IWUA	Irrigation Water User Associations
kg	Kilogram
kg per ha	Kilo gram per hectare
KIs	Key informants
L	Litre
MHHs	Male-headed households
Mha	Million hectares
N	Number of respondents
NGOs	Non-governmental organizations
No	Number
POLKA	Policy Learning, Local Knowledge and Advocacy
s	Second
SPSS	Statistical Package for Social Science
SSI	Small scale irrigation
WUAs	Water user associations
%	Percent

ABSTRACT

Irrigation management practices involve strategies and techniques designed to optimize water resource use for agricultural purposes. In the smallholder irrigated vegetable-producing areas of the Ziway Lake Watershed, understanding the role of gender in irrigation management is essential for development of sustainable and equitable agricultural development. Gender significantly influences various aspects of agricultural systems, including decision-making, resource access, and irrigation practices. However, research on the role of gender in small-scale irrigation management across Ethiopia remains limited. This study examines the role of gender in irrigation management practices among smallholder farmers in the Ziway Lake Watershed. The research aimed to assess and characterize the performance of irrigation management organizations, evaluate gender roles in irrigation practices, and conduct a gender-based performance analysis of small-scale irrigated farms. Data were collected from both primary and secondary sources through a field study conducted from February to September 2024. A total of 313 smallholder vegetable producers participated in the study, with data gathered through questionnaires, focus group discussions with water user association representatives, and key informant interviews with local authorities and development agents. Detailed case studies were conducted on two male-managed and two female-managed farms. Data analysis was performed using SPSS (version 27) and Excel. The findings revealed that irrigation management in the study area is governed by water users' associations. Significant gender disparities were observed in responsibilities, resource access, and decision-making processes between male and female farmers. Productivity assessments showed that male-managed cabbage farms produced 232.9 quintals per hectare, while female-managed cabbage farms yielded 252.6 quintals per hectare. For onion crops, male-managed farms achieved a yield of 220 quintals per hectare compared to 130 quintals per hectare for female-managed farms. The results indicated that vegetable productivity was influenced more by on-farm practices and inputs than by gender disparities. In conclusion, gender plays a critical role in shaping irrigation management practices within the Ziway Lake Watershed. Addressing inequalities in resource access and decision-making is essential for improving water use efficiency and promoting sustainable agricultural practices among smallholder farmers.

Keyword: Ziway Lake Watershed; Role of gender; Small-scale irrigation

1. INTRODUCTION

1.1 Background

Throughout the world, irrigation is appreciated because of its huge contribution to agricultural production, food, and nutrition security, combating poverty, and enhancing development, especially in rural areas (Muchemwa-Munasirei, 2018). Agriculture is the leading sector of the Ethiopian economy as well as the overall economic growth (Ahmed, 2019). Irrigation in Ethiopia is considered a basic strategy to alleviate poverty and hence improve food security (Ahmed, 2019). Irrigation as an agricultural intensification plays a crucial role in increasing agricultural production and productivity (Ahmed, 2019).

Consideration of gender imperatives would help define and structure who uses water, when, and how (Muchemwa-Munasirei, 2018). Women are major contributors to household and national food security, particularly in irrigated areas (Kalkidan, 2016). Women indicate that if they formally participate in water institutions, they would achieve better status and respect in society. Additionally, other benefits include greater knowledge of water management, the ability to change rules that limit their participation, and better water management (Khandker et al., 2020). Most of the time, female-headed irrigation users are more involved in management activities such as planting, removing weeds, hoeing, and harvesting while male headed participate in heavy and risky tasks such as land clearing, cultivation, crop watering, chemical spraying, and transporting agricultural products (Fikirie et al., 2016). However, there is limited knowledge about how gender impacts irrigation management practices.

Water use efficiency in irrigated agriculture remains to be a critical challenge in many instances (Kang et al., 2011). By supporting sustainable and efficient water and land resource management, irrigated agriculture has the potential to meet the challenges of the growing global population and climate change. In sub-Saharan Africa, the majority of smallholder irrigation schemes have difficulties or lack adequate irrigation water management systems and skills (Muchemwa-Munasirei, 2018). Inefficient water use not only wastes a valuable resource but also leads to reduced crop productivity. Ethiopia's urban population is rapidly expanding due to a high rate of rural-urban migration combined with overall population growth (Kassa & Andualem, 2020). Ethiopia possesses 5.3 million hectares (Mha) of potential land for irrigation which 3.7 Mha can be developed using surface water sources and 1.6 Mha with groundwater and rainwater management (Awulachew & Ayana, 2011).

Global experiences demonstrate that government organizations managing irrigation place a significant financial strain on governments, and irrigation performance has sometimes fallen short of expectations (Langan, 2016). Without the proper organizations to manage, maintain, and operate the systems, irrigation systems cannot achieve their intended goals (Langan, 2016). An Irrigation Water User Association (IWUA) is a collective organization formed by water user farmers and other stakeholders who share and manage irrigation water resources for agricultural purposes. The recent IWUA announcement in Ethiopia, which suggests that participation in the plan be required of all water users (Wang & Wu, 2018). WUAs have been created by government financing but they are responsible for ensuring the collection of water fees as well as service-related fees for infrastructure maintenance (Mahdhi et al., 2014). However, their performance is found to be low due to capacity limitations and a lack of enforcement mechanisms for their by-laws. Ziway Lake Watershed is one of the major agricultural potential areas where smallholder farmers primarily depend on irrigation to produce vegetables. The Meki and Katar rivers, which drain the western and eastern plateaus, respectively, supply the majority of the water to Lake Ziway (Cergy, 2019).

Smallholder irrigators commonly use traditional or modern small-scale irrigation systems. In the Ethiopian context, the small-scale irrigation system is an irrigable land area of less than 200 hectares of modern/communal schemes. These schemes are typically constructed and managed by the user groups themselves, who are primarily smallholders (Wudineh Feleke, 2017). One of the main factors affecting the performance of smallholder irrigation programs is farmer engagement (Muchemwa-Munasirei, 2018).

The majority of smallholder farmers lack access to irrigation technologies (Tesfaye et al., 2021). Utilizing improved production packages, such as high-yielding vegetable varieties, better seeds, ideal sowing rates, spacing, tillage, and irrigation frequency, is necessary to increase the production of vegetable crops (Etissa et al., 2014). Performance indicators of agricultural productivity could be production per unit irrigation area, production per unit command area, production per unit water supply, and production per unit irrigation supply (Moges, 2022b). An effective irrigation management system reduces water usage while boosting agricultural productivity (Olwal et al., 2020). To promote inclusive and sustainable water management methods that address the demands and challenges experienced by both men and women must be addressed. This study aimed to analyze the effectiveness of irrigation management organizations, the role of gender in irrigation management practices, and to understand the performance of gender in small-scale irrigation practices.

1.2 Statement of the problem

Ethiopia is experiencing frequent food crises due to population growth, land degradation, and increasing droughts. Despite the availability of water resources, suitable climate, and low-cost labor for irrigation, many projects underperform, and gender participation is limited. This has resulted in inefficiencies and inequities in water management, disproportionately affecting female-headed households (Awulachew et al., 2010; Smur & Teka, 2021)**.** The abstraction of water is done randomly as they went and the management is low due to this the loss of water is very high and water distribution is not equitable and female-headed households are suffering water shortage. Although the loss of water and the performance of the irrigation project have not been studied still there is no coherent and reliable record and detailed-studied document on the performance of the project in the study area.

Water users for irrigation were organized into hundreds of associations depending on their localities. It was always a common concern whether female-headed households were appropriately included in the membership and management positions where they could make decisions on access to and management of resources. However, there is a shortage of baseline data for the development of the WUA and to measure an increase in the performance of organizational structures.

Gender disparities significantly affect irrigation management outcomes such as access to resources, decision-making power, economic outcomes, and participation in agriculture. Limited studies have applied to the Role of Gender in Small-Scale Irrigation Management Practices in different areas of Ethiopia using different indicators. Female-headed households face barriers to resource access and decision-making, resulting in lower crop yields and reduced incomes. Research indicates that women have limited access to resources, credit, and market opportunities, which affects their ability to participate effectively in irrigation agriculture (Fikirie et al., 2016; Smur & Teka, 2021)**.** The current literature lacks comprehensive data on these dynamics, hindering effective policy and project development. However, the role of gender and the performance of Ziway Lake watershed small-scale irrigation has not been still covered. This study aimed to address these gaps by assessing the role of gender in irrigation management and evaluating the performance of small-scale farms. It utilized various methods, including interviews, questionnaires, and focus group discussions, to gather relevant data. The results from this study help local decision-makers and stakeholders.

1.3 Objectives

1.3.1 General objective

The main objective was to study the role of gender in small-scale irrigation management practices in smallholder irrigated vegetable-producing areas of the Ziway Lake watershed.

1.3.2 Specific objectives

i. To assess, characterize and evaluate the performances of irrigation management organizations.

ii. To examine the role of gender in shaping irrigation practices, decision-making processes, and the productive use of resources for food production

iii. To conduct a gender-based performance evaluation of small-scale irrigated farms in terms of crop yield, resource access, and income generation.

1.4 Questions

i. How was the irrigation management organized and what was the level of its performance?

ii. What was the extent of gender participation in irrigation management and decision-making processes?

iii. Was there a gap in maintenance and operation activities, productivity, and resource use efficiency gap between male-headed and female-headed households within small-scale irrigation farms?

1.5 Significance of the study

This study has significant potential to improve the effectiveness and sustainability of small-scale irrigation in the Ziway Lake watershed by ensuring equitable participation and resource utilization for both men and women. The importance of examining how gender would influence irrigation management strategies in smallholder irrigated vegetable production areas around the Lake Ziway watershed was multifaceted. The study contributes to the understanding of gender inequality and the obstacles faced by women, highlighting the importance of programs that promote women's empowerment and gender equality in the workplace. By analyzing gender-specific opportunities and constraints, the research contributes to the creation of more sustainable and inclusive resource management practices in the Lake Ziway watershed. In addition, the evaluation of local community attitudes about sustainable environmental practices and resource use can inform the policy-makers to design eco-friendly farming practices. The findings of this study are beneficial for gender equality, organizational improvement, resource optimization, environmental sustainability, and informed decision-making in irrigation management practices.

By conducting this research on the role of gender in irrigation management practices, it is possible to gain a better understanding of the challenges and opportunities faced by female vegetable growers. Generally, farmers who lived in the Ziway Lake watershed area enjoyed many benefits, but there were still many farmers, especially women, living at the lowest levels of livelihood. To understand and address this issue, a study was conducted on the role of gender in irrigation management practices within smallholder irrigated vegetable-producing areas of the Ziway Lake watershed, specifically the performance of irrigation management organizations, the role of gender in defining irrigation practices and gender-based performance evaluation of small-scale irrigation farms.

1.6 Scope and limitation of the study

The research focused on the smallholder irrigated vegetable-producing areas around the Ziway Lake Watershed. The study analyzed the role of gender in the practices of managing irrigation specifically within this geographical context. Adopting a gender perspective, the study aimed to investigate how gender influenced decision-making, resource utilization, and market involvement in smallholder vegetable production. With an organizational focus, the study evaluated the irrigation management organizations operating in the research area, examining their organizational structures, policies, bylaws, and performance, with a specific emphasis on gender inclusion. Additionally, the study explored the relationship between resource usage for food production and environmental sustainability.

The study was conducted in an environment characterized by male-dominated land ownership, which significantly reduced the number of female farmers available for selection. This structural barrier limits the representation of female perspectives and experiences in irrigation practices. Therefore, this issue was addressed by gathering responses from male-headed households, as well as including female farmers to understand the challenges faced by both groups in participating in irrigation management practices. In this context, male-headed households were aware of the situations concerning female farmers and the surrounding environments in their communities.

The data collection occurred during a season when female farmers were notably absent from the fields. The sample included only four farms two managed by female-headed households and two by male-headed households resulting in a limited sample size that restricted the ability to draw broader conclusions about gender dynamics in irrigation management across the study area. This problem was solved by interviews from the previously filed practices to enhance accuracy. These limitations highlight the need for further research with a larger, more diverse sample to fully understand the role of gender in irrigation management practices and to develop strategies that promote equitable participation, decision-making, resource utilization, income generation.and resource access .

2 . LITERATURE REVIEW

2.1 Irrigation management and practices

Water is the most essential resource for the production of agricultural goods and services (Nazari et al., 2018). Irrigation management involves the efficient and effective use of water to meet the irrigation needs of crops while minimizing water loss and optimizing crop production. Comprises the carefully controlled application of water to crops, typically in addition to natural rainfall, to compensate for insufficient or erratic precipitation. It is impossible to overstate the role that farming plays in ensuring food security, improving nutrition, creating jobs, and reducing poverty in Africa (Agula et al., 2018). A cornerstone of irrigation reforms for at least 40 years has been participatory irrigation management, in which farmers take on greater accountability for the management of surface water in centrally controlled irrigation systems (Cooper et al., 2023).

2.2 Gender and irrigation management

Gender refers to the societal distinctions that exist between men and women, particularly in the context of their respective duties, responsibilities, and interpersonal relationships (Muchemwa-Munasirei, 2018). It plays a significant role in shaping access to and control over resources, decision-making processes, and participation in agricultural activities. Most agricultural roles are defined by gender (Carnegie et al., 2020). Most women recognize that their work burden is increasing, but many refer to their new farming roles and identities with pride and joy (Leonardelli, 2023). Ways to increase female participation in technical learning are discussed, but the most basic measure may be to address the underlying gender norms that prescribe gender roles in the household, on the farm, and in the community, which are the source of female farmer disadvantage (Carnegie et al., 2020). The importance of gender norms in agricultural innovation processes has been recognized. However, the operational integration of these normative issues into the innovation strategies of agricultural interventions remains challenging (Lopez et al., 2022).

2.3 Irrigation Performance in Ethiopia

2.3.1 Performance of irrigation management practices

The performance of irrigation management practices in Ethiopia can vary depending on various factors, including the specific region, infrastructure, resources, and management approaches. The main cause of the majority of Ethiopia's small-scale irrigation schemes' poor performance is inadequate management of irrigation water coupled with water constraints (Yohannes et al., 2017). Efficient water use is a critical aspect of irrigation management. However, in some cases, the performance of irrigation systems in Ethiopia may be hampered by challenges such as outdated technology, poor maintenance, inadequate training, and limited access to irrigation water. These factors can lead to water losses, inefficient water distribution, and suboptimal crop yields. While irrigation expansion remains crucial, equal attention must also be paid to the operational management and poor performance of currently operating irrigation projects (Gebul, 2021).

2.3.2 Irrigation management organization

2.3.2.1 Organizational structure

The Ethiopian Government considers irrigated agriculture as a primary engine of economic growth and has plans to increase the current level of irrigation infrastructure threefold by the end of 2015. However, there have been increasing concerns regarding the performance and management of existing small-scale irrigation (Amede, 2015). It must be the responsibility of government institutions under their legal mandate from top to bottom structures to support and coordinate all stakeholders to best protect Lake Ziway and its watershed (Desta et al., 2017a).

The Water User Association (WUA) is a user-based organization that aims to manage the irrigation system for its members mostly on a nonprofit basis. A WUA is generally small in scale with a limited number of members (usually no more than several hundred members), so self-management by users is possible. The actual size of a WUA often depends on the irrigation system (Moges, 2022a). To support the establishment and operation of irrigation water users' associations, the Ethiopian government enacted Proclamation No. 841/2014. Reducing the financial burden of operating and maintaining irrigation systems can be achieved by shifting irrigation management from government agencies to farmer organizations like IWUA (Langan, 2016). Factors influencing WUA's effectiveness include governance structure and institutional rules (Wang & Wu, 2018). There is no coordination or promotion initiative in place by government institutions to get local farmer communities, private companies, fishers, and non-governmental organizations involved and working closely with local, regional, and federal government institutions toward the lake and its watershed management. These organizations rely on user fees to fund the operation of massive water networks and modern irrigation services, with potential support from local or national governments (Ağizan et al., 2024).

The availability of funding, community support and involvement, efficient organizational coordination and communication, the management team's expertise, adequate technology, and infrastructure are some of the elements that determine an association's success (Ağizan et al., 2024). Two types of irrigation institutions are IWUAs and cooperatives, over 30% of schemes lacked institutions, and membership is higher in traditional schemes than in modern or semi-modern (Yohannes et al., 2022). Water User Associations (WUAs) aim to enhance irrigation system efficiency (Wang & Wu, 2018). According to Mahdhi et al. (2014), WUAs are tasked with the responsibility of collecting water and service fees, which underscores their importance in ensuring the sustainable use of water resources. This growing network of WUAs not only facilitates efficient irrigation practices but also promotes accountability among users in the management of shared water resources.

WUAs are responsible for managing irrigation services and hydraulic networks, as well as supplying and delivering irrigation water to farmers in various agricultural regions. The performance of an irrigation management organization (IMO) on the ground refers to how effectively and efficiently the organization carries out its responsibilities in managing irrigation systems and water resources. It involves the actual implementation and outcomes of the IMO's activities in the field. The effectiveness of institutional and other systems is significantly influenced by the broader social and cultural milieu in which they operate (Lefore et al., 2019). To support the establishment and operation of irrigation water user associations, the Ethiopian government enacted Proclamation No. 841/2014.

2.3.2.2 Gender Participation

Farmers with limited resources have even less access to land, and water input supply services due to the absence of institutions for the shared management of natural resources (Lefore et al., 2019). This absence creates barriers for these farmers, making it increasingly difficult for them to access the resources necessary for sustainable farming practices. By offering training on loan evaluation and monitoring to lower transaction costs and risk, public-sector institutions and development groups can facilitate more lending to irrigators (Lefore et al., 2019). Public-sector institutions and development groups have a crucial role in alleviating some of these challenges. By offering training on loan evaluation and monitoring, they can help reduce transaction costs and risks associated with lending to irrigators. Another significant aspect of this case study is the low inclusion of women in decision-making bodies of Water User Associations (WUAs). Low inclusion of women in WUA decision-making bodies, hinders social equity (Khandker et al., 2020). Institutional facilitation exists, but the impact on enhancing women's participation is weak (Khandker et al., 2020). Efforts are needed to enhance women's involvement in water institutions for better outcomes (Khandker et al., 2020). By actively engaging women in decision-making processes, communities can benefit from diverse perspectives and foster more equitable resource management practices.

2.3.2.3 Policies and bylaws

According to Desta et al. (2017a), these claims provided policymakers with essential insights into challenges faced by local farming communities. This understanding enables the development of sustainable long-term plans to protect the lake and its watershed from further serious problems. A unified policy in the form of legislation is more effective in preventing pollution of lakes, rivers, and ponds than individual and group efforts. This is because legal authorities ensure the regulation and enforcement necessary to protect water resources effectively. Legal provisions to water resources management are issued by the Federal Democratic Republic of Ethiopia in the Ethiopian Water Resources Management Policy (1999), Ethiopian Water Resources Management Proclamations No 197/2000, Water Resources Management Policy (1999), Proclamations No 197/2000 and Regulation No 115/2005, and other related policies and regulation. Conflicts between farmers and irrigation groups typically arise when the agreed-upon irrigation services are not provided following the agreement or the water distribution regulations, and when the deliveries are not honored (Langan, 2016).

2.4 The role of gender in irrigation management practices

2.4.1 Resource use

In the study area, male-headed households (MHHs) own an average of 2.27 hectares of land, while female-headed householders (FHHs) own an average of 1.4 hectares. Although these figures seem to exceed the national average of landholding (Fikirie et al., 2016), a significant disparity between male and female land ownership remains evident. Young farmers in productive age groups are likely to be more productive (Dossah & Mohammed, 2016). Factors affecting vegetable production are farm size, labor, seed, and fertilizer (Dossah & Mohammed, 2016). Both MHH and FHH encounter constraints like access to credit and market as well as limited training opportunities to enhance irrigators' skills (Kalkidan, 2016). However, addressing gender disparities in education, training, and extension services is essential for promoting more equitable resource use. Effective and sustainable irrigation management practices. Women had less access to irrigation water than men (Sinyolo & Mudhara, 2018). Limited access to resources, services, and decision-making opportunities for women hinders their participation and empowerment in irrigation interventions (Nigussie et al., 2023).

