

Research Article

Assessments of the Current Status and Major Challenges of Irrigated Agriculture in Fogera, Ethiopia

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Abstract

This study explores the challenges and current state of irrigated agriculture in the Fogera Plain, Ethiopia, which is vital for food security and economic stability. Agriculture in Sub-Saharan Africa, particularly Ethiopia, faces growing challenges due to climate change, population growth, and the degradation of natural resources. In Ethiopia, the heavy reliance on rainfed agriculture, compounded by climate variability, water scarcity, and inefficient practices, hampers agricultural productivity. This research adopts a mixed-methods approach, combining both quantitative and qualitative data to offer a comprehensive understanding of irrigation practices and their socio-economic impacts. Primary data were gathered through household surveys, focus group discussions, interviews, and field observations, focusing on smallholder farmers, irrigation managers, and local stakeholders. Secondary data from government reports and academic studies further complemented the findings. A stratified random sampling method ensured the inclusion of various irrigation systems and geographic locations. Quantitative data were analyzed using SPSS statistical methods, while qualitative data were analyzed thematically to identify key themes such as technical challenges, institutional weaknesses, and environmental impacts. In Fogera, about 20% of the arable land is irrigated, with small-scale practices like furrow and canal irrigation predominating. The region primarily relies on surface water from the Gumara and Ribb rivers, although seasonal flow fluctuations present challenges. Groundwater is also a supplementary resource but is at risk due to over-extraction and seasonal changes. Irrigated farming supports the cultivation of staple crops such as maize, wheat, and teff, as well as high-value vegetables like onions and tomatoes, contributing to the shift from subsistence to market-oriented farming. Despite its importance, irrigated agriculture in Fogera faces significant challenges, including water scarcity, poor resource management, inefficient irrigation systems, and inadequate infrastructure. The over-extraction of groundwater and seasonal river flow fluctuations threaten crop yields and ecological balance. Fuel shortages limit the operation of diesel-powered pumps, further reducing agricultural output. Poor infrastructure, characterized by inadequate design and lack of maintenance, exacerbates productivity issues. Market barriers such as poor transportation and price volatility also restrict farmers' access to profitable markets. The study recommends improvements in water management, infrastructure maintenance, alternative energy solutions, and better market access to ensure sustainable agricultural development and food security.

Keywords

Irrigated Agriculture, Food Security, Water Scarcity, Groundwater and Surface Water, Smallholder Farmers, Irrigation

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1. Introduction

Meeting the global food demand has become increasingly challenging due to rapid population growth, climate change, and the degradation of natural resources. The world population, estimated at 8.5 billion in 2030, is projected to grow to 9.4–10.1 billion by 2050 and potentially 12.7 billion by 2100 [1]. This rise, combined with changing diets due to increasing incomes, necessitates substantial growth in food production. Agriculture is the main source of food in Africa. In Sub-Saharan Africa (SSA) rainfed agricultural systems dominate the region, making crop production highly dependent on erratic rainfall. Ethiopia, a predominantly agrarian nation, agriculture contributes 41.4% of the GDP, 83.9% of exports, and 80% of employment [2]. This sector, however, is largely rain-fed, making it highly vulnerable to climate variability and frequent droughts, uneven rainfall distribution, and soil degradation, which threaten food security. Rainfed systems dominate, exposing smallholder farmers to the risks of rainfall variability, which often results in crop failures [3]. Consequently, agricultural productivity and food security remain persistently low. Due to this 4.6 million Ethiopians annually require food assistance, underscoring the critical need for sustainable agricultural practices [4]. Boosting our agricultural system is mandatory to produce more food and feed the Ethiopian population. However, limited land availability, water scarcity, and climate variability present significant obstacles to expanding agricultural production [5]. These challenges are particularly pronounced in developing countries where population growth rates are high and agricultural systems often rely on inefficient traditional practices [6]. To mitigate these challenges, irrigation development is essential for enhancing agricultural productivity, improving rural livelihoods, achieving food self-sufficiency, enabling the cultivation of high-value crops, and reducing poverty [7].