2.4.1 Decision-making

Gender norms influence women's access to decision-making positions in irrigation water management and impact their participation (Muchemwa-Munasirei, 2018). Men are the main decision-makers in households and women have some decision-making power as dependents (Carnegie et al., 2020). Gender mainstreaming strategies, such as rule-based participation and gender-responsive approaches, can enhance women's inclusion and empowerment (Nigussie et al., 2023). Women are involved in farming and water management decisions together with men but not independently (Khandker et al., 2020). Limited women's participation in the decision-making process restricts the potential benefits of effective water management (Khandker et al., 2020). Male dominance in decision-making, lack of confidence, and need for spousal permission are the main challenges preventing women's participation (Khandker et al., 2020).

2.4.2 Market participation

Markets and inputs are needed for irrigated agriculture to be profitable. Many barriers, such as high investment prices, the lack of financial services, poor market integration, insufficient information services, inadequate extension service, and labor constraints, limited equity in access to water management technologies and practices (Lefore et al., 2019). Price fluctuation due to the oversupply of similar crops in a season negatively affects the income of irrigators (Kalkidan, 2016). Moreover, a lack of coordination among vegetable producers affects pricing, market problems impact the timely delivery and quality of products (Fikirie et al., 2017). Female-headed users have better access to selling products (Fikirie et al., 2017).

2.4.3 Technology adoption

Most of the developing economies are characterized, inter alias, by heavy dependence on the agricultural sector, traditional type of farm practices, higher labor-to-capital ratio, low adoption rate of technology and farm inputs, poor infrastructure facilities including roads, transport, marketing, etc. and low farm productivity (Hailu & Mengistu, 2022). New or modern technology in the irrigated agricultural sector can substantially improve agricultural production and sustainability (Abdul Rehman et al., 2017). Modern agricultural technology has been developed with two key objectives in mind: maximizing crop yield and achieving the highest economic profit possible (Abdul Rehman et al., 2017). Irrigated agricultural technologies refer to a variety of methods, systems, and tools designed to manage and optimize water use for agriculture and other inputs like improved crop varieties and agrochemicals. The majority of smallholder farmers do not yet have access to supplementary water management technologies (Lefore et al., 2019). The modern technologies adoption in developing countries is limited due to several issues ranging from strategic to operational level (Javaid & Rab, 2023). Education level influences irrigation technology adoption (Smur & Teka, 2021). This suggests that higher levels of education lead to a greater understanding of technology's benefits, resulting in quicker adoption.

The adoption of agricultural innovation in developing countries attracts considerable attention because it can provide the basis for increasing production and income (Hailu & Mengistu, 2022). The adoption of these modern technologies is extremely challenging (Javaid & Rab, 2023). The majority of irrigation users applied watering by motor pump since technically pump operation is difficult for women (Fikirie et al., 2016). Operating motor pumps typically requires technical knowledge and physical strength. Cultural norms and expectations can also limit women's roles in technical fields, further exacerbating this issue.

2.5 Irrigation development

Irrigation performance in developing nations generally, and in Ethiopia specifically, is still low (Adane, 2020). Irrigation development has been slow in these countries and has been mainly through traditional schemes (Nakawuka et al., 2018). Recently, individual irrigation technologies such as small motorized pumps, drip kits, treadle pumps, and rope and washer pumps have been promoted (Nakawuka et al., 2018). Adoption of these technologies and expansion of smallholder irrigation, however, face several challenges including land tenure issues; lack of access to appropriate irrigation technologies, improved agricultural inputs, reliable markets, finance and credit services, and research support; poor transport and communication infrastructures; poor irrigation water management; poor extension systems;

and the over-dependence on national governments, NGOs, and donors for support (Nakawuka et al., 2018). The primary goal of irrigation development is to supplement natural rainfall by providing water to plants during dry periods or in regions with limited water availability. Agricultural fields and settlement areas jointly grew from 57 % of the watershed's total area in 1973 to 75 % in 2014, while the extent of forests declined from 26.16 % to 6.63 % (Desta et al, 2017).

2.6 Environmental sustainability

Environmental sustainability refers to the practice of using natural resources in a way that preserves the ecological balance and meets the needs of present and future generations. This requires an integrated and holistic approach to the use and development of natural resources for specific purposes. Understanding the interconnectedness of natural system components is crucial, as the impact or overuse of one component can have significant consequences on others. For instance, over-extraction of groundwater can lead to soil degradation and diminished water availability for ecosystems, while excessive abstraction of lake water can result in the depletion of the lake, causing the loss of vital socio-economic benefits. Because of soil erosion, Lake Ziway's sedimentation level is rising with time, and finally, the lake's depth has dropped (Negasa, 2023). Risks to environmental and human health from accelerated irrigation investments (Lefore et al., 2019). These land use land cover changes and their effects on the natural conditions of the lake are mostly caused by human influences, including deforestation, changes in land use policies, and population increase (Desta et al., 2017). The root reasons for the observed changes in the watershed resources are growing demands for more land and water resources, such as land for agriculture and habitation, wood for fuel and charcoal, and water for irrigation and municipal water supplies (Desta et al., 2017). The amount and quality of water have decreased, making the watershed's water scarcity the highest it has ever been (Negasa, 2023).

Sustainable land management and reforestation efforts can help sequester carbon dioxide from the atmosphere. Environmental sustainability requires minimizing pollution and its adverse impacts on ecosystems and human health. The efficiency with which these resources are used influences farm profits, but the environmental footprint of a farm is also impacted by their production or diversion from other uses (German et al., 2017). To prevent human influences on Lake Ziway's coastal areas and to facilitate investment projects for the lake's environment management, government entities at all levels have not yet established buffer zones (Desta et al., 2017a).

2.7 Performance evaluation of small-scale irrigated farms

2.7.1 Small-scale irrigation management practices

Small-scale irrigation systems are either traditional or modern owned and operated by smallholder farmers. Their management encompasses techniques and strategies employed to effectively manage and utilize water resources for agricultural purposes on a small scale. These practices aim to optimize water use efficiency, increase crop yields, and sustainably manage water resources. The achievable average water application efficiency is 65% for surface irrigation methods (Kang et al., 2011). However, under Ethiopian practices, the surface irrigation efficiency is below this value. The main cause of irrigation schemes' poor performance is poor management of irrigation water coupled with water shortages (Yohannes et al., 2017). While irrigation expansion remains crucial, equal attention must also be paid to the operational management and poor performance of currently operating irrigation projects (Gebul, 2021).

2.7.2 Water productivity in small-scale irrigation (SSI) schemes

Productivity is the ratio between of output and a unit of input. The performance of smallholder irrigation schemes is challenged by several factors: among which water insecurity and low land and water productivity are the main ones (Haileslassie et al., 2016). Increasing water productivity is an important element in improved water management for sustainable agriculture, food security, and healthy ecosystem functioning (Descheemaeker et al., 2013). Crop water productivity denotes the amount or value of the product (i.e., crop) over the volume or value of water used depleted, or diverted. Improving water productivity is crucial for sustainable water management, especially in regions facing water scarcity or competing water demands. Water productivity is used exclusively to denote the amount or value of the product over the volume or value of water used depleted or diverted (Upadhyaya, 2019). Crop water productivity varies with location, depending on such factors as cropping patterns, climatic conditions, irrigation technology, field water management and infrastructure, labor, fertilizer, and machinery inputs (Kijne et al., 2003).

2.7.3 Gender participation in SSI management practices

Gender differences impact farm productivity (Dossah & Mohammed, 2016). The roles, duties, resources, and priorities of men and women in the context of small-scale irrigation water use are impacted by several social, economic, political, cultural, and environmental issues (Muchemwa-Munasirei, 2018). Understanding the gender dynamics in small-scale irrigation management practices can help to identify opportunities for improving the efficiency and effectiveness of irrigation systems. Small-scale irrigation significantly increased income for women-headed households in Ethiopia (Smur & Teka, 2021)**.** Female-headed households face more constraints in small-scale irrigation practices (Fikirie et al., 2017). Improving the participation of women as independent members of WUAs, and in particular allowing more women to occupy leadership positions, would strengthen the self-governance of communal irrigation, and provide a positive effect on the sustainability of small-scale irrigation systems (SSIS) (Version, 2021). Participation in irrigation management practices is very crucial to improving the productivity of small-scale irrigation agriculture (Kalkidan, 2016). Male heads are responsible for heavy and risky tasks such as land clearing, cultivation, crop watering, chemical applications, and loading and unloading while tasks like planting, removing weeds, hoeing, and harvesting are carried out usually by female heads (Kalkidan, 2016).

2.7.4 Evaluation of performance indicators in SSI farm

The Ethiopian government always advises beneficiaries of irrigation schemes to produce their irrigated land at least three times and above per year. Evaluation concerns include: who or which group has profited (or suffered harm), by how much (in comparison to the pre-activity state), in what way (directly or indirectly), and why (trying to establish causal linkages between actions and outcomes) (Manual, 2002). The effectiveness of the plans differed depending on the quantity of institutional assistance provided by government agencies, the communities' organizational ability, their expertise in irrigation agriculture, their access to dependable markets, and the quality of the plans' design (Amede, 2015). Performance assessment of irrigation systems plays a big role in evaluating the productivity of schemes (Adane, 2020).

To improve management and control, it is important to evaluate the irrigation scheme's performance. The indicator is typically expressed as the ratio of actual performance to target performance (Moges, 2022a). Performance evaluation for any irrigation system is basic to assess the goals (Adane, 2020). The performance of agriculture, water consumption, and physical performance were the comparable indicators used (Shiberu et al., 2019). Physical indicators are related to the changing or losing irrigated land in the command area for different reasons (Shiberu et al., 2019). Physical indicators are related to the changing or losing irrigated land in the command area for different reasons. The ratio of water delivered from an inlet canal or secondary canal to water transferred to an out canal or field canal is known as conveyance efficiency (Ec) (Abera et al., 2018). The primary reasons for excessive water loss or inefficient conveyance included weed growth and sedimentation, silting with dirt and other debris, overflowing an unlined canal, non-operation of all flow control gates, and illicit water abstractions (Kibret et al., 2021).

During water conveyance, seepage losses occurred in the sub-canals, and not all water diverted from the main canal reached the field (Kang et al., 2011). Water use performance indicators, relative water supply, and relative irrigation supply for all schemes were greater than one which indicated that enough water was supplied to the schemes to satisfy the irrigation requirement or irrigation demand (Adane, 2020). In water use performance indicator (relative water supply) depicts whether there is enough irrigation water supplied or not (Shiberu et al., 2019). Among the major reasons for low crop productivity in the central Rift Valley of Ethiopia low soil fertility, low-yielding verities, and poor agronomic practices can be mentioned (Aweke & Diriba-Shiferaw, 2024). Crop production was considered the primary output and land and water were considered the primary inputs in the basic agricultural performance metrics (Kibret et al., 2021). The inputs of production, productivity, and pricing were utilized to determine the comparative assessment indicators (Shiberu et al., 2019). Population pressure along with the prevalence of traditional agricultural production technologies, such as ancient farming methods and implements, and the sparing use of contemporary inputs like better seeds and fertilizers are the main obstacles to Ethiopia's agricultural progress (Tulu, 2014).

Fertilizers are substances, either natural or artificial, organic, or inorganic, that contain one or more chemical components necessary for the growth and development of plants. Plant growth is hampered by a limited supply of nutrients, and these deficiencies manifest as visible symptoms in the plants (Endris, 2021). DAP and urea are the fertilizers that are most frequently provided in Ethiopia (Negasa, 2023). The average amount of fertilizer consumed nationwide was as high as 14.4 kg per ha. The fertilizer use per nutrient base does not exceed 12 kg per ha (Endris, 2021). Since the district does not produce Belg, its agricultural calendar is based on the Meher season for rain-fed output and the entire year for irrigation-based production (Tulu, 2014). Rain is used to cultivate corn, haricot beans, teff, wheat, barley, and sorghum; the Lake Ziway basin is irrigated to grow vegetables like tomato, onion, green beans, and cabbage (Tulu, 2014). Most of the population in the study area produces maize for feeding their households (Negasa, 2023).

Globally, onions (Allium cepa L.) are the most widely consumed vegetable (Jula et al., 2021). Adequate management measures, with a particular focus on disease control and irrigation, can increase onion productivity. Many diseases affect onions, but the most harmful is leaf purple blotch, which is caused by Alternaria porri (Ellis) Cif. and is widespread (Jula et al., 2021). While irrigation alone had no discernible impact on disease infection, the application of a combined fungicide and irrigation interval dramatically decreased the severity of the disease. However, when irrigation frequency increased, the severity of the condition decreased (Jula et al., 2021). Just 2528 hectares of the district's estimated 14,000 hectares of irrigation potential were irrigated. (Tulu, 2014). Market-oriented production systems have been the focus of policy attention in many developing nations, including Ethiopia, as a means of boosting the income of smallholder farmers (Teshome et al., 2022). The water requirement of cabbage varies with climate, soil type, crop variety, and management practices (Beshir, 2017).

2.8 Summary of research findings and identified research gaps

Research findings	Research gaps	Reference
There are significant gender differences in technical efficiency among irrigated vegetable farmers in Plateau State, Nigeria.	The need for further investigation into the underlying factors contributing to the gender differentials in technical efficiency among vegetable farmers.	Dossah & Mohammed, 2016
Women's involvement in Water User Associations (WUAs) is limited, with decision-making roles predominantly occupied by men.	➢ Limited quantitative studies on women's participation in WUAs and their impact on decision-making. ➢ Further research is needed to identify the barriers that hinder women's active participation in WUAs.	Khandker et al., 2020

Research findings	Research gaps	Reference
➢ Engaging women in technical learning can improve agricultural practices. ➢ Gender-awareness workshops can create a safe space for discussing gender norms.	➢ Need for evidence-based strategies to address underlying social norms shaping gender relations. ➢ Limited understanding of the effectiveness of interventions in shifting adverse gender norms.	Carnegie et al., 2020
➢ Gender and resource disparities impact the adoption and benefits of small-scale irrigation. ➢ Accelerated investments in smallholder irrigation could lead to environmental degradation and conflicts over natural resources.	A deeper understanding is required to address underlying socio-political and economic factors contributing to inequities.	Lefore et al., 2019
WUA executive committees can enhance gender equality and bring new perspectives to water management discussions, leading to better outcomes for society and the economy.	Despite efforts to address barriers, there remains a gap in understanding and promoting women's active participation in water institutions, highlighting the need for further research on enhancing women's roles in water management for sustainable development.	Khandker et al., 2020
Women face limited access to resources and market constraints, impacting their participation and income generation in small-scale irrigation agriculture.	➢ Further research is needed to explore interventions that can address the gender disparities in access to resources and market opportunities in small-scale irrigation agriculture. ➢ Investigating the effectiveness of gender-sensitive policies and programs in promoting equity and enhancing the livelihoods of female-headed households in agricultural settings would be beneficial.	Kalkidan, 2016

Research findings	Research gaps	Reference
➢ Male Headed Household (MHH) irrigation users own more livestock and land compared to Female Headed Household (FHH) users. ➢ FHHs mainly engage in planting, weeding, and harvesting, while MHHs are involved in land clearing and cultivation. ➢ Cultural barriers hinder women's participation in land cultivation activities.	➢ Lack of research on the relationship between gender and agricultural production activities in small-scale irrigation among smallholder farmers. ➢ Limited exploration of the involvement of women in small-scale irrigation agricultural management activities in the study site.	Fikirie et al., 2016
➢ Both male and female-headed households encounter challenges in accessing credit services, training, and improved seed varieties. ➢ Market challenges impact pricing and product quality, affecting female-headed households more due to lack of knowledge and bargaining power.	➢ The need for continuous training and extension services to overcome technology and market-related problems faced by both male and female-headed households in small-scale irrigation.	Fikirie et al., 2017
Small-scale irrigation significantly increased income for women-headed households in Ethiopia, leading to improvements in overall social and economic benefits.	➢ Limited access to extension services for women-headed households hinders their knowledge and skills development in agriculture. ➢ There is a need to address the low education levels among women-headed households to enhance their adoption of irrigation technologies.	Smur & Teka, 2021

3 . MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location of the study area

Lake Ziway watershed has two sub-watersheds Meki sub-watershed in the northwestern part and the Katar sub-watershed in the southeastern part and the remaining part of the watershed covers the predominantly flat rift floor (Desta & Lemma, 2017). According to Desta et al. (2020), the Lake Ziway watershed spans 7032 km^2, of which 3337.7 km^2 is covered by the Katar sub-watershed and 2049.3 km^2 by the Meki sub-watershed. The heights of both regions exceed 3500 meters above sea level (masl) (Desta et al., 2020). The Lake Ziway Watershed is located between latitudes 7°21′′N, and 8°16′N and longitudes 38°2′E and 39°5′E. The study map is shown in Figure 3.1 below.

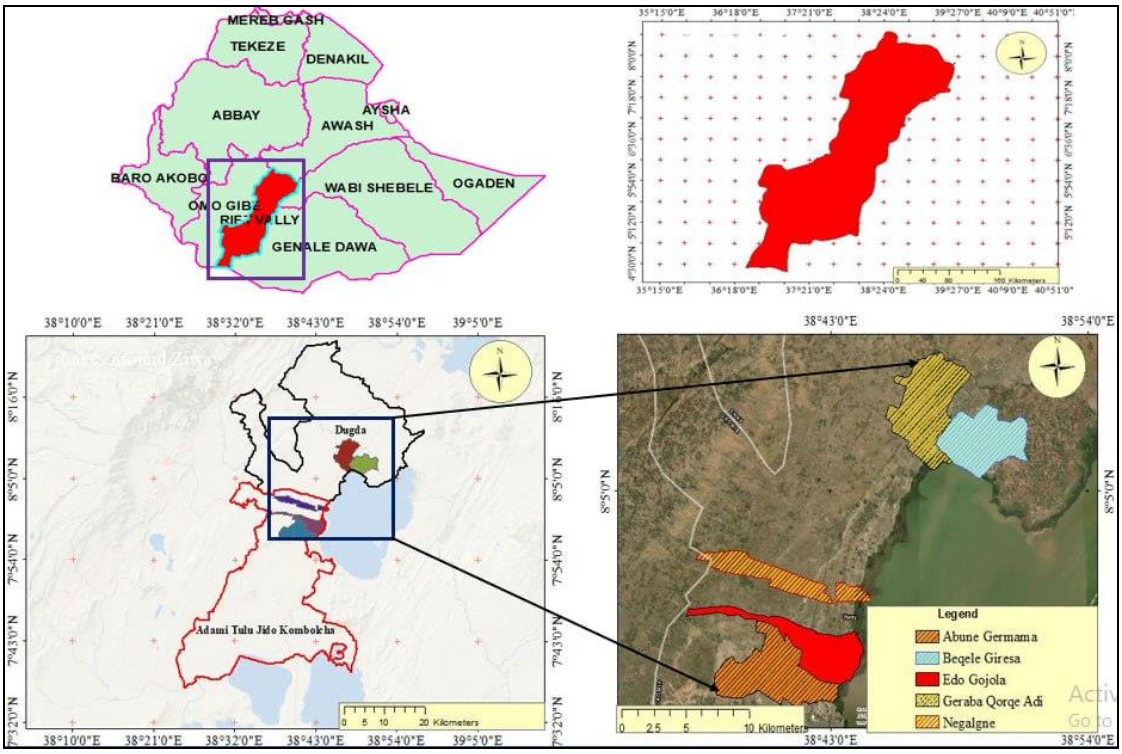

Figure 3. 1 Location map of the study area

3.1.2 Topography of Ziway Lake watershed

These areas are characterized by gentle slopes and are often used for agriculture. The Ziway Lake Watershed is distinguished by its rough terrain and complicated structural features, with step faults and mountain chains predominating in the rift border (Mechal et al., 2022).

It is one of the largest freshwater lakes in Ethiopia and serves as an important water resource for irrigation, domestic use, and fisheries in the area. Overall, the topography of the Ziway Lake watershed is diverse and influenced by both highland and lowland features. The combination of mountains, hills, plateaus, and wetlands contributes to the overall ecological richness and water availability in the area.

3.1.3 Land use and land cover of the study area

The land use and land cover (LULC) of the Ziway Lake watershed vary over time due to human activities and natural processes. The watershed is predominantly characterized by agricultural land use, including both rainfed and irrigated farming. Crops such as cereals (maize, barley, wheat, etc.), vegetables, and fruits are commonly cultivated in the area. The Ziway Lake watershed contains wetland areas, including marshes, swamps, and floodplains. These wetlands provide important habitats for various plant and animal species, as well as supporting ecological processes.

3.1.4 Climate of the study area

The Ziway Lake watershed is situated in the Ethiopian highlands, which generally receive a significant amount of rainfall. The area experiences a bimodal rainfall pattern with two rainy seasons: the short rainy season from February to April and the main rainy season from June to September. The region generally has a moderate to cool climate due to its high elevation. Average temperatures can vary depending on the specific location within the watershed. Due to the presence of Ziway Lake and other water bodies within the watershed, evaporation rates can be relatively high. Evaporation is influenced by factors such as temperature, wind, humidity, and surface area of the water bodies.

3.1.5 Soil types and characteristics of the study area

The soil types in the Ziway Lake watershed can vary depending on factors such as topography, parent material, climate, and land use practices. The fertile soils in these areas support a variety of crops, including cereals, vegetables, and fruits. The major soil type is Luvisols, and other soil types such as Andosols, Cambisols, Fluvisols, Nitosols, Vertisols, and Leptosols are also present around Ziway Lake (Negasa, 2023. The dominant texture of soil the Ziway district such as Edo Gojola and Negalgne is sandy loam soil (A.T.J.K. soil analysis laboratory office expert). The infiltration rate of sandy loam soil is high next to sand soil. The FAO-recommended infiltration rate is listed in Table 3.2 (Wubetu et al., 2022).

Table 3. 1 FAO recommended infiltration values for soil types

Soil texture	Basic infiltration rate (mm/hr)
Sand	<30
Sandy loam	20-30
Loam	10-20
Clay loam	5-10
Clay	1-5

Source : (Wubetu et al., 2022)

3.2 Data collection

3.2.1 Types and sources of data

Data for this study were captured from two sources: primary and secondary sources. The main primary sources of data were farmers, field observation and measurement, focus group discussions, and interviews with selected farmers and key informants were conducted. Primary data were collected from the sample households by using structured questionnaires, personal interviews, and focus group discussions discussed in the sample size determination part. Additionally, secondary sources of information were used for this study, including published materials, international journals, reports from district offices, plans, official records, census records, and project reports.

Table 3. 2 Description of types and sources of data

Types of data	Sources of data	Descriptions
Categorical, qualitative, and numerical data	Primary (female and male-headed household and KIs) and secondary (written document)	➢ Resource ownership ➢ Role of gender in irrigation practices ➢ Irrigation management practices ➢ Sustainability of the lake ➢ Current performance of water user associations
Numerical and qualitative data	Primary (field-measured data, field observations, and interviews) and secondary (published and unpublished material)	➢ Soil data ➢ Agricultural practices ➢ Application of irrigation water ➢ Physical and water use performance ➢ Yield ➢ Transportation and product use

3.2.2 Research design

The research adopted a mixed-methods approach, combining qualitative and quantitative methods. This design allowed for a comprehensive understanding of the role of gender in irrigation management practices. Qualitative methods were used to gather rich, contextual data through interviews, focus group discussions, and observations. Quantitative methods were employed to collect data on irrigation performance, productivity, and resource utilization. Household surveys were conducted with male and female-headed households in selected irrigation farms to gather data on resource access, participation in irrigation management organizations (IMOs), irrigation practices, and productivity. Focus group discussions were held with male and female farmers to explore gendered experiences and perspectives on irrigation management, decision-making, and resource use. In-depth interviews were conducted with IMO leaders and stakeholders to understand organizational structures, policies, and gender dynamics within IMOs. Direct field observations were conducted to assess the physical and water use performance indicators, water use practices, and land productivity in small-scale irrigation farms.

The survey was created in English language (refer to Appendix one to three) and subsequently translated into the local language (Afan Oromo). The purpose of the interview and a few scientific terminologies from the questionnaire that the respondents needed to understand during the interview were first explained to the data collectors. Before the main survey began, a pretest of the questionnaire was conducted by some female and male-headed households. The research was conducted from February to September 2024.

3.2.3 Sampling procedures

3.2.3.1 Site selected for the study area

The focal point of this study was the Ziway Lake Watershed, which serves as a center for numerous irrigation activities and requires significant attention. The research specifically focused on two districts, Adami Tulu Jido Kombolcha and Dugda (purposively selected), which were the primary beneficiaries of this lake and easily accessible for the study, and the five kebeles selected by random sampling techniques. The study centered on investigating the dynamics of irrigation management organizations, gender roles in irrigation practices, and the gender gap in efficiency within these districts.

3.2.3.2 Selection of irrigation management organizations and key informants

The study focused on smallholder irrigated vegetable-producing areas of Ziway Lake Watershed. A purposive sampling technique was used to select representatives. Key informants were selected from a sample of irrigation management organizations (local government officials and irrigation experts). The selection considered factors such as gender composition, organizational structure, role in the management, and decision-making related to irrigation and performance. Key informants (KIs) were those people who were knowledgeable and understanding about the existing trends in irrigation management practices.

Table 3. 3 Description of key informants (KIs)

No.	Institution		Job description	No. of Interviewees
1	East Shewa Zone Irrigation and Pastoralist Development Bureau		WUA expert	1
			Water resource expert	1
2	Districts	A.T.J.K	Environmental expert	1
			WUA and irrigation expert	2
			Soil laboratory expert	1
		Dugda	WUA and irrigation expert	2

3.2.3.3 Selection of committee members of WUAs

In the selected study area, there were water user associations (WUAs). Participants for the focus group discussions (FGDs) were selected using a purposive sampling method. Five groups were formed, each consisting of eight members. A participatory data collection workshop was held in Ziway. As a result, the total sample size for the FGDs was 40 committee members illustrated in Appendix Figure 1. The distribution of members across the five groups is provided in Table 3.5.

Table 3. 4 Organization of groups and members for focus group discussion

Ziway Lake Watershed Districts	Selected Kebeles	Total numbers of WUA	Number of sample groups	Sample members of WUA	Gender participation	
					Female	Male
A.T.J.K	Edo Gojola	41	G1 &G2	16	7	9
	Abune Germama	15	G3	8	3	5
	Negalgne	8	G4	8	3	5
Dugda	Beqele Giresa	4	G5	8	2	2
	Graba Qorqe Adi	5			2	2
Total		73	5 groups	40	17	23

3.2.3.4 Determination of sample size for detailed study

In this study, a random sampling technique was used to select smallholder vegetable producers from A.T.J.K (3 Kebeles) and Dugda (2 Kebeles) listed in Table 3.6. Stratification was based on gender to ensure the representation of both male and female farmers. The sample of the households included both male-headed and female-headed households. In general, a sample of smallholder farmers was selected, and the sample size was determined by using a sample size determination formula developed by Yamane (1967) as follows (Abdul, 2012):

$$n = \frac{N}{1+N(e)^2} \qquad 3.1$$

Where, n = № of sample size

N= Total number of households' beneficiaries

e = is the level of precision (confidence) (3 %, 5 %, 7 % and 10 %). For this study is 5 % (selected confidence level was 95 % of precision).

$$n = \frac{1452}{1+1452(0.05)^2} = 313$$

About 313 sample households were to be included in the study. This amount of sample was then proportionally divided into each studied kebele within 241 male-headed and 72 female-headed households. Therefore, the sample distribution is listed in Table 3.6.

Table 3. 5 Males and females head household sample size distribution

Ziway Lake Watershed	Total beneficiaries' households					Sample size determination	
Districts	Selected Kebeles	Male	Female	Total households	Command area (ha)	Male headed household	Female-headed household
A.T.J.K	Edo Gojola	179	88	267	122.25	$\frac{313*179}{1452} = 39$	$\frac{313*88}{1452} = 19$
	Abune Germama	201	109	310	93.75	$\frac{313*201}{1452} = 43$	$\frac{313*109}{1452} = 24$
	Negalgne	148	55	203	96.5	$\frac{313*148}{1452} = 32$	$\frac{313*55}{1452} = 12$
Dugda (Scheme levels)	Beqele Giresa	409	62	471	211	$\frac{313*409}{1452} = 88$	$\frac{313*62}{1452} = 13$
	Geraba Qorqe Adi	183	18	201	79.125	$\frac{313*183}{1452} = 39$	$\frac{313*18}{1452} = 4$
Total	1120		332	1452	623.125	241	72
	Total sampled households = 313						

3.2.3.5 Selection of sample farms

To deepen the understanding of on-farm irrigation management, two male-managed farms, and two female-managed farms were purposively selected to understand on-farm irrigation management (1 male and 1 female for cabbage, and similarly for onion). These farms were monitored to assess gender-based performance across several key areas, including agricultural and irrigation practices, resource utilization efficiency, and overall productivity. This approach allows for a comprehensive evaluation of how gender influences farm management and outcomes.

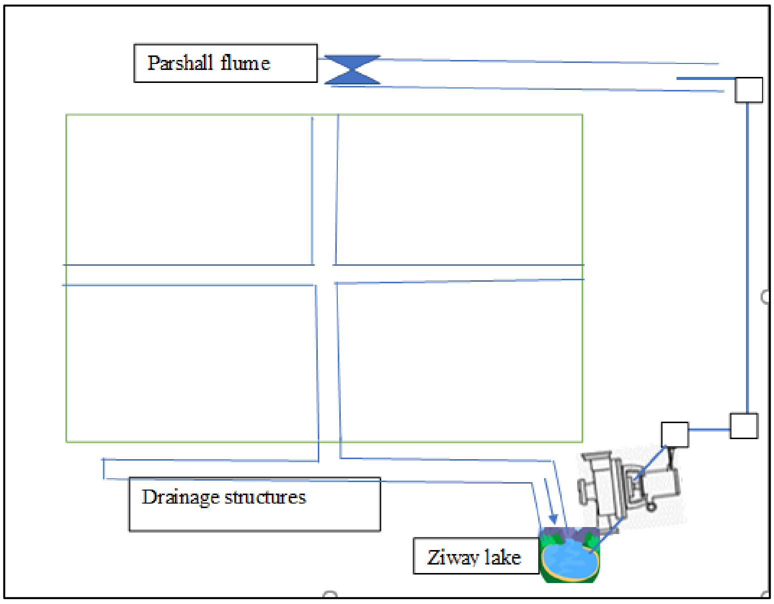

Figure 3. 2 Field layout for female and male-managed fields.

3.3 Materials and tools

The materials and tools utilized in this study include the following:

Table 3. 6 Materials and tools utilized in this study

Materials and tools in this study	Purpose
Stopwatch	For precise timing of various activities.
Measuring meter	To ensure accurate measurements in field assessments.
Microsoft excels	For data organization and analysis.
SPSS software (version 27)	For statistical analysis of collected data.
Questionnaires	To gather qualitative and quantitative information from participants.
GPS (geographical positioning system)	For accurate location tracking and measuring the distances.
Digital camera	To document visual data and observations.
GIS (Geographical information system)	For spatial analysis and visualization of geographical data
CROPWAT 8.0 software	For modeling crop water requirements and irrigation scheduling.
Parshall flume (three inch)	For measuring water flow rates in irrigation systems.
Water level measurement tools	To monitor water levels in various contexts.
Scale	To measure the crop yield

3.4 Field data collection methods

3.4.1 Performances of irrigation management organizations

For assessing, characterizing, and evaluating the performances of irrigation management organizations, data required to measure the performance indicators were collected. Quantitative data were collected through structured surveys and questionnaires that were administered to members of irrigation management organizations (IMOs) and smallholder vegetable producers. The surveys assessed irrigation management organizational structures, policies, and bylaws, as well as gender participation and performance on the ground.

Relevant documents, reports, and records produced by the IMO, such as annual reports, strategic plans, or performance assessments were reviewed. Surveys or interviews were conducted with stakeholders, including water users, farmers, employees, or community members associated with the IMO. On-site visits were conducted to observe the operations and management practices of the IMO.

3.4.2 The role of gender in defining irrigation practices and resource use

For examining the role of gender in defining irrigation practices and resource use, IMO document analysis, interviews, and focus group discussions were the main data collection tools. The irrigation management organizational structures, policies, and bylaws of IMOs were reviewed to assess gender inclusivity and potential barriers to women's participation. Data were collected on gender participation in decision-making processes, resource allocation, technology adoption, input use, and market access. Key stakeholders, such as community members, smallholder women, and leaders of irrigation management organizations (IMOs), were interviewed in-depth to collect qualitative data.

The main goals of these interviews were to understand gender engagement in irrigation management methods, resource consumption, and community perceptions on environmental sustainability matters. Groups of male and female farmers gathered to discuss their experiences in managing irrigation systems, as well as their opinions on gender roles in irrigation management, decision-making procedures, market accessibility, environmental concerns, and recommendations for better irrigation management practices, and techniques. In this instance, two channels of communication were used to enhance the efficiency of the data-gathering process between farmers and interviewers.

3.4.3 Gender-based performance evaluation of small-scale irrigated farms

In this study, the necessary data were measured, the field activities were monitored, and the inputs used were recorded. In addition to measurement (quantitative data). Qualitative data were also collected by interviewing the selected female and male farmers. To address the third objective, farms managed by females and males were selected and monitored for agricultural practice (land preparation, seedling, weeding, fertilizer application, and harvesting), irrigation water application (irrigation methods, amount of irrigation water applied, irrigation time (IT), interval (II) and drainage management), transportation, use of agricultural produce, input and technology use, environmental sustainability and determine physical performance indicators, water use performance and resource use efficiencies (water productivity, land productivity and efficiencies,).

3.4.3.1 Amount of water used

Out of the four farms, two used pumps to withdraw water, which is directly delivery through a pipe system to the field. In this case, the amount of water used could be determined by the pump's discharge rate by the operating time. The other two farms also use pumps to withdraw water from the source (lake) and release water into the secondary unlined canal where leakage and seepage might be high. Here, the determination of the amount of water used must consider the losses. In this case, the determination of the volume of water used by the two selected male and female fields was done by measuring the flow rate through a 3-inch Parshall flume and the duration of water delivery. Before the measurement, the Parshall flume was leveled using a water level instrument when it was installed. The Parshall flume was used to measure the flow rate at the secondary canal and water into the fields. This instrument could determine the discharge head, which is the measurement of the water pressure or depth at the flume. After measuring the discharge head, the amount of water flowing through each field could be determined by referencing a calibration chart specific to the 3-inch Parshall flume or by an empirical formula indicated in the equation 3.2 below. This chart provides the corresponding flow rate for the measured discharge head (ASTMD, 2007). Then, by multiplying the flow rate by the duration of water delivery, it was possible to calculate the total volume of water used by each field.

$$Q = 176.5{H_m}^{1.55} \quad 3.2$$

Where,

Q = Flow rate in l/s

Hm = discharge head in m

Figure 3. 3 Measurement of discharged at the farm using a 3-inch Parshall flume

The comparison was made between the amount of water delivered or used by the fields and the theoretically calculated water requirement which is determined using, the crop water assessment tool (CROPWAT 8.0). FAO Irrigation and Drainage Papers 24 and 56 were used to determine the recommended value used in this model (Wubetu et al., 2022). To determine the water requirement of the irrigated crops, meteorological data (such as temperature, rainfall, sunlight hour, wind speed, and relative humidity) were required. The required amount of irrigation water was calculated by the following formulas (Kibret et al., 2021):

$$ET_c = ET_o * k_c \quad 3.3$$

$$IWR = ET_c - P_e \text{ if } ET_c > P_e \quad \text{otherwise} \quad IWR = 0 \quad 3.4$$

Where,

IWR = Irrigation water requirement (mm/season)

ET_c = Crop water requirement (mm/season)

Pe = Effective rainfall (mm/season)

3.4.3.2 Determination of physical performance indicators in SSI farms

In the study area, the water was distributed to the farms by pumps. Physical performance indicators are useful in monitoring and assessing the condition, functionality, and maintenance needs of infrastructure systems. Data were collected on the condition and maintenance of the pump systems used in the farms. Interviews were conducted with farmers, water user associations, irrigation committee members, maintenance staff, and project implementers who were involved in the operation and maintenance of the pump systems. The functionality and maintenance needs of the pump systems were assessed. On-site visits were conducted to visually inspect the pump systems, including the pumps, pipes, and other components.

In the selected four sampled farms, the two female and male farms (cabbage farms), water was distributed directly to the field by delivery pipes whose discharge rates are known. However, in the case of the other two female and male (onion farms) farms the water is delivered through pipes and directed into an unlined channel. These measurements were done over a certain distance. The conveyance efficiency of all later two farms (Ec) was calculated by the following formula:

$$\mathrm{Ec} = \left(\frac{\mathrm{Q_{outflow}}}{\mathrm{Q_{inflow}}}\right) * 100\% \qquad 3.5$$

Where, Ec = conveyance efficiency (%)

Q_{inflow} = inflow discharge (m^3/s) and

$Q_{outflow}$ = outflow discharge (m^3/s)

3.4.3.3 Determination of water use performance indicators in SSI farms

A set of water use performance indicators specifically related to water allocation and distribution were identified. Common indicators included water allocation equity (fair distribution of water among users), and water distribution uniformity (evenness of water distribution across the irrigation scheme).To conduct surveys or interviews, water users were asked to provide information on the volume of water used, cropping areas, and irrigation practices. Primary data collection methods included field measurements, surveys with farmers, interviews with irrigation scheme managers, and reviewing records and documents related to water allocation and distribution.

3.4.4 Determination of water and land productivity and efficiency

To conduct a gender-based evaluation of the efficiency in resource utilization and management (water and land productivity, efficiency), water and land productivity data were collected through direct measurements and calculations. A representative sample of female-headed and male-headed farms was identified for a detailed study. The questions were designed to capture information about gender-based differences in agricultural practices and efficiency. Productivity metrics such as crop yield per unit of water used or land area cultivated were calculated and the productivity levels between male and female managed fields were computed and compared. This involved assessing the efficiency of female and male-headed farms in selected fields. Water and land productivity and efficiency were important measures in assessing agricultural performance. Productivity is a measure of performance expressed as the ratio of output to input (Crop, 2012).

3.4.4.1 Water productivity

Water productivity measures the amount of agricultural output or yield obtained per unit of water used. It can be calculated using the following formula:

$$\text{Water Productivity} = \frac{\text{Output from water use}}{\text{Water applied}} \tag{3.6}$$

Where: Output derived from water use refers to the total amount of agricultural output or harvest obtained in quintals and water consumed represents the total amount of water used to produce the agricultural output in cubic meters.

3.4.4.2 Land productivity

Land productivity measures the amount of agricultural output or yield obtained per unit of land area. It can be calculated using the following formula:

$$\text{Land Productivity} = \frac{\text{Crop Yield}}{\text{Land Area}} \tag{3.7}$$

Where: Crop yield refers to the total amount of agricultural output or harvest obtained in quintal and land area represents the total area of land under cultivation (gross cropped area) in hectares.

3.4.4.3 Water use efficiency

Water use efficiency assesses how water is efficiently utilized in agricultural production. It can be calculated using the following formula:

$$\text{Water use efficiency} = \frac{\text{Crop Yield}}{\text{Water applied}} \tag{3.8}$$

Where: Crop yield refers to the total amount of agricultural output or harvest obtained in quintal and water input represents the total amount of water supplied or applied for irrigation or other agricultural purposes in cubic meters.

3.4.4.4 Land use efficiency

Land use efficiency measures how efficiently land is utilized in agricultural production. It can be calculated using the following formula:

$$\text{Land use efficiency} = \frac{\text{Crop yield}}{\text{Land input}} \quad 3.9$$

Where: Crop yield refers to the total amount of agricultural output or harvest obtained in quintals and land input represents the total area of land utilized for cultivation or agricultural activities in hectares.

Generally, resource use efficiency measures the efficiency of resource use, such as water, land, and inputs (fertilizers and pesticides).

3.4.5 Input and technology use

The use of agricultural technologies or innovations in each field was evaluated. Data was gathered on the adoption of improved seeds, mechanization, precision agriculture tools, and other relevant technologies. The extent of technology use and its impact on productivity and resource efficiency were compared. Data was collected on the types and quantities of inputs used in each field, such as fertilizers, pesticides, and seeds. The input use patterns were analyzed and compared between female and male-managed fields.

3.4.6 Use of agricultural product

The marketing strategies and channels used by farmers for marketing their agricultural produce were assessed. Data was collected on various aspects of market access, price realization, and value-added activities. A comparative analysis was conducted to evaluate the marketing practices and outcomes between female and male farmers.

3.4.7 Environmental Sustainability

To assess environmental sustainability, utilized indicators such as soil health, water quality, and biodiversity conservation. Generally, for a comprehensive gender-based performance evaluation of the four selected small-scale irrigated farms, the following conceptual framework.

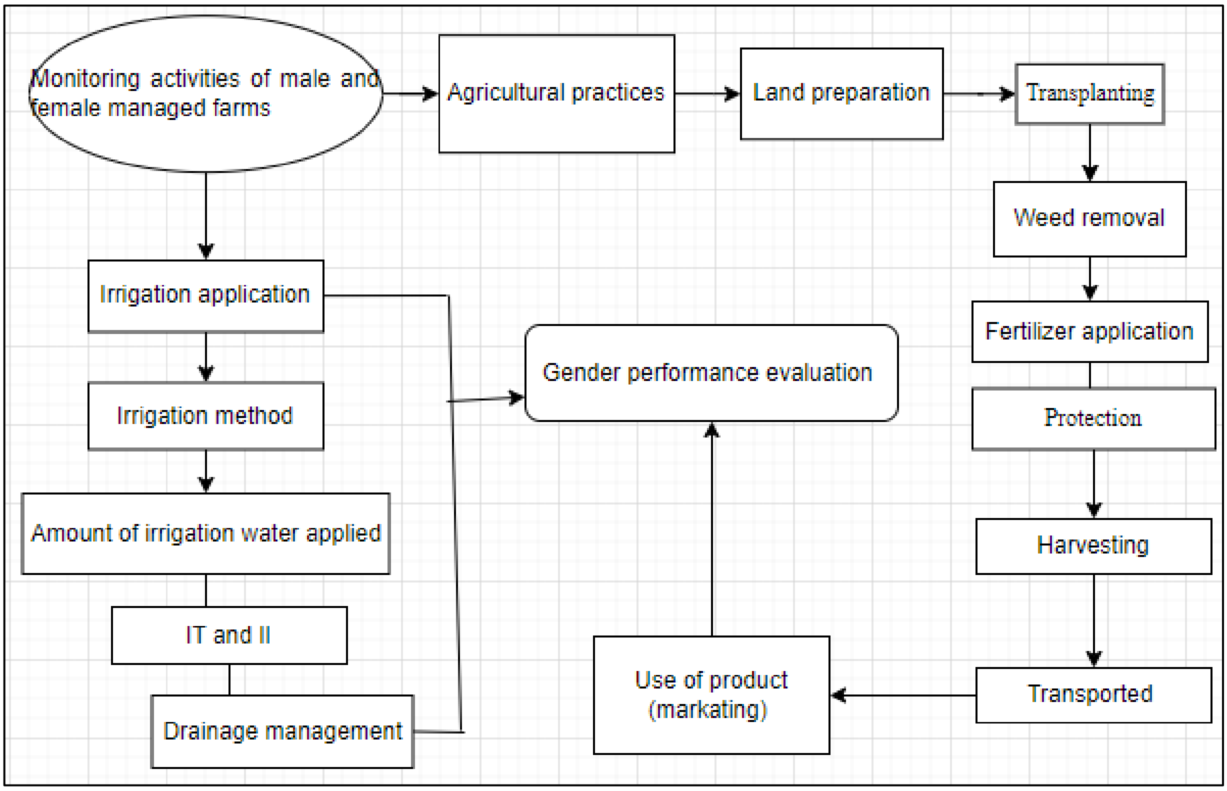

Figure 3. 4 Monitored procedures for male and female-managed fields

3.5 Methods of data analysis and presentation

Gender composition, education level, ways of land acquisition, water resources, irrigation challenge, and gender disparities in resources access, community perceptions about changes in resource use impacts on resources, irrigation management organization, land cultivated under irrigation and rainfall, the major crop has grown and its crop production use of the agricultural product was analysis by using descriptive statistics. The household size of the respondent was analyzed by one-way ANOVA. Theoretical crop water requirement was analyzed CROPWAT 8.0 software, field irrigation water requirement, water conveyance efficiencies resulting from water and land productivities and its efficiencies, and output production of male and female managed fields were analyzed by using Microsoft Excel software. Major crop produced under small-scale irrigation agriculture by smallholder farmers was analyzed by using multiple responses. In addition, close-ended questions were analyzed by using narrative.

In general, the collected data were analyzed using GIS software, SPSS software version 27 which are one-way ANOVA, chi-square test, multiple responses, descriptive statistics (mean, frequency, and percentage), CROPWAT 8.0 software, and Microsoft Word Excel. The study's findings were presented using figures, charts, and tables.

3.6 Conceptual framework of the materials and methods for this study

Figure 3.5 illustrates the interconnected components of the research process, highlighting how data sources, collection methods, sampling techniques, and analytical tools contribute to the overall research objectives.

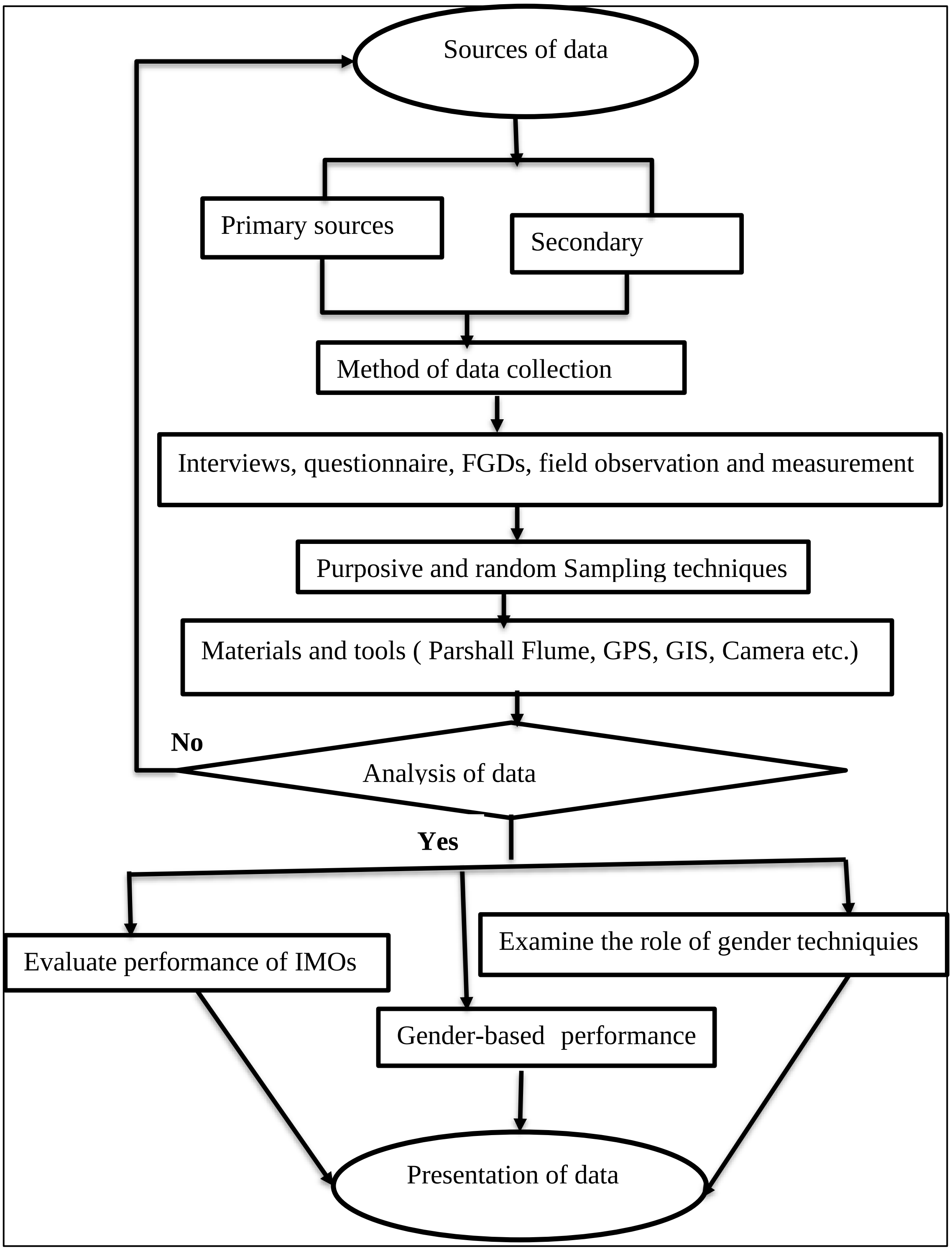

Figure 3. 5 Materials and methods framework for this research

4 . RESULTS AND DISCUSSIONS

This chapter presents the findings of the study and discusses in comparison with the results of previous similar scholars. In this chapter, the results are organized under six sections such as demographic characteristics, resource ownership and access to resources, performances of irrigation management organizations, the role of gender in irrigation practices, sustainability, and gender-based performance evaluation of the small-scale irrigated farms.

4.1 Demographic characteristics of the respondents

4.1.1 Gender

There was a total of 313 respondents, with males making up the majority at 77.0%, while female respondents were 23.0% of the sample. The primary occupation of both male and female-headed households was farming. The data exposed a significant gender imbalance, with male respondents dominating the sample across all the districts. Table 4.1 depicts the gender distribution in each district. This result is similar to Kalkidan (2016), who stated that the participation of FHHs in small-scale irrigation agriculture in Ziway Lake Watershed is limited in number.

Table 4. 1 Gender composition of respondents by District

Name of the district	Gender of the respondent				Total	
	Male		Female			
	N	%	N	%	N	%
Abune Germama	43	17.8%	24	33.3%	67	21.4%
Negalgne	32	13.3%	12	16.7%	44	14.1%
Edo Gojola	39	16.2%	19	26.4%	58	18.5%
Beqele Giresa	88	36.5%	13	18.1%	101	32.3%
Graba Qorqe Adi	39	16.2%	4	5.6%	43	13.7%
Total	241	100.0%	72	100.0%	313	100.0%
%	77.0%		23.0%		100.0%	

4.1.2 Age of households or beneficiaries for Ziway Lake Watershed

The work of irrigation requires labor, which means that age plays an important role. It is assumed that most of the work that will be done in the field of irrigation the ones that will be successful. In this research area, older age male farmers and the majority of women farmers use their land by renting to another person or investor. The survey conducted from February to September 2024 examined the relationship between the age and gender of the respondents. The data collected showed that most of the participants were in the 36-55 age group, accounting for 84.7% of the total respondents. More than half of MHHs and FHHs are in the middle age group (31-55) and the proportion of younger household heads is higher for MHH groups (Kalkidan, 2016). Among the male respondents, the highest percentage was in the 36-55 age group (80.0%). In contrast, the female respondents had a different age distribution, with the highest percentage in the 25-35 age group (53.3%). This female and male age group was good for irrigation tasks.

The statistical analysis, using a chi-square test, exposed a statistically significant relationship between the age and gender of the respondents. The chi-square test statistic was 17.34, and the p-value was 0.001, which was less than the significance level of 0.05. Therefore, there was a meaningful association between these two variables in the survey. This finding contradicts the results of Kalkidan (2016), who suggested that age differences between male and female participants in small-scale irrigation (SSI) agriculture were statistically insignificant, the analysis indicates not a strong association between age and gender.

Table 4. 2 Respondent’s age and gender distribution in the survey

			Age of the respondents					
			25-35	36-55	>56	Total	X^2	P value
Gender	Male	Count	14	212	15	241		
		%	46.7%	80.0%	83.3%	77.0%		
	Female	Count	16	53	3	72		
		%	53.3%	20.0%	16.7%	23.0%		
Total		Count	30	265	18	313		
		%	9.6%	84.7%	5.8%	100.0%	17.34	0.001**

Note: ** Significant at $P < 0.05$

4.1.3 Marital status of the samples

According to key informants and women farmers in the study area, the prevailing marital culture is characterized by polygamy. They noted that women often bear the primary responsibility for family-related tasks. This heavy workload, combined with the diverse expectations placed upon them, has contributed to feelings of inadequacy among many women. The demographic data reveals that a significant majority of respondents in this area are married, comprising 94.9% of the total sample. Among male respondents, 230 (95.4%) reported being married, while 11 (4.6%) were unmarried. In contrast, among female respondents, 67 (93.1%) were married; however, there were also 1 (1.4%) who were unmarried, 1 (1.4%) who was divorced, and 3 (4.2%) who were widowed, as shown in Table 4.3. The results of the chi-square test indicate a statistically significant difference in the marital status distribution between male and female respondents (p = 0.002). A Chi-square test indicated a strong statistical significance (X^2 = 14.88, P = 0.002**), indicating that the distribution of marital statuses significantly differed between male and female respondents.

Table 4. 3 Marital status distribution by gender

Marital status of the respondent	Gender of the respondent				Total		X^2	P value
	Male		Female					
	N	%	N	%	N	%		
Married	230	95.4%	67	93.1%	297	94.9%		
Not married	11	4.6%	1	1.4%	12	3.8%		
Divorced	0	0.0%	1	1.4%	1	0.3%		
Widower	0	0.0%	3	4.2%	3	1.0%		
Total	241	100.0%	72	100.0%	313	100.0%	14.88	0.002**

Note: ** Significant at P < 0.05

4.1.4 Level of education

Education is generally required for farmers, especially when it comes to adopting and managing small-scale irrigation systems. Farmer education helps promote the adoption of small-scale irrigation technologies and practices. Most respondents (54.0%) had a primary education level. This result is contrary to Kalkidan (2016), who reported that most of the sample respondents are found to be uneducated. The second largest group (21.4%) had no formal education. Secondary education (14.4%), preparatory education (6.4%), and tertiary education (3.8%) were less common among the respondents.

Table 4. 4 Education level of the respondents

Level of education	N	%
No formal education	67	21.4%
Primary education	169	54.0%
Secondary education	45	14.4%
Preparatory education	20	6.4%
Tertiary education	12	3.8%
Total	313	100

4.1.5 Household size of the respondents

Household size played a significant role in irrigation practices, largely depending on whether the household members were of productive age. Since irrigation activities are labor-intensive, large households particularly those with more working-age members benefit more from the available workforce. The survey data indicated that the maximum and the mean household size were 15 and 6.61 (7) persons respectively. However, when broken down by gender, there was a significant difference observed. Male-headed households had a larger average size of 6.9 (7) persons, compared to female-headed households of 5.7 persons (6). The minimum household size was 1 person for both genders, while the maximum was 15 persons for male-headed households and 12 persons for female-headed households. The statistical analysis showed that the difference in household size between male and female-headed households was significant at the $p<0.05$ level suggesting that gender is an important factor influencing household composition within the surveyed population. This result is in line with Lakew (2018)**,** who reported that vegetable production is a labor-intensive activity; accordingly, families with more household members tend to have more labor which in turn increases vegetable production**.**

Table 4. 5 Household size of the respondents

	N	Mean	Minimum	Maximum	F value	P
Male	241	6.9	1	15		
Female	72	5.7	1	12		
Total	313	6.61			7.47	0.01**

Note: ** significant at $P<0.05$

4.2 Resources Ownership and Access to Resources

4.2.1 Land Resources

A farmer must possess land to be able to farm. According to the information gained from the field, the common land size owned by a single farmer varies from 0.25 to 1 hectare. The maximum land size is 11 hectares which is owned by commercial farmers. All respondents involved in this research have land under their possession. In the survey conducted in 2024, the distribution of land ownership methods among the people was revealed. The most common method was through transfer from parents, accounting for 47.28% of the land owners and the FGDs stated that the major sources of land ownership in the area were families, highlighting that a substantial portion of the land had been inherited within families.

Land ownership through land redistribution by the government accounted for 14.7%. About 11.2% and 3.2% of the respondents have access to land through liaising and renting respectively. Only 1.0% have managed to acquire the land through a combination of transfer from parents, redistribution, and renting. Overall, the data indicated that inheriting land from parents was the common way respondents acquired ownership of their land as shown in Table 4.6.

Table 4. 6 Ways of Land Acquisition

Common ways of acquiring land	N	%
Through redistribution of land	46	14.7%
Through transfer from parents	148	47.3%
Renting	10	3.2%
Liaise	35	11.2%
Through transfer from parents and renting	62	19.8%
Renting and liaise	7	2.2%
Through transfer from parents and liaising	2	0.6%
Through transfer from parents, redistribution, and renting	3	1.0%
Total	313	100

The land is the primary input resource for the farming community. The size of the land owned by farmers determines the farmer's opportunity to produce more or less. As illustrated in Figure 4.1, more than half of the sampled households (52.7%) own land parcels ranging from 0.25 to 1.0 hectares. The second (30%) cultivate plots between 1.125 and 2 hectares, while only a small fraction (3.5%) possess land exceeding 4.0 hectares. This highlights the scarcity of land resources, underscoring the need for efficient utilization and effective management to optimize production. The average cultivated landholding size in the Lake Ziway watershed is 1.59 ha (Desta et al., 2017b). However, the average household land holding size in this watershed is less than the country's average for rural areas, 1.77 ha (Desta et al., 2017b).

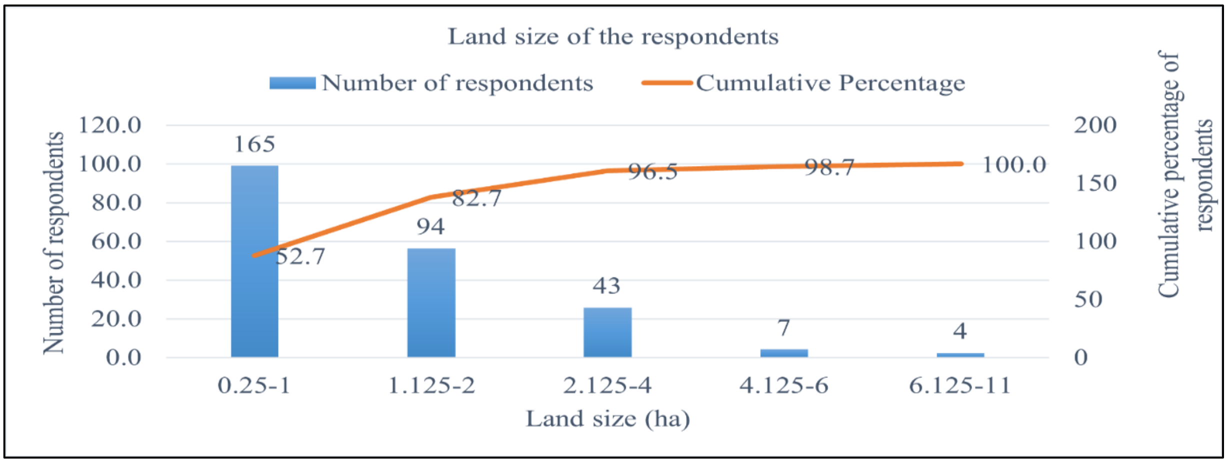

Figure 4. 1 Land size distribution

4.2.2 Water Resources

Concerning the water sources, the data indicates that respondents in this region have access to various water sources to facilitate their small-scale irrigation practices. Insights from key informants in this study suggest that farmers are permitted to extract groundwater from the lake, provided they possess the economic means to do so. The primary water source is lake water, utilized by 211 respondents, representing 67.4% of the total. Groundwater also plays a significant role, with 45 respondents (14.4%) depending exclusively on this resource for irrigation. This underscores the existence of functional groundwater infrastructure, such as wells or boreholes, enabling the extraction and use of subsurface water. Notably, a considerable segment of respondents 57 individuals (18.2%) employ a hybrid approach, utilizing both lake water and groundwater, as illustrated in Figure 4.2. This reflects a more diversified and potentially resilient water management strategy, allowing the community to leverage multiple sources to ensure a dependable supply, particularly during periods of water scarcity or fluctuations in lake levels.

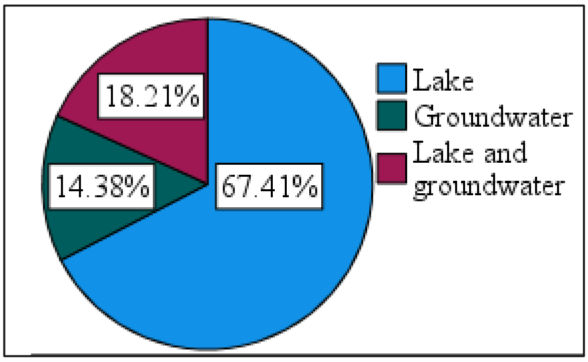

Figure 4. 2 Percentage respondents using different water sources (N=313)

4.2.3 Assessing Irrigation Challenges and Gender Disparities in Resource Access

The research found that 179 (57.2%) of respondents reported experiencing water shortages, while 134 (42.8%) said they did not experience water shortages. For most farmers who did experience water shortages, the key solution they found was digging shallow boreholes with a depth of 2 to 8 meters to access groundwater. Some farmers responded to the shortages of water by reducing the size of land they cultivated, based on water availability. Another strategy employed was building small ponds or reservoirs around existing lakes to store additional water. The research found that 235 (75.1%) of farmers reported facing constraints or challenges in accessing land and water resources, while the remaining 84 (24.9%) of farmers said they did not face such constraints.

The major causes and challenges include the distance of water sources, which posed financial problems for many farmers; the topography of the cultivated land, as the recommended slope was supposed to be less than 15% to access lake water; an inability to pay the required fees; farmers being absent when the land was originally distributed; and discriminatory rules or bureaucratic burdens during the initial allocation of land and water. The lake water is used by anyone who has access without being controlled. According to the pump owners, about 53 (16.9%) states that no rules and regulations restrict the amount of water they withdraw and use but 260 (83.1%) of the respondents said that some rules and regulations restrict the amount of water used by their group. KI (East Shewa zone WUAs experts) responded that no rules and regulations restrict the use of water from the lake for the farmers. Based on the survey results, the majority of respondents 207 (66.1%) had faced gender-specific constraints in accessing resources for irrigation. However, about 106 (33.9%) had not faced gender-specific constraints in accessing resources for irrigation. The major causes cited included limited seasonal availability of input supplies, financial problems, no transparency during the distribution of resources, cultural beliefs that deemed it improper for women to be involved, and having more land but limited access to water because of the distance of water far from the irrigated land.

According to the results of male and female-headed households, the main challenges faced by women while participating in irrigation activities were cultural beliefs that discouraged women’s involvement, high input costs, inadequate support from stakeholders, financial difficulties, limited access to gender-focused training services, crop diseases, the heavy burden of household responsibilities. Gender norms are part of broader, formal, and informal, social institutions that regulate people’s interaction in a given community (Lopez et al., 2022). Additionally, a lack of interest, gender stereotypes that view irrigation and farming as male-dominated activities, and skill gaps, and knowledge further hinder women’s participation. As a result, these challenges lead to inefficient irrigation management and lower productivity among women farmers.

A survey of female-headed and male-headed households revealed several gender-specific barriers that had hindered women's participation in irrigation. Respondents highlighted women’s exclusion from irrigation-related meetings and decision-making processes, insufficient skills and knowledge due to limited training and education, socio-cultural norms, and gender biases that undervalued women's agricultural contributions. Additionally, factors such as age, marital status, and whether women are in their productive years also play a role in these challenges. The result is similar to Khandker et al. (2020), who reported that only men participated in the meetings and made all decisions related to farm management however educated women would be less affected by many barriers.

4.3 Performances of irrigation management organizations

Irrigation management organizations are instrumental in the success of irrigation. The female and male-headed household respondents state that the major water management institution in this area is WUA. East Shewa Zone Irrigation and Pastoralist Development Office is responsible for organizing the WUA. According to KIs, there is no permit mechanism for water withdrawal from the lake. KIs states that WUAs have access to extension and input support services from district experts but decrease this service for today because of the current security issues. According to KIs response, there is a fee that members contribute to the WUA based on the size of the land. An association on modern irrigation in which its member has land with a size of 0.25 and below hectare shall be required to initial payment of a membership contribution of 50 ETB annually, and the one having land above this size shall be paid by calculating in such a way. An association on traditional irrigation whose member has land with a size of 0.25 and below hectare shall be required to initially pay of membership contribution of 25 ETB annually, and the one having land above this size shall be paid by calculating in such a way.

According to KIs, and during the field visits and the response of water user members of the respondent farmers there were four main sources of conflict such as land border disputes, queues waiting to use the available motor pump, during distribution of agricultural input, and theft of irrigation material like pipes from the fields. This organization manages the conflict-by-conflict resolution committees, district land management committees, and through reconciliation. According to male-headed and female-headed respondents, the strength of the irrigation management organizations appears to be the existence of established laws and regulations. However, the organizations exhibit several notable weaknesses in managing the irrigation systems effectively. The major issues were personal thinking (putting personal interests first), the culture of austerity was weak, lack of professional supervision, inadequate skill and knowledge, and lack of awareness by all members about the law and regulations.

The research found that all selected 313 (100.0%) farmers were members of Water User Associations (WUAs). The majority 283 (90.4%) of the samples were simply members of WUA without special responsibility. The remaining 30 (9.6%) hold positions in the WUA committees. Regarding the current performance of the WUAs, about 148 (47.3%) of the farmers considered the WUAs as efficient in their performance, 77 (24.6%) believed that the WUAs are only moderately efficient, and 88 (28.1%) rated the WUAs as inefficient. The research further revealed that all sampled households 313 (100%) are aware of the fact that the WUAs have written bylaws. However, when it came to the members' awareness of their duties and responsibilities within the WUAs, the results were less favorable, only 133 (42.5%) of the members confirmed that they knew their roles, while a majority, 180 (57.5%) admitted that they did not know. The major problem committees face while discharging their duties is the lack of continuous meetings, follow, and evaluations for committees. Moreover, the research examined the nature of the decision-making processes within irrigation management organizations. The responses revealed a diverse range of approaches, with 64 (20.4%) of the organizations described as having a centralized decision-making structure, 148 (47.3%) characterized as decentralized, and 101 (32.3%) reported to have participatory decision-making.

Regulation No.204/2018 issued by Oromia Regional State proves legal grounds for the establishment and functioning of Irrigation Water Users Associations. It gives due attention to gender participation in WUA management. The regulation states that at least 30% of the selected members of the founders committee shall be female, and the Bureau shall facilitate conditions for capacity building of women who are beneficiaries of irrigation development. The regulation further articulates that those farmers who own land in the territory of the WUA can be members. It is evident that the ownership of the land is dominated by men and hence, the female is not benefiting from some of the provisions of the regulation. In addition to that women affair’s office is not giving due attention to female farmers participating in irrigation practices. Female farmers lack special support services from the government which represents major constraints to their participation in farming. This outcome is in line with Khandker et al. (2020), who made the report that the inclusion of women in the Water User Associations was very low.

Land owners’ members greater than five can come together and form a water users association (WUA). The organizational structure of WUAs in this research area was organized based on two cases the first WUA members were small in numbers (5-10) it had executive committees (chairman, deputy chairman, secretary, accountant, and casher) and the second the number of WUA were large in number the structure organized in three main organization (executive, control, and dispute settlement committees) and other committees include these committees in Figure 4.3.

The duties of the executive committee were the implementation of the decision passed by the general assembly, passing administrative decisions, preparing the work, and budget plan of the association, preparing the agenda for the meeting, recording in writing the agenda of the meeting, and presenting the work and budget. The duties of the control committee are explanation of property and liability, financial investigation balancing of bank accounts, and conducting control. The duties of the dispute settlement committee are to give the solution when the body is aggrieved by the administrative decision of the executive committee. However, WUAs members report that in the current situation, these duties were not implemented on the ground.

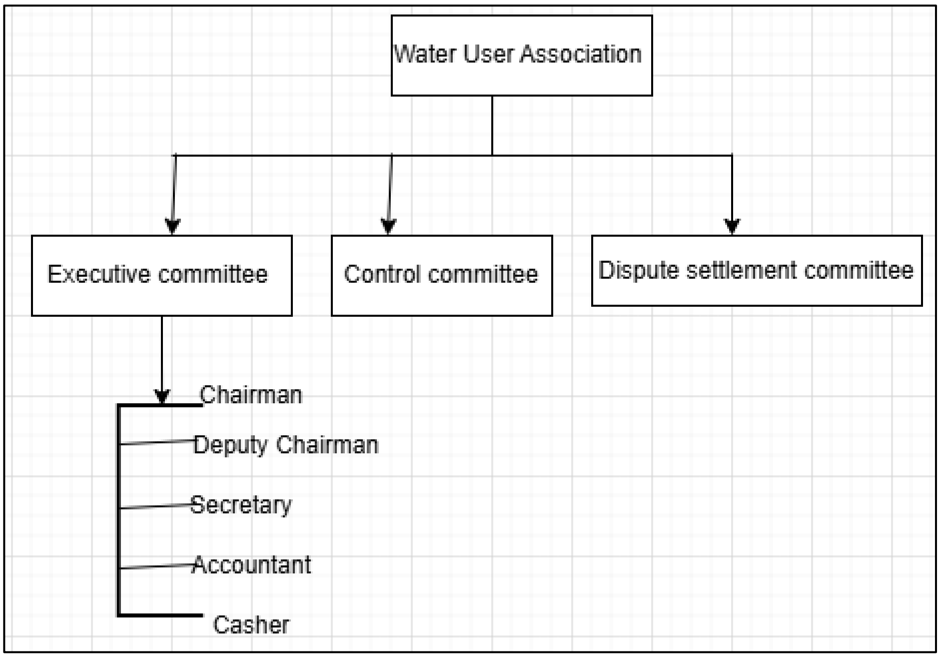

Figure 4. 3 Organizational structure of WUAs

4.4 The Role of Gender in Irrigation Practices

According to the result of group discussions, site visits, and interviews in the selected kebeles, the majority of respondents stated that the role of men is largely related to input supply, land preparation, agro-chemical application, water distribution (both day and night), operation and maintenance of pump or irrigation structures, and engagement with wholesalers. In contrast, women's roles were concentrated more in labor-intensive, subsistence-oriented activities such as seed sowing, transplanting of seedlings, food preparation for workers, weeding and cultivation, sometimes daytime water distribution, harvesting, and retail marketing activities. Almost this result is in line with Kalkidan (2016), who stated that most of the time, female-headed irrigation users are more involved in management activities such as planting, removing weeds, hoeing, and harvesting while male-headed participate in heavy and risky tasks such as land clearing, cultivation, crop watering, chemical spray and transport products in Figure 4.4. Gender-based share of activities in irrigated agricultural practices is summarized in Table 4.7.

Table 4. 7 Gender roles in irrigated farming practices

Role of men	Role of women
Input supply	Ideal support
Land preparation	Transplant/ seed sowing
Agrochemical application	Food preparation for the worker
Weeding and cultivation	Weeding/cultivation
Water distribution in the day and night time	Care for the household
Operation and maintain irrigation structure and pump	Sometimes water distribution in the daytime
Loading and unloading activity	Harvesting
Participation in large markets or wholesalers	Marketing activities (retailer)

Figure 4. 4 Site visit and group identified the role of women and male farmers.

Based on the survey results of female-headed and male-headed households, most respondents 213 (68.1%) had indicated that there were expectations regarding gender roles in irrigation. However, 100 respondents said that no expectations. The findings suggested that there was an expectation for women to be actively involved in irrigation works, but their low level of participation was identified as a key weakness. To address this, the respondents believed there should have been targeted efforts to increase women's participation, likely through training and capacity-building programs. Additionally, the prevalent practice of farmers renting out their land to investors rather than cultivating it themselves was seen as problematic. Crucially, the rules and regulations governing the irrigation organizations needed to be effectively applied in practice, not just exist on paper. There were also expectations that the laws and regulations should have empowered women and enabled them to take on leadership roles within the irrigation associations, rather than just participating as members.

According to the results of this study, the roles of women in irrigation practices differ significantly between male-headed and female-headed households illustrated in Table 4. 8. In male-headed households, women's access to resources is found to be restricted, as the ownership and control of these resources rested predominantly with males. Women's participation in key irrigation-related roles such as acquiring input services, engagement in the field works, farm-level decision-making process, and decision-making on marketing was limited. According to smallholder farmers' responses, under female-headed households’ women contributed a greater role in acquiring resources (land and water), acquiring input services, engaging in the field works, farm-level decision-making process, and decision-making on marketing. They also had a higher degree of control over irrigation-related decisions at the farm level.

According to the survey result, agricultural inputs such as seeds, fertilizers, and pesticides were officially distributed through multi-purpose cooperative associations based on the size of landholdings in the respondents’ communities or organizations. However, the respondents reported that the distribution process lacked transparency and was not carried out equally, particularly for female farmers. Furthermore, most respondents indicated that the supply of these inputs was insufficient, leading them to purchase these inputs with higher costs from different agro-input suppliers. The results further revealed that there were significant gender-based disparities in access to financial resources for acquiring agricultural inputs, including irrigation technology-related supplies.

Table 4. 8 Comparison of roles in irrigation practices between male-headed and female-headed households

Major activities	Major roles of women under	
	Male headed-household	Female headed-household
Acquiring resources (land and water)	In this research area, the most common method of acquiring land was from families. However, the family gives more attention to males than females so the females restricted access to resources or resource ownership controlled by the male. In this case, the role of women was contributed like one family member.	Access to resources/resources ownership by women but the size of land was limited. In this case the role of women acquiring resources required more contribution.
Acquiring input services	Restricted access to agricultural inputs because they were frequently distributed through male farmers, such as fertilizers, seeds, etc.	More direct access to input services.
Engagement in the field works.	Participation in field activities may be more limited, as men dominate the more labor-intensive tasks. In this case, the women participated in household activities and labor work such as weed removal, harvesting, etc.	Allow greater responsibility and involvement in carrying out the various field works from land preparation to marketing.
Farm-level decision-making process	Male-dominated	Have a greater role in making farm-level decisions.
Decision-making on marketing	Men have more control	The main role of women

According to female and male respondents, 209 (66.8%), reported that females don't have equal access to all irrigation inputs, with men getting more of the agricultural inputs than females. There is no microfinance service in the area to enable access to financial resources. Additionally, interview results indicated reports of corruption in this research area, particularly during the distribution of irrigation pumps. However, 104 (33.2%) respondents stated that access to the pumps was equal.

The respondents of this survey further stated that there is a gender disparity in access to extension services and training related to irrigation and water-efficient agricultural practices. According to the respondents, women and men do not have equal access to these services and training. In this regard, men are more likely to benefit from having access to these extension services and training compared to women. This finding is in line with (Fikirie et al., 2017), who reported that MHH irrigation users have more access to extension services than their FHH counterparts. However, gender played a significant role in determining the participation of women and men in agricultural markets, particularly in the sale of irrigated agricultural products. The fact that women were often confined to working at home and did not have access to market-related information, has disadvantaged them in setting market prices for their agricultural products.

The survey results indicate significant disparities in pricing and value chains for agricultural products based on the gender of the producers. During the observation period and FGDs, men dominated the market linkages, while both female and male producers participated in price determination, their influence was often mediated by the brokers within the value chain. This finding is consistent with the work of Fikirie et al. (2017), who stated that in on-farm selling, irrigation users from female-headed households (FHH) were challenged by brokers regarding crop prices.

The research has identified key challenges and opportunities for both women and men in accessing and benefiting from agricultural markets related to irrigated food production in the Ziway and Meki areas. This finding is contrary to Kalkidan (2016), who described that distance from the local market is the major market problem in the Ziway Lake Watershed. Challenges include seasonal price fluctuations and oversupply of produce leading to low demand, issues with brokers and transportation, unequal market linkages favoring men, and overall low production. This finding is similar to Kalkidan (2016), who stated that market problems such as frequent low prices at peak supply periods, lack of marketing chain, and information gap. However, the area offers also significant opportunities, such as abundant water resources, skilled labor, and experts, access to markets in nearby cities like

Addis Ababa, Adama, Hawassa, etc., support from NGOs, the ability to cultivate using both irrigation and rainfall and secure land and water ownership right.

4.5 Sustainability

The Federal Democratic Republic of Ethiopia is aware of the importance of sustainable use and management of natural resources. In line with this, the Government has issued several Proclamations and Regulations. To mention some: Ethiopian Water Resources Policy (1999), Ethiopia Water Resource Management Proclamation No. 197/2000, Ethiopian Water Resources Management Regulation (115/2005), Environmental Pollution Control Proclamation (No.300/2005) and Rural Land Administration and Land Use Proclamation (No. 456/2005). Policies and legal provisions exist across all relevant sectors to promote the sustainable use of natural resources. However, their consistent implementation on the ground remains a persistent challenge.

During the survey, respondents were asked whether they perceive changes in resource use and development impacts on resources. The results are presented in Table 4.9. The lack of a buffer zone along the lake shore and the absence of agroforestry, and soil conservation upstream contributed to the siltation of all lakes (Etissa et al., 2014). Agricultural use of groundwater is rising due to shallow to very shallow water tables along the lake shores and rivers and the availability of various sizes of water pumps in the study area (Etissa et al., 2014). Table 4.9 shows that the local community is well aware of the agricultural land expansion and its associated impacts, including increased water withdrawal from the lake, fertilizer use, pollution, wetland shrinkage, and rising soil erosion.

The survey results presented in Table 4.10 reveal that the predominant perception among respondents is that intensified water withdrawal from the lake will lead to a decrease in its water level, as indicated by 50.5% of participants. Additionally, a notable portion of respondents anticipates that the lake will diminish (10.2%) and that vital ecosystem services will be adversely affected (11.5%). Conversely, only a small minority (4.5%) believe that intensified water withdrawal will have no impact on the lake. These findings underscore widespread concern regarding the potential consequences of increased water extraction on the lake's health and sustainability.

Table 4. 9 Community perceptions about changes in resource use impacts on resources as a measure of sustainability.

Resources use and impacts	Increasing		Decreasing		No change		I don't know	
	N	%	N	%	N	%	N	%
Agricultural land	301	96.2%	11	3.5%	1	0.3%		
The level of soil fertility	98	31.3%	206	65.8%	7	2.2%	2	0.6%
Crop productivity	134	42.8%	171	54.6%	7	2.2%	1	0.3%
Chemical fertilizer use	276	88.2%	25	8.0%	7	2.2%	5	1.6%
Water withdrawal from the lake	245	78.3%	45	14.4%	18	5.8%	5	1.6%
Groundwater use	238	76.0%	39	12.5%	25	8.0%	11	3.5%
Lake level	38	12.1%	252	80.5%	16	5.1%	7	2.2%
Lake water pollution	262	83.7%	26	8.3%	14	4.5%	11	3.5%
Wetland around the lake	199	63.6%	53	16.9%	21	6.7%	40	12.8%
Industries around the lake	262	83.7%	27	8.6%	20	6.4%	4	1.3%
Discharging poor-quality water into the lake	250	79.9%	39	12.5%	14	4.5%	10	3.2%
Buffer zone around the lake	80	25.6%	210	67.1%	12	3.8%	11	3.5%
Soil erosion	270	86.3%	19	6.1%	16	5.1%	8	2.6%
Intrusion of sediment into the lake	281	89.8%	14	4.5%	10	3.2%	8	2.6%

Table 4. 10 Perceptions of Community on the Impact of Intensified Water Withdrawal on Lake

Choices	N	%
Nothing will happen to it	14	4.5%
The lake level decreases	158	50.5%
The lake will diminish	32	10.2%
Ecosystem services will be affected	36	11.5%
The lake level decrease and the lake will diminish	27	8.6%
The lake level decrease and ecosystem services will be affected	27	8.6%
The lake level decreases, the lake will diminish and ecosystem services will be affected	19	6.1%
Total	313	100.0%

About 27.5 % of respondents reported being not aware of the consequences of over-irrigation, while 72.5% said they were aware similarly, 42.8% of respondents stated they were unaware of the consequences of under-irrigation, while 57.2% indicated they were knowledgeable about the consequences in Table 4.11. The respondents were also requested to mention some of the consequences of over- or under-irrigation. The key consequences they mentioned are summarized below:

The main consequences of over-irrigation that were identified include:

- Removal or uprooting of early transplanted seedlings
- Root damping (a fungal disease that affects plant roots)
- Depletion of soil nutrients
- Water loss
- Environmental diseases
- Generally, over-irrigation can lead to low crop production.

The main consequences of under-irrigation that were identified include:

- Plants are unable to resist disease
- Unhealthy plant growth and color change
- Increased input costs to compensate for low production
- Minimize crop production

As it is depicted above, the local farmers have adequate knowledge about the consequences of over-irrigation or under-irrigation.

Table 4. 11 Farmer's awareness about consequences of over-irrigation and under-irrigation

	Over irrigation		Under irrigation	
	N	%	N	%
Yes	227	72.5%	179	57.2%
No	86	27.5%	134	42.8%

4.6 Gender-based performance evaluation of the small-scale irrigated farms

4.6.1 Agricultural practice

4.6.1.1 Land preparation

Land clearing is the first step in preparing the land. As shown in Figure 4.5, dried leaves, roots, and weeds on the field were burned. Afterward, three farms were plowed in five rounds. The first round was done using machinery (modern farming), while subsequent rounds were completed using oxen (traditionally) over a month. This finding is similar to Hailu & Mengistu (2022), who stated that most of the time tractors are used only for primary tillage or for land preparation. This multi-pass plowing approach helped to preserve the soil and minimize weed regrowth. The same process was followed across all three selected farms. It is recommended that the land be plowed at least one month before planting (Project et al., 2019b). Therefore, this is also a good and supported activity. But one onion (female farm) has plowed the farm in three rounds until half a month. This was the main cause of the decreased crop yield for this farm. Compared to the four farms, Negalegn female farm, the land was not well leveled. The consequence of this problem was that the quantity and quality of the yield were reduced due to water logging that had been encountered by the rainfall.

Figure 4. 5 Different weed and unwanted material removal before land preparation

Figure 4. 6 Discussion with farmers during land preparation

4.6.1.2 Input and technology use

An improved variety of seeds is the most dynamic instrument for increasing agriculture production and is also an economical input (Hailu & Mengistu, 2022). The seed variety of the two onion farms was the Nafis seed variety. Farmers can use a variety of Nafis and a 10 cm distance between plants to increase their onion production (Alemu et al., 2022). The Seed variety of the two-cabbage farm was Victoria seed. The total plant population of the Edo Gojola male farm and Edo Gojola female farm were 3100 and 3640 plants respectively. The total plant population of Negalgne female and male farms were 220668 and 129312 plants respectively. Generally, the farmers used improved variety. This finding is in line with Tadesse et al. (2023), who stated that greater yield was achieved through the proper use of recommended technology packages, such as the use of the improved Nafis variety with its proper agronomic management. In this study, the farmer used machinery and tools like the tractor, Knapsack spryer, pumps, etc.

4.6.1.3 Weeding

High weed infestation would be seen through direct field observation. The farmers remove this weed by labor or manually. However, some farmers lose the product due to weeds because of a lack of finance to pay for labor workers, late start of weed removal, and manual weed removal is not enough to remove the weeds. The main cause of Negalgne female farm (onion crop) crop yield decreases due to less or insufficient weed control strategies and water logging during the rain period. According to the response of the farmer this cause occurred because of a lack of finance for the payment of labor workers .

4.6.1.4 Fertilizer and pesticide

Oromia region is the second from Ethiopia to use (natural + commercial) fertilizers (ESS, 2022). All female and male selected farmers' fertilizers applied for the first time (during transplant) one quintal of DAP and 0.5 urea and after cultivation, one quintal of NPS with 0.5 urea for each farm and Ajanta, Radical high protector was liquid fertilizer for cabbage crop. Tutan and Bravo to prevent insects for cabbage. Profit, Blom, Agrofit, and Best were liquid fertilizers. Orozem and Road Mall was a pesticide for onion crops in Appendix Figure 2. Cabbage worms attack the productivity of the cabbage crop (male-managed farm) in a significant amount under the studied area and would be recognized in Figure 4.8. One of the main reasons for the decrease in the quality of yield and the deterioration of this product was the late use of pesticides. This was due to a lack of knowledge about how to use and when to use pesticides.

Figure 4. 7 Image of low-quality yield in Edo Gojola male farm

4.6.2 Irrigation application in the study areas

4.6.2.1 Irrigation method

According to smallholder farmers' responses and direct site observation these two districts such as Dugda (scheme levels) and A.T.J.K. were that all of them were used for furrow irrigation. The result of this study is in line with Desta et al, (2017b); and Etissa et al. (2014), who indicated that furrow irrigation is the only type being practiced by farmers in the watershed. According to the female-headed and male-headed households' responses, the respondents stated that they used 243 (77.6%) modern and 70 (22.4%) traditional irrigation practices. This result agrees with the findings of Hailu & Mengist (2022), who argued that major irrigation systems or schemes that were used by respondents were modern types (76.81 percent of respondents).

4.6.2.2 Theoretical crop water requirement

The most commonly used to determine the ETo is the Penman-Monteith method, which is described in detail in FAO Irrigation and Drainage Paper 24. The general ETo values of this research were calculated using climatic data in Appendix Figure 3. The average daily ET_o values of this study were 4.22 mm/day. The value of the calculated crop water requirement and irrigation water requirement for each managed field are listed in Table 4.12. The recommended seasonal CWR of cabbage and onion are (350-500 mm) and (350-550 mm), respectively (Brouwer et al., 1987). However, this recommendation was old, and new varieties matured over a short time and required less water.

Table 4. 12 Growing period of each farm from transplanting to harvesting

Crop types	Managed farms	Starting date	Harvesting date	Total days from start to harvest	Reference
Cabbage	Male	April 16	July 14	90	2.5 – 4 months depending on variety and location after transplanting (Project et al., 2019a)
	Female	May 9	August 5	89	
Onion	Male	April 13	July 18	97	90-100 (Alemu et al., 2022) for the Nafis variety after transplanting
	Female	April 3	July 11	100	

Table 4. 13 Result of theoretical CWR and irrigation water requirement

Managed fields	Crop types	Area (ha)	CWR mm/season	Pe mm/season	IWR mm/season	IWR m^3/season
Male farm	Cabbage	0.17	337.9	152.3	184.2	313.14
Female farm		0.19	309.1	179.9	133	252.7
Male farm	Onion	0.22	426.6	172.6	246	541.2
Female farm		0.24	446.3	169	276.7	664.08

4.6.2.3 Crop water requirement, IT, and II in the field study

During the monitored and observation of activities seen in the research area, it was found that the irrigation time depended on the number of water users per available motor pump. Farmers who owned their motor pumps were able to irrigate in both the morning and afternoon, as they did not have to wait in line. In the same way, Etissa et al. (2014)) explained that 38.14 percent of the household vegetable growers surveyed stated they used to irrigate their vegetables in the morning and the afternoon. However, farmers who shared pumps within a group or rented motor pumps had to wait their turn in the queue. As the number of water users per pump increased, the waiting time in the queue also increased, and the irrigation time for these farmers who shared or rented pumps became longer, so they did not know the irrigation time. Therefore, in this study area, the irrigation interval is irregular. The smallholder vegetable producers stated that irrigating their vegetables during the night is more suitable for crops. This finding is similar to Etissa et al. (2014), who stated that the farmers who irrigated in the morning reportedly assumed that they would use this specific time for water-saving techniques and minimize irrigation water loss due to mid-day evaporation. Water efficiency at the field level is by design between 50-60% for surface irrigation (Salman, 2020). The overall mean application efficiency of the scheme is estimated at 58.2% (Haile et al., 2020).

Table 4. 14 Result of seasonal IWR used by farmers

Managed field	Crop types	Area ha	IWR m^3/season
Male farm	Cabbage	0.17	191.56
Female farm		0.19	197.46
Male farm	Onion	0.22	467.49
Female farm		0.24	365.81

In the comparison of theoretical and field irrigation water requirements (IWR) for cabbage, male farms decreased their IWR from 313.14 m^3 to 191.56 m^3, while female farms reduced theirs from 252.7 m^3 to 197.46 m^3 respectively, indicating improved irrigation efficiency for both genders. In onion cultivation, male-managed farms saw a reduction from 541.2 m^3 to 467.49 m^3, while female farms decreased from 664.08 m^3 to 365.81 m^3. Compared to all farmers, field irrigation water requirements or the amount of water used by the male-managed farm (onion crop) and the theoretical irrigation water requirement calculated by CROPWAT 8.0 had been closer. Therefore, it would have been better for all farmers to share their experiences and receive professional help.

Drainage structures are the main benefit of irrigation water management. From the four selected sample farms, two had a drainage canal in Figure 4.9, while the two other farmers did not have a drainage canal to dispose of the excess amount of irrigation water. Most farmers did not have any awareness or understanding of the benefits of drainage structures. Thus, to improve the knowledge and skills of farmers in irrigated vegetable production, due attention should be given to enhancing extension services on irrigation and drainage management (Etissa et al., 2014).

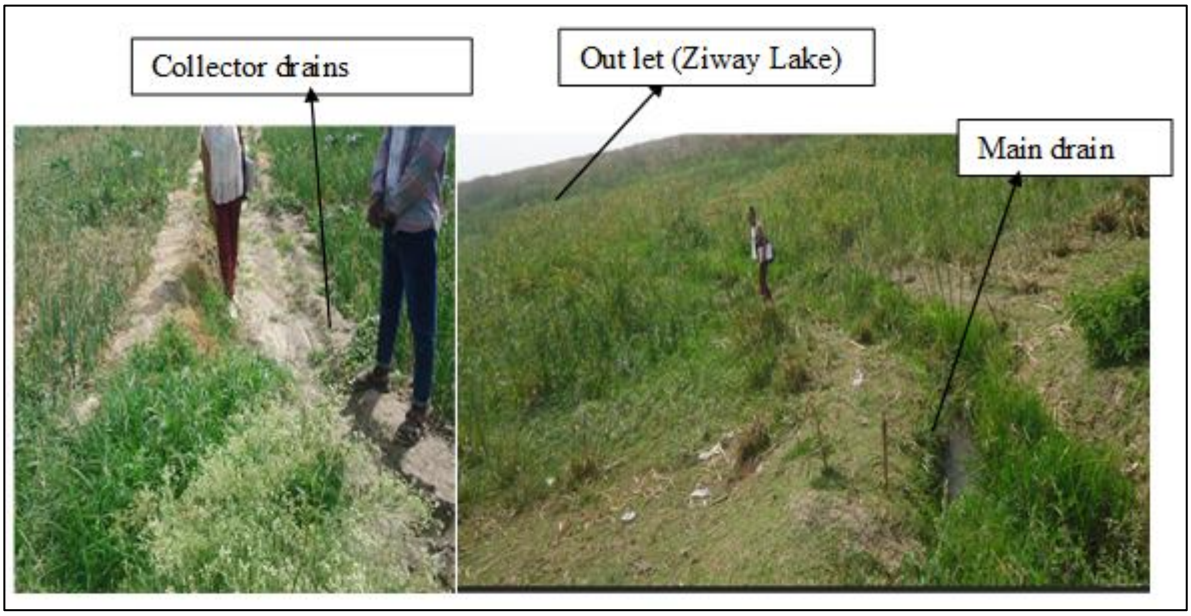

Figure 4. 8 Drainage canal for Negalgne female and male-managed farm

4.6.3 Physical performance in SSI farms

During the observation period in the research area, two types of water transportation systems were observed for delivering water from the motor pumps to the fields. Some farmers directly irrigated their fields from the delivery hoses connected to the pumps. In contrast, other farmers distributed the irrigation water through constructed canals before it reached their fields. This result is similar to Etissa et al. (2014), who stated that many vegetable growers have motor pumps for lifting water that is supplied to vegetable crops in fields through furrow irrigation methods. However, during site visits, it was evident that the sampled farms experienced significant water loss due to leakage from poorly maintained delivery pipes. The condition of these pipes was inadequate for effective irrigation water distribution, as illustrated in Appendix Figure 5.

4.6.4 Water conveyance efficiencies

In this field site, the main cause of conveyance water loss was percolation. The conveyance efficiency was calculated using equation 3.5, and its values were 88.6 % with a conveyance discharge loss of 0.057 L/s and 77% with a conveyance discharge loss of 0.23 L/s for the unlined earthen canals of Negalgne female and male managed farms respectively listed in Table 4.15. The conveyance efficiency for long unlined canals (>

2000 m) is 60, 70, and 80% for sand, loam, and clay soil, respectively; for medium-length unlined canals (200–2000), it is 70, 75, and 85% for sand, loam, and clay soil, respectively; and for short canals (200 m), it is 80, 85, and 90% for sand and loam (Wubetu et al., 2022).

Table 4. 15 Discharge rate of pump, conveyance loss, and efficiencies in selected fields

Managed field	Qinflow (L/s)	Head(m)	Qoutflow (L/s)	Conveyance loss (L/s)	Length of pipe from source to field
Negalgne female farm	0.5	0.021	0.443	0.057	-
Negalgne male farm	1	0.03	0.77	0.23	-
Edo Gojola male farm	0.5	-	0.5	-	360
Edo Gojola female farm	0.5	-	0.5	-	563
Conveyance efficiencies of Negalgne farms (onion crops)					
	Average Ec	Length of canal	Length of pipe from source to secondary canal		Remark with reference
Male farm	77 %	17 m	184		Good when Ec above 70 % (Kibret et al., 2021)
Female farm	88.6 %	5 m	183		Very good when Ec above 70 % (Kibret et al., 2021)

Figure 4. 9 Water transport from delivery pipe to secondary canal

4.6.5 Water use performance in SSI farms

According to feedback from farmers in the area, they are unable to measure the amount of water used in liters per second or total volume directly. Instead, they estimate water application based on their fuel consumption, specifically the amount of diesel used for irrigation. The farmers have determined that approximately 5 liters of diesel is needed to irrigate 0.25 hectares, which includes footpaths and field canals. This estimation is based on their practical experiences and indigenous knowledge.

A formal water allocation system is in place within the district, designed to ensure the fair distribution of water resources among various users, including agriculture, domestic needs, and industrial activities. Although these guidelines aim to promote equitable access, the implementation of water allocation practices often suffers from a lack of transparency, which can lead to inequities in resource distribution. Many communities remain unaware of their rights regarding water usage and the formal allocation processes that govern these resources. This knowledge gap can hinder their ability to advocate for fair access and may exacerbate existing disparities among different user groups.

4.6.6 Result of water and land productivity and efficiency

According to responses from both Female-Headed Households (FHH) and Male-Headed Households (MHH), the average size of land cultivated under irrigation is 0.94 hectares, with a minimum of 0.25 and a maximum of 8.00 hectares. In comparison, the mean size of land cultivated under rainfed conditions is 0.91 hectares, ranging from 0.125 hectares to 5.00 hectares. In total, the area cultivated under irrigation amounts to 295.75 hectares, while the land under rainfed conditions covers 164.62 hectares from 313 sampled households, as detailed in Table 4.16. Regarding harvest frequency, 92.3% of respondents reported achieving two harvests per year, while 7.7% indicated that they manage to harvest three times annually. This data highlights the agricultural practices and productivity levels within the community, reflecting both irrigation and rainfed farming systems.

Table 4. 16 Cultivated land under irrigation and rain-fed conditions (N=313)

	Cultivated land under irrigation (ha)	Cultivated land under rainfed (ha)
Mean	0.94	0.91
Minimum	0.25	0.125
Maximum	8.00	5.00
Sum	295.75	164.62

The major crops grown in the Ziway Lake watershed are cereal and cash crops. Most of the time cereal crops such as (maize, teff, wheat, etc.) were grown as rain-fed, and cash crops such as (tomato, onion, cabbage (head), kale crop, green pepper, etc. were grown under irrigation. However, during group discussions and interviews with female- and male-headed households, the respondents stated that in the current situation, they do not produce cash crops due to the increasing price of agricultural inputs over time. The consequence of this reason was that farmers had to rent out and share their land with investors and private farmers. The respondent's responses to the average yield per crop per hectare were illustrated in Table 4.17.

In this study area the most grown crop was maize, reported by 59.7% (187) of the respondents, followed by tomato 117 (37.4%), onion 93 (29.7%), kale crop 72 (23.0%), wheat 67 (21.4%) and other crops, such as teff, green bean (fossolia), green pepper, head cabbage, barley, and soya bean, are also reported, but with lower frequencies. This data was analyzed by multiple response analysis method illustrated in Figure 4.11.

Table 4. 17 Major crop grown and its crop production

Major crops grown in the studied areas	Average crop production in the study area (Qt/ha)	According to a CSA (2021) report of Ethiopia's average crop production (Qt/ha)
Maize	45	41.79
Teff	12	18.82
Wheat	32	30.46
Barley	19	25.26
Green pepper	40	50.38
Green bean	18	-
Tomato	150	65.2
Onion	120	88.84
Head cabbage	160	84.37
Soya beans	20	24.9
Ethiopian cabbage (kale crop)	115	97.39

Table 4.18 Frequency and percent of major crops produced under small-scale irrigation agriculture

The major crop grown in this area	Response	Percent of cases
	N	Percent
Maize	187	25.4%
Wheat	67	9.1%
Teff	16	2.2%
Tomato	117	15.9%
Onion	93	12.7%
Kale crop	72	9.8%
Green bean	37	5.0%
Green pepper	37	5.0%
Cabbage	34	4.6%
Barley	3	0.4%
Beans	5	0.7%
Total		100%

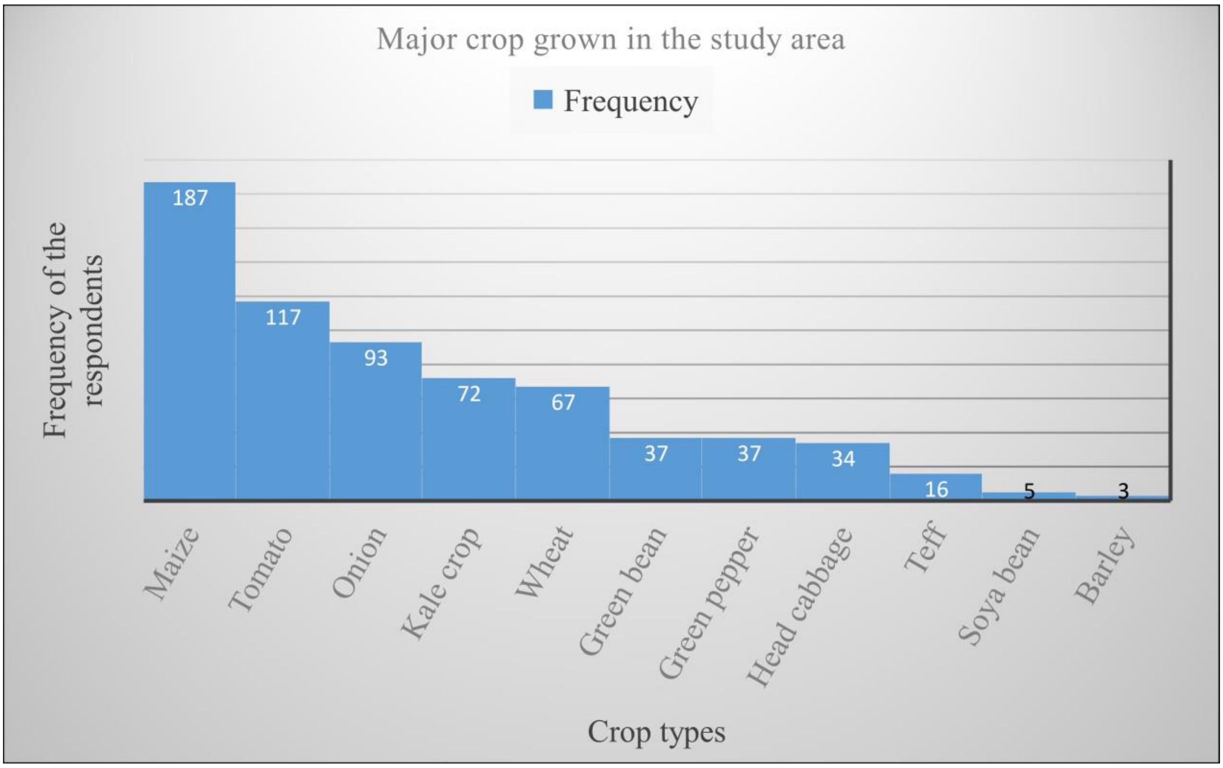

Figure 4. 10 Major crops produced under small-scale irrigation agriculture in the studied area

The main production costs in this study fields are the rent of equipment (tractor and motor pump), inputs (seedling, fertilizers, gasoline/nafta, and pesticides), labor costs (from land preparation to harvesting), etc. The total price from each field was calculated as the multiple of the total yield and the market price of each managed farm at the time of harvesting.

Table 4.19 illustrates that female-managed farms generally achieve higher yields for cabbage but lower profits for onion compared to males. The female cabbage farm not only produced more but also commanded a higher market price because of quality yeild, resulting in substantially higher profits. Conversely, while the male onion farm generated a significantly higher profit due to a greater yield and unit price, the female onion farm, despite lower yields and profits, still contributed positively to overall production. The Nafis onion varieties have yielded the uppermost commercial bulb's total yield (35.4 t ha^{-1} or 354 Qt ha^{-1}) than Bombay Red and Adama Red (Alemu et al., 2022). Yields of cabbage were 300-750 Qt/ha depending on the variety and crop husbandry (Project et al., 2019a).

Table 4. 19 Output production of male and female-managed fields

Managed fields	Crop type	Location	Area (ha)	Yield (Qt/ha)	Total yield (Qt)	Unit price per Qt (ETB)	Total price (ETB)	Production costs	Profit
			1	2	3 = (1) *(2)	4	5 = (3) *(4)	6	(5)-(6)
Male farm	Cabbage	Edo Gojola	0.17	232.9	39.6	960	38000	30000	8000
Female farm	Cabbage	Edo Gojola	0.19	252.6	48	1333	63984	40000	23984
Male farm	Onion	Negalgne	0.21	220	46.23	3700	171051	72800	98251
Female farm	Onion	Negalgne	0.23	130	30	3000	90000	74800	15200

Water productivity (kg/m³): Water productivity was calculated using Equation (3.6), and the results were 21, 24, 10, and 80 kilogram per cubic meter at the Edo Gojola male and female farms and Negalgne male and female farms respectively. Both cabbage types show almost similar water productivity, indicating that they utilize water efficiently relative to their yield. For onions, male-managed crops exhibit higher water productivity (10 kg/m³) compared to females, which also stands at 10 kg/m³ but with a significantly lower yield.

Land productivity (kg/ha): Land productivity was calculated using Equation (3.7), and the results were 22765, 25263, 21014, and 12500 kilogram per hectare at the Edo Gojola male and female farmers and Negalgne male and female farmers respectively. Meki scheme showed the highest land productivity for onions with a magnitude of 145.5 quintals/ha (Haileslassie et al., 2016).

The comparison of agricultural output based on gender reveals distinct differences in productivity for cabbage and onion crops. Cabbage yields from female farmers exhibit the highest land productivity at 25260 kilogram per hectare (kg/ha), followed closely by male farmers at 22770 kg/ha. This indicates that female farmers are more effective at converting land area into yield for cabbage. In contrast, male farmers achieve better onion yields, producing 21010 kg/ha, compared to female farmers' 12500 kg/ha. This further reinforces the trend of gender-based productivity differences in agricultural outputs.

Water use efficiency: The efficiency of water productivity was calculated using Equation (3.8), and the results were 22 kg/m^3, kg 61 kg/m^3, 19 kg/m^3, and 21 kg/m^3 at the Edo Gojola male and female farms (cabbage crop) and Negalgne male and female farms (onion crop) respectively. The water use efficiency metrics show that a female-managed farm (cabbage crop) has a higher efficiency compared to male cabbage.

Land use efficiency: The efficiency of land productivity was calculated using Equation (3.9), and the results were 15840 kg/ha, 19200 kg/ha, 18492 kg/ha, and 8000 kg/ha at the Edo Gojola male and female farms (cabbage crop) and Negalgne male and female farms (onion crop) respectively.These results indicate a disparity in land productivity which was influenced more by on-farm practices and inputs than gender disparities. According to the response of the farmers and site observation the main factors for this diffrences lack of finace and lack of knowalege for use pesticide. Compared to the four farms, in the Negalgne female farm the land was not well leveled the consequence of this problem was that the quantity and quality of the yield was reduced due to water logging that had been encountered by the rainfall. Generally, female farmers demonstrated superior performance in cabbage production, while male farmers excelled in onion yields so this farmer shared experience with other farmers very well.

Table 4. 20 Productivity and water use efficiency of each managed farm

Managed farms	Yield (kg)	Water input (m^3)	Cultivated land (ha)	WP (kg/m^3)	LP (kg/ha)	Water use efficiency kg/m^3	Land use efficiency kg/ha
Male (cabbage)	3960	191.6	0.17	20	22770	22	15840
Female (cabbage)	4800	197.5	0.19	20	25260	61	19200
Male (onion)	4623	467.5	0.22	10	21010	19	18492
Female (onion)	3000	365.8	0.24	10	12500	21	8000

WP = water productivity; LP = land productivity

4.6.7 Harvesting

In this study, the two selected farmers harvest their onion production immediately and sell it directly to merchants. In contrast, the two selected farmers growing cabbage engage in day-to-day harvesting, utilizing a retailer marketing system for sales. During the harvesting period, both male and female laborers participate in agricultural activities, reflecting a collaborative approach to labor. Both onions and cabbages are easily marketable; however, after harvesting, the farmers do not utilize any storage facilities for long-term preservation. This lack of storage options may impact the shelf life and marketability of their produce.

4.7 Transportation

Two selected onion crop farmers were transported in a car, while the other two cabbage were transported in a cart. Therefore, this selected farm was close to transport however far from this site like the other rural parts of Ethiopia it is difficult for farmers to transport.

4.8 Use of agricultural products (marketing and own use)

According to the smallholder irrigation farmer response cereal crops are for domestic consumption and cash crops are used for marketing. According to the smallholder irrigation farmer response in this research area, the community used for domestic consumption was cereal crops, especially maize. This result is in line with Negasa (2023), who stated that most of the communities in the study area produce maize for feeding their households. However, cash crops are used for marketing. Table 4.21 illustrates the average utilization percentage of agricultural products for the combination of cereal and cash crops.

Table 4. 21 Utilization percentages for agricultural products

	Use for selling %	Use consumption%	Use reserve as seed material %	Use donation for relatives %	Use others %
Mean	78.50	11.14	5.17	3.74	3.86
Minimum	20	1	1	1	1
Maximum	99	70	37	10	15

4.9 Environmental Sustainability

The KIs response stated that there were no regulations or monitoring mechanisms that help to avoid the over-use of water and chemical fertilizers. However, there is a legal training requirement under the direction of the Bureau of Agriculture. There is no law for farmers level but for large projects, there is environmental protection by control mechanism for discharging of poor-quality water into the lake. KIs state that there is no buffer zoning to protect the lake from shore farming and intrusion of sediment and pollution into the lake. However, expert advice for farmers, but not implemented. The chemicals used by these farmers enter the lake differently. This means that the water and biodiversity make an impact. While the commercial fertilizer they use looks good for the plant and also produces good yields, it is clear that in the future, it will degrade the fertility of the soil.

5 . CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study reveals significant gender disparities in agricultural participation and decision-making, particularly within the context of irrigation activities. Women face numerous challenges, including cultural beliefs that discourage their involvement, high input costs, inadequate support from stakeholders, financial constraints, limited access to gender-focused training services, crop diseases, and the heavy burden of household responsibilities. Sustainability in resource management is a pressing concern in the Ziway Lake Watershed, where agricultural practices significantly impact both water resources and the environment. Despite the Ethiopian government's commitment to sustainable resource management through various policies and regulations, effective implementation continues to pose challenges. Establishing buffer zones along the lake shore is essential to protect water quality and biodiversity while reducing siltation and erosion.

The performance of irrigation management organizations, specifically Water User Associations (WUAs), is crucial for the success of irrigation practices in the Ziway Lake Watershed. Although all surveyed farmers are members of a WUA, many lack awareness of their roles and responsibilities within these organizations. While the existing legal framework promotes gender inclusivity, practical implementation remains insufficient, hindering women's participation and access to vital resources. The advantages of having a WUA such as sharing experiences, pooling resources, and enhancing effective water management practices are evident. However, without proper supervision and guidance, these associations risk stagnation or breakdown.

The study also highlights the ineffective management of drainage structures in irrigation systems, which remain underutilized due to a lack of awareness among farmers. Analysis of water productivity and efficiency indicates that female farmers exhibit superior water use efficiency for cabbage cultivation, while male farmers perform better with onion production. These findings emphasize the critical role of gender dynamics in agricultural productivity and resource management. Overall, this research not only aimed to collect data but also served as a platform for professional guidance and advice from experts during focus group discussions (FGDs). This collaborative approach fosters knowledge exchange between male and female farmers, enhancing their understanding of sustainable practices and resource management strategies. Addressing these issues will be vital for promoting equitable participation in agriculture and improving overall productivity in the Ziway Lake Watershed.

5.2 Recommendations

Based on the findings from the study on the role of gender in small-scale irrigation management practices in the Ziway Lake Watershed, several recommendations can be made to enhance environmentally sustainable and equitable irrigation and agricultural practices:

- The research indicates that farmers do not have equal access to various services, with female farmers facing significant challenges. It is essential to develop and implement targeted training programs that address the specific needs of both male and female farmers. These programs should focus on effective irrigation management techniques, resource allocation, and decision-making processes to ensure equal participation and empowerment across genders.
- Given the critical role of the Ziway Lake in the community, stakeholders including environmental experts, irrigation specialists, local communities, and NGOs must collaborate to protect the lake from pollution and waste. The government should design policies that raise awareness among water users about sustainable practices and the importance of preserving this vital resource.
- The study reveals a knowledge gap among some farmers regarding irrigation and agronomic practices. Future initiatives should aim to modernize farming techniques by strengthening skills through workshops and experience-sharing sessions with model farmers who possess advanced knowledge in irrigation and agronomy. This will benefit all members of Water User Associations (WUAs).
- Weeds and crop diseases significantly reduce yields in the area. To combat these issues, Integrated Pest Management strategies incorporating cultural, mechanical, biological, and chemical control methods should be promoted as effective solutions to enhance crop health and productivity.
- While this study addressed conveyance efficiency, future research should also include application efficiency metrics to provide a comprehensive understanding of water use effectiveness in irrigation practices. This will help identify areas for improvement and optimize resource management.

By implementing these recommendations, stakeholders can work towards creating a more equitable and sustainable agricultural landscape in the Ziway Lake Watershed, ultimately enhancing productivity and resource conservation for all farmers.

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APPENDICES

Survey/Questionnaires for water users and KIs

Appendix 1: Household Survey Questionnaires

A. Personal and demographic information

- Name: ___________________________________
- Gender: __________________________________
- Your age: ___________________
- Your marital status: □Married □Not married □Divorced □Widower
- Level of education: ______________
- Household size: _________________
- Primary occupation: _____________

B. Resources ownership or access to resources

1. Do you own the land? □Yes □No
2. If your answer to question 1 is yes, respond to the following questions: how did you own the land?
   a) Through redistribution of land
   b) Through transfer from parents
   c) Renting
   d) Liaise
   e) If others, mention:____
3. What is the size of the land in ha? _________________
4. Do you have access to water for your land? □Yes □No
5. If your answer to question 4 is yes, what is the source of water?
   a) River b) lake c) groundwater d) other, _____________
6. Do you experience water shortage? □Yes□No, if yes, how do you overcome it? For example, water conservation practices or any technology…

   ____
7. Are there any constraints or challenges you face in accessing land and water? Mention the major causes:

8. Is there any bylaw or regulation that restricts the amount of water you use? □Yes □No, .

If yes, describe____

9. Are there any gender-specific constraints you face in accessing resources for irrigation? □Yes □No. If yes, mention the major causes________________________________

10. Challenges and barriers:

1. What are the main challenges faced by women in participating in irrigation activities?
2. Are there any gender-specific barriers that hinder participation in irrigation?

C. Role of gender

1. In your area, what are the typical roles of men and women in irrigation?

Role of men	Role of women

2. Are there any expectations regarding gender roles in irrigation?
3. How do the major roles of women under male-headed and female-headed households differ in irrigation practices?

	Major activities	Major roles of women under	
		Male headed household	Female-headed household
1	Access to resources (land and water)		
2	Access to input services		
3	Engagement in the field works.		
4	Farm level decision-making		
5	Decision-making on marketing		
6			

4. How are agricultural inputs, such as seeds, fertilizers, and pesticides, distributed among women and men in your community or organization?

5. Are there gender-based disparities in access to financial resources for acquiring agricultural inputs, including irrigation-related supplies?
6. From your perspective, do women and men have equal access to extension services and training related to irrigation and water-efficient agricultural practices?
7. How does gender influence the participation of women and men in agricultural markets, including the sale of irrigated agricultural products?
8. Have you observed any disparities in market access, pricing, and value chains for agricultural products based on the gender of the producers?
9. What are the specific challenges and opportunities for women and men in accessing and benefiting from agricultural markets related to irrigated food production, based on your observations and experiences?
10. From your perspective, what are the gender-based differences in the productivity and yield of small-scale irrigated farms, particularly about the use of irrigation pumps?
11. Have you observed any disparities in the performance of farms operated by women and men, specifically concerning the use of irrigation pumps?

D. Irrigation practice

1. What is the size of land you cultivate under?

a) Irrigation:____________ha b) rainfed:__________ha

2. What are the irrigation methods you adopt?

a) Furrow irrigation b) Basin irrigation c) Sprinkler irrigation d) Border irrigation

e) others: ________

3. Are your farming dominated by traditional or modern irrigation practices?

4. Do you know the amount of water you apply every time you irrigate? □Yes □No

5. What are the typical roles and responsibilities of women and men in utilizing water resources for agricultural production in your community or organization?

6. How do gender dynamics impact the access to and utilization of water resources for agricultural purposes, particularly about irrigation?

7. What are the major crops you grow?________________________________

8. How often you harvest per year:___________________________________

9. What is the yield you get per crop per hectare?______________________

10. Indicate what percentage of your agricultural produce you use for:

	Use for	%
a)	Selling (marketing)	
b)	Own consumption	
c)	Reserve as seed material	
d)	Donation for relatives	
e)	Others:	

E. Irrigation management

1. What is the major water management institution in your area? □WUA □Other
2. Are you a member of the WUAs? □Yes □No
3. What is your role in the WUA? a) member b) committee member c) others
4. How do you rate the current performance of WUA?
   a) Efficient
   b) Moderately efficient
   c) inefficient
5. Does the WUA have written bylaws? □Yes □No
6. Do the members of the WUA know their duties and responsibilities? □Yes □No
7. How would you describe the decision-making processes within the irrigation management organization?

a) Centralized c) Participatory

b) Decentralized d) Others:______________

8. What are the strengths of the organization in managing irrigation systems?
9. What are the weaknesses of the organization in managing irrigation systems?
10. What are the major sources of conflict in the area related to land and water use?
11. How does the organization manage the conflict?

F . Sustainability

1. Respond to the following questions (by marking √) based on your experiences in the area over the last 5-10 years.

		Increasing	Decreasing	No change	I don’t know
1	Agricultural land				
2	The level of soil fertility				
3	Crop productivity				
4	Chemical fertilizer use				
5	Water withdrawal from the lake				
6	Groundwater use				
7	Lake level				
8	Lake water pollution				
9	Wetland around the lake				
10	Industries around the lake				
11	Discharging poor-quality water into the lake				
12	Buffer zone around the lake				
13	Soil erosion				
14	Intrusion of sediment into the lake				

2. Do you know the consequences of over-irrigation? □Yes □No

If yes, mention some:____

3. Do you know the consequences of under-irrigation? □Yes □No

If yes, mention some:____

4. Which sector relies most on the lake for its water supply?

a) Irrigation
b) Municipality
c) Floriculture

5. According to your perception, what will happen to the lake if water withdrawal intensifies?

a) Nothing will happen to it.
b) The lake level decreases.
c) The lake will diminish.
d) Ecosystem services will be affected.
e) Others,________________

Appendix 2: Checklist for discussion with committee members of WUA

1. How many members does your association have?
2. What are the major duties of the committee?
3. How is your WUA structured in terms of irrigation management?
4. How are the members of the committee elected? (participatory)
5. Do you have bylaws or regulations that describe the duties and responsibilities of all members and the committee?
6. Are females well-represented at all levels of decision-making?
7. Is there any barrier that hinders female representation at the management level?
8. Is there any approval or control mechanism as to how much water members can withdraw from the lake?
9. Is there any fee that members contribute to the WUA? If yes, how much?
10. Is there any policy or regulation that your members have to respect (for example, buffer zone, fertilizer use, water quality, etc.?
11. How rate the performance of the management committee?
12. What are the major problems the committee faces while discharging its duties?
13. What are the major problems facing the members in their irrigation practices?
14. Do you get enough support from the local agricultural office?

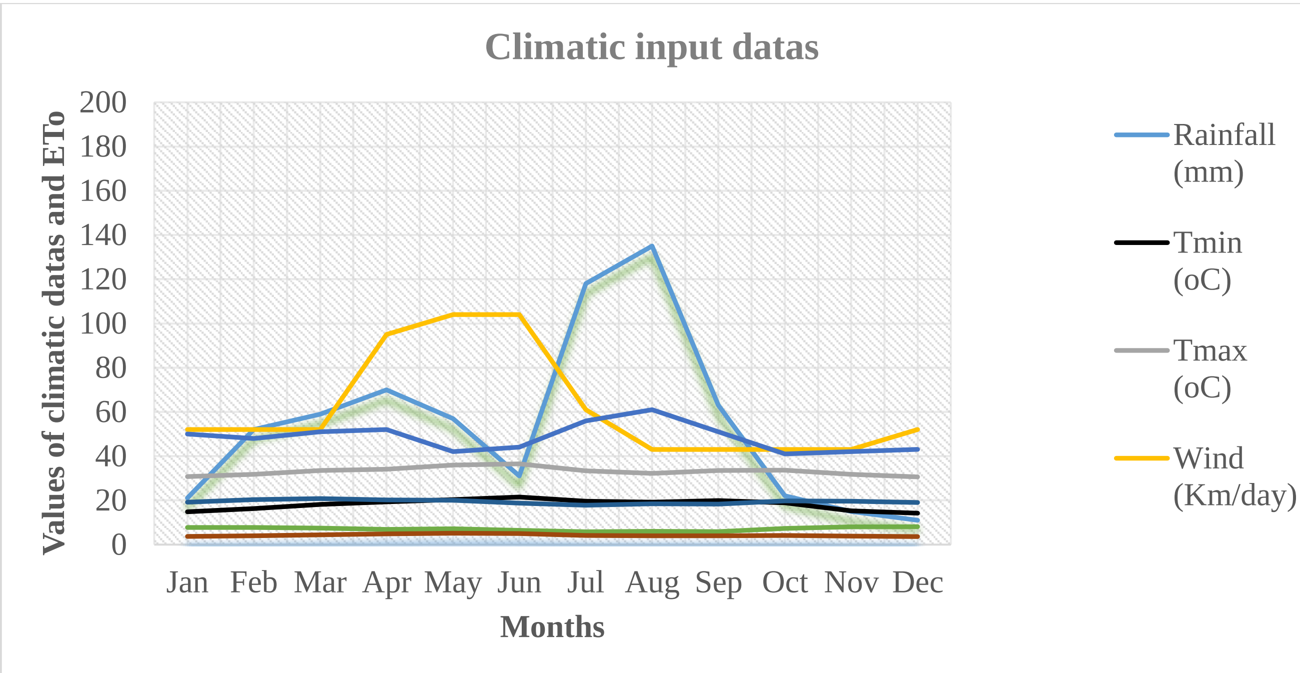
Appendix 3: Checklist for key informant discussion (local government officials, irrigation expertise…

1. What are the major sources of land ownership in the area?
2. WUAs are important institutions for irrigation management at the grassroots level. Who is responsible to organize and legalize the associations?
3. Is there written laws and regulations that govern the operation of the associations? Who prepared it and what is the level of users' participation?
4. Is there any provision that encourages female participation in decision-making?
5. Is there any special support for female farmers in terms of access to resources?
6. Are there any regulations or monitoring mechanisms that help avoid the over-use of water and chemical fertilizers?
7. Is there any control mechanism for discharging poor-quality water into the lake?
8. Do the WUAs have access to extension and input support services? Who is responsible for providing these services?
9. Which farming practices are dominant in the area, traditional or modern?

10. Is there any permit mechanism for water withdrawal from the lake?
11. Is there any buffer zoning to protect the lake from shore farming and intrusion of sediment and pollution into the lake?
12. What environmental, agricultural, water use, etc. policies do you use to guide the irrigation practices in the area?
13. How do you see the disparity between federal, regional, and local policies or regulations related to resource conservation and utilization?

Appendix Figure 1: Image of KIs during group discussion

Appendix Figure 2: Image of fertilizer and pesticide used by cabbage and onion farmers

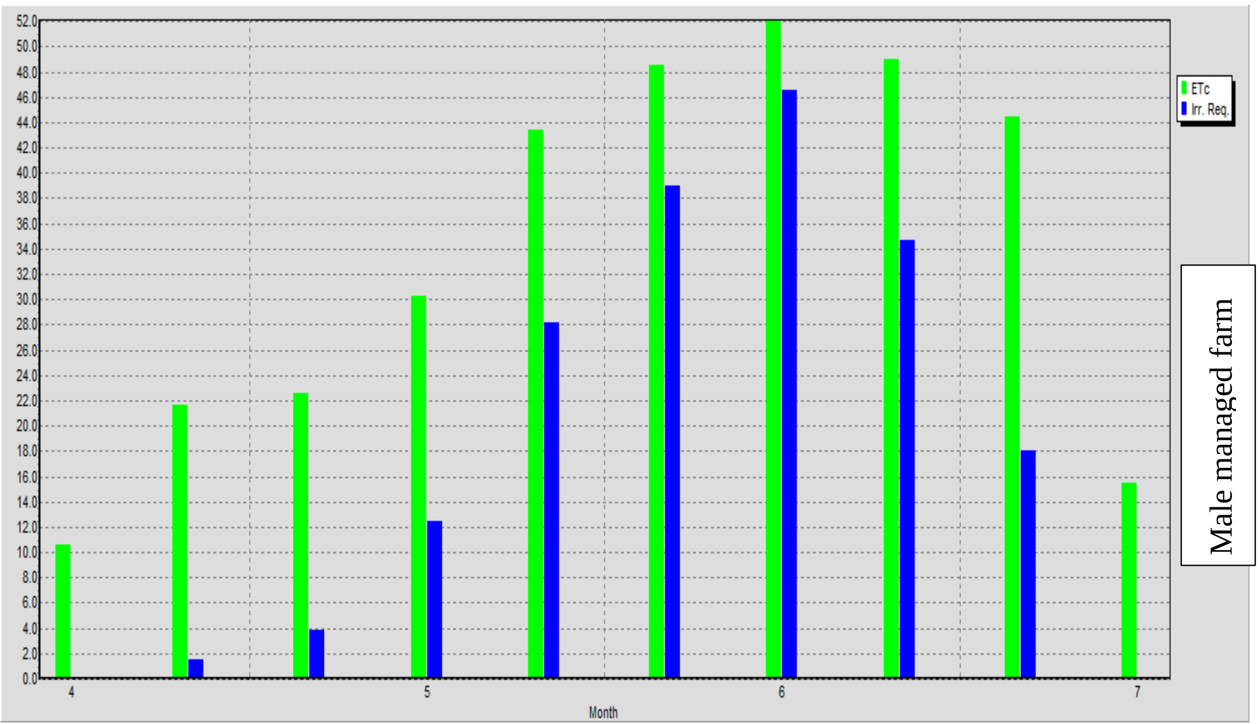


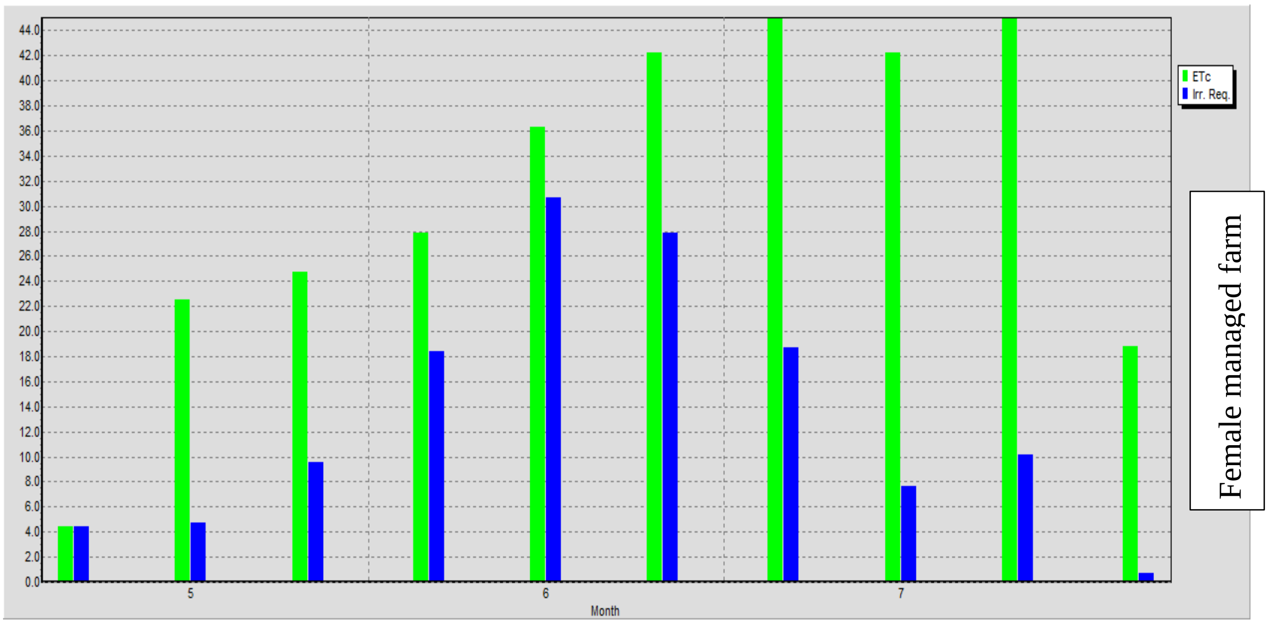
Appendix Figure 3: Graphical representation of climatic input data and ETo

Appendix Figure 4: Edo Gojola male-managed farm after transplanting.

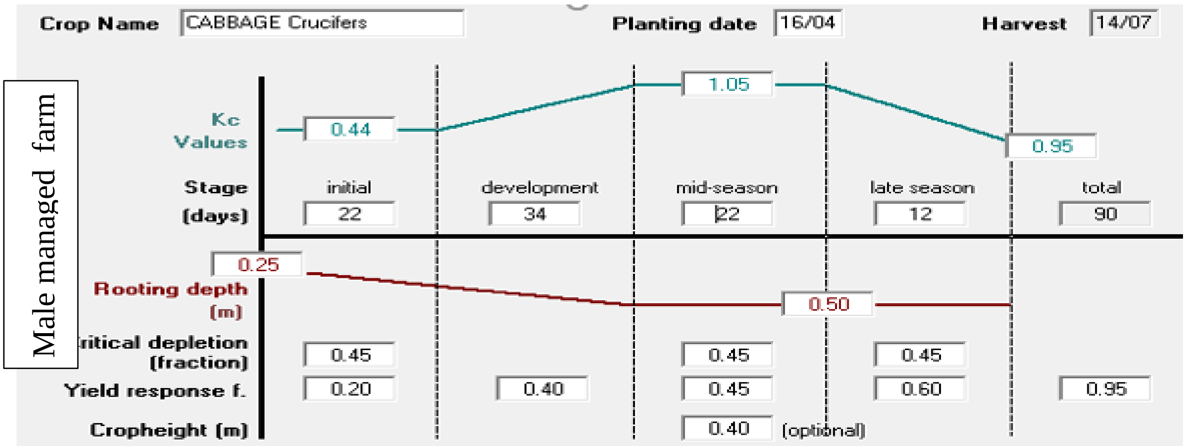
Appendix Figure 5: Observation of water delivery system by pump

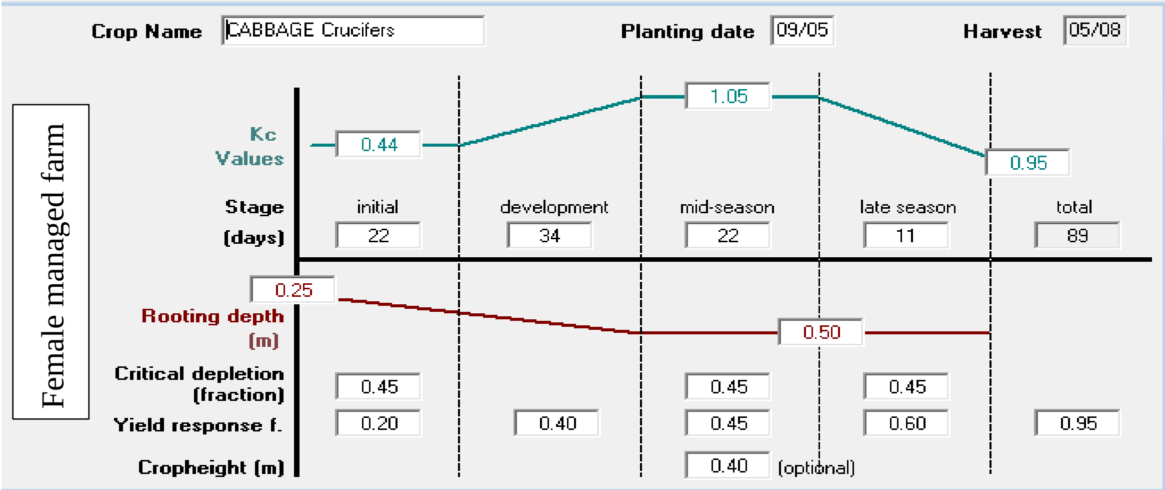
Appendix Figure 6: Water distribution system of the two managed farms

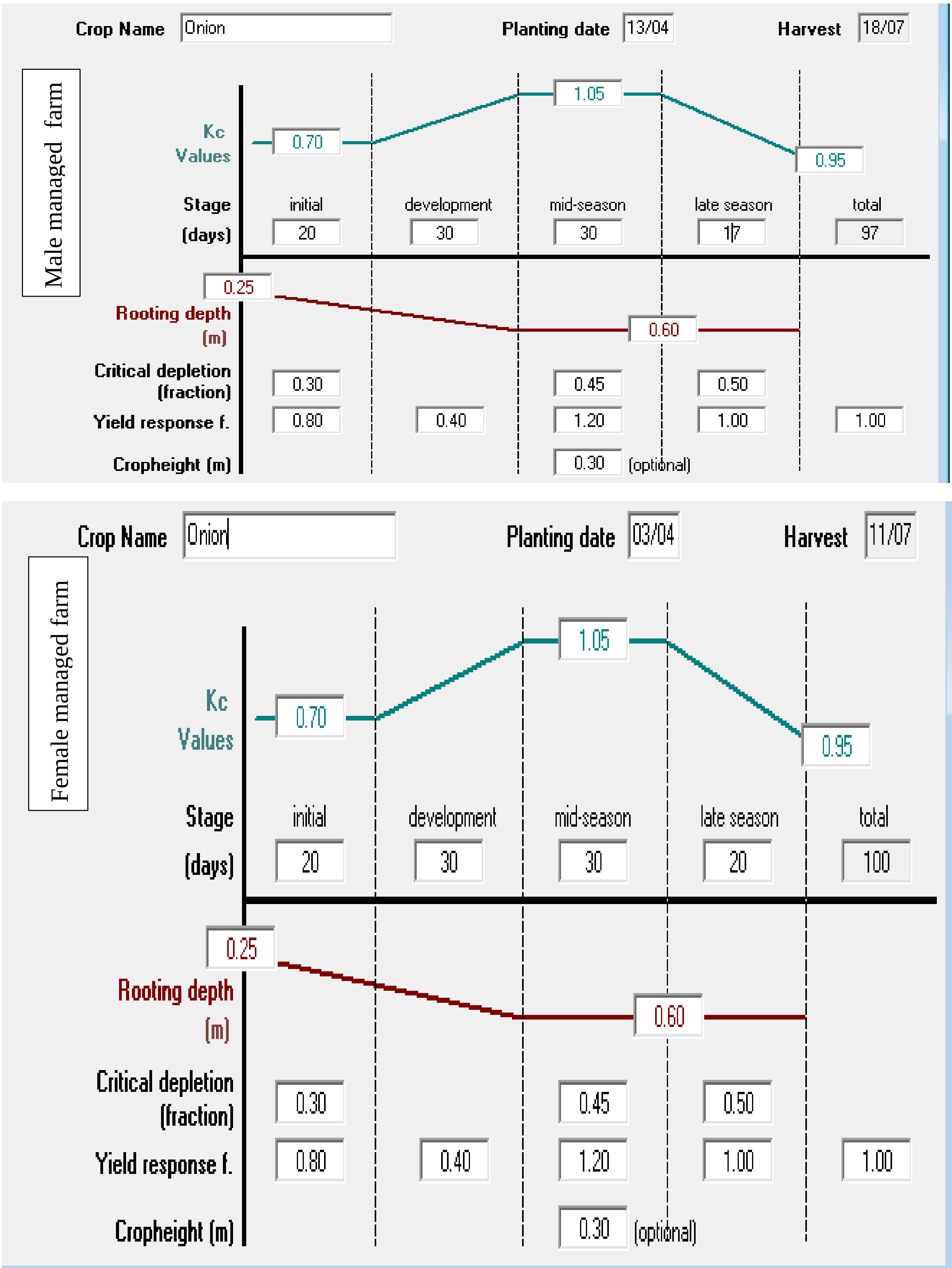




Appendix Figure 7: Crop water requirement (ETc) and IWR values for cabbage crop







Appendix Figure 8: Kc values for each managed farm

Appendix Table 2 : Climatic parameters and average daily evapotranspiration

Month	Rainfall (mm)	Tmin (°C)	Tmax (°C)	Wind (Km/day)	Rh (%)	Sunshine (hr)	Rad ($MJ/m^2/day$)	ET_o (mm/day)
Jan	21	14.8	30.8	52	50	7.8	19.1	3.68
Feb	52	16.3	31.7	52	48	7.8	20.4	4.02
Mar	59	18.1	33.5	52	51	7.5	20.8	4.35
Apr	70	19.3	34.1	95	52	6.9	20.2	4.81
May	57	20.3	36	104	42	7.1	20	5.13
Jun	31	21.5	36.5	104	44	6.5	18.7	5.02
Jul	118	19.6	33.4	61	56	5.8	17.8	4.13
Aug	135	19.1	32.2	43	61	6	18.4	3.93
Sep	63	19.9	33.5	43	51	5.9	18.3	3.99
Oct	22	18.9	33.6	43	41	7.3	19.7	4.13
Nov	15	15.3	31.8	43	42	8	19.6	3.81
Dec	11	14.2	30.6	52	43	8.1	19	3.62
Average	54.5	18.1	33.1	62	48	7.1	19.3	4.22

RH = relative humidity; Tmin = minimum temperature; Tmax = maximum temperature; Rad = radiation

Appendix Table 2: Crop water requirement (ETc) and IWR values for onion crop

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	2	Init	0.70	3.37	26.9	17.3	5.4
Apr	3	Init	0.70	3.44	34.4	20.1	14.3
May	1	Deve	0.74	3.72	37.2	18.8	18.4
May	2	Deve	0.85	4.37	43.7	17.8	25.9
May	3	Deve	0.97	4.95	54.4	15.2	39.3
Jun	1	Mid	1.04	5.26	52.6	9.5	43.1
Jun	2	Mid	1.04	5.22	52.2	5.6	46.6
Jun	3	Mid	1.04	4.91	49.1	14.4	34.7
Jul	1	Late	1.01	4.47	44.7	26.3	18.4
Jul	2	Late	0.95	3.92	31.3	27.6	0.0
					426.6	**172.6**	**246.0**

Female managed farm

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.70	3.26	26.1	16.3	5.8
Apr	2	Init	0.70	3.37	33.7	21.6	12.1
Apr	3	Deve	0.74	3.64	36.4	20.1	16.3
May	1	Deve	0.85	4.29	42.9	18.8	24.1
May	2	Deve	0.97	4.96	49.6	17.8	31.8
May	3	Mid	1.04	5.30	58.3	15.2	43.1
Jun	1	Mid	1.04	5.27	52.7	9.5	43.2
Jun	2	Mid	1.04	5.23	52.3	5.6	46.7
Jun	3	Late	1.02	4.80	48.0	14.4	33.7
Jul	1	Late	0.96	4.26	42.6	26.3	16.3
Jul	2	Late	0.93	3.85	3.8	3.5	3.8
					446.3	**169.0**	**276.7**

Male managed farm