Recognizing the critical role of irrigation, the Ethiopian government has prioritized its expansion through initiatives such as the Growth and Transformation Plans (GTP I & II). However, progress has been hindered by numerous challenges, including limited access to modern irrigation technologies, weak institutional frameworks, inadequate water management, and environmental degradation. Addressing these issues is vital for maximizing the benefits of irrigated agriculture and achieving sustainable food security. Despite Ethiopia's potential for irrigation with 51.3 million hectares of arable land and significant groundwater resources, only about 4-5% of cultivated land is irrigated, covering roughly 640,000 hectares [8, 9].

Fogera Plain is an agriculturally significant region with fertile soils and diverse cropping systems. However, the area faces recurrent droughts and water scarcity due to high irrigation demand and unsustainable water management practices, over pumping and abstraction of groundwater [10]. The Gumara and Ribb Rivers, vital sources of irrigation water, experience significant flow reductions during the dry season,

often leading to conflicts among upstream and downstream users [11]. Sedimentation and unregulated water extraction have further diminished river discharge, exacerbating the challenges of maintaining a consistent water supply for agriculture [12] mesha 18. Also, groundwater resources play a critical role in supplementing surface water for irrigation in Fogera. The region has seen a rapid increase in the use of hand-dug wells and shallow tube wells, which provide water for dry-season irrigation. However, these wells have limited discharge capacity, and over-extraction has led to groundwater depletion and declining water table levels [13, 14]. The cost of diesel-powered pumps for groundwater extraction further constrains smallholder farmers, many of whom rely on traditional irrigation methods that are inefficient and wasteful. To address these challenges, innovative water management strategies are essential. Techniques such as deficit irrigation, mulching, and regulated water use can significantly enhance water use efficiency [15, 16]. Conservation agriculture practices have shown promise in reducing irrigation water requirements while maintaining or increasing crop yields [17].

The Ethiopian government recognizes the critical role of irrigation in achieving food security and economic growth. Policies and programs have been introduced to expand small-scale irrigation systems and improve water management practices [18]. In the Fogera Plain, efforts to optimize water use and increase agricultural water productivity are crucial for sustaining livelihoods and minimizing conflicts over water resources. Enhanced irrigation infrastructure, efficient water-saving technologies, and farmer training on sustainable practices are needed to address the region's challenges effectively. This study aims to assess the current status and challenges of irrigated agriculture in the Fogera Plain, focusing on the factors limiting irrigation efficiency and water resource sustainability and guiding policymakers, researchers, and development agencies in enhancing agricultural sustainability and productivity. By identifying practical strategies for improving water management and addressing water scarcity, this research seeks to contribute to the development of resilient agricultural systems in Ethiopia.

2. Methods and Methodology

To assess the current status and major challenges of irrigated agriculture in Fogera, a strong methodological framework is necessary.

2.1. Research Design

This study employs a mixed-methods approach, combining both quantitative and qualitative research techniques. The mixed-methods approach ensures a comprehensive understanding of the irrigation practices, challenges, and their socio-economic impacts in the Fogera Plain.

2.2. Study Area Description

Fogera Plain was located in the South Gondar Zone of the Amhara Region, Northwestern Ethiopia. The area is characterized by its predominantly black clay soils and a "woinadega" agroecological setting. This area is characterized by fertile soils and diverse agricultural activities but faces challenges such as water scarcity, environmental degradation, and conflicts over water use. Which is found at a distance of 657 km from Addis Ababa and 57km from Bahir Dar. The

climatic data of the experimental site, which is situated in the middle of Fogera Plain, show that the mean annual minimum, maximum, and mean temperatures of the area are 14.0 °C, 27.7 °C, and 20.8 °C, respectively. Rainfall in the area is unimodal, usually occurring from June to October, and its mean annual rainfall is 1216.3mm and ranges from 1103 to 1336mm [19]. The land in Fogera shows that 44.2% is arable and another 20% is irrigated, 22.9% is used for pasture, 1.8% has shrubland, 3.7% is covered with water, and the remaining 7.4% is considered degraded or other.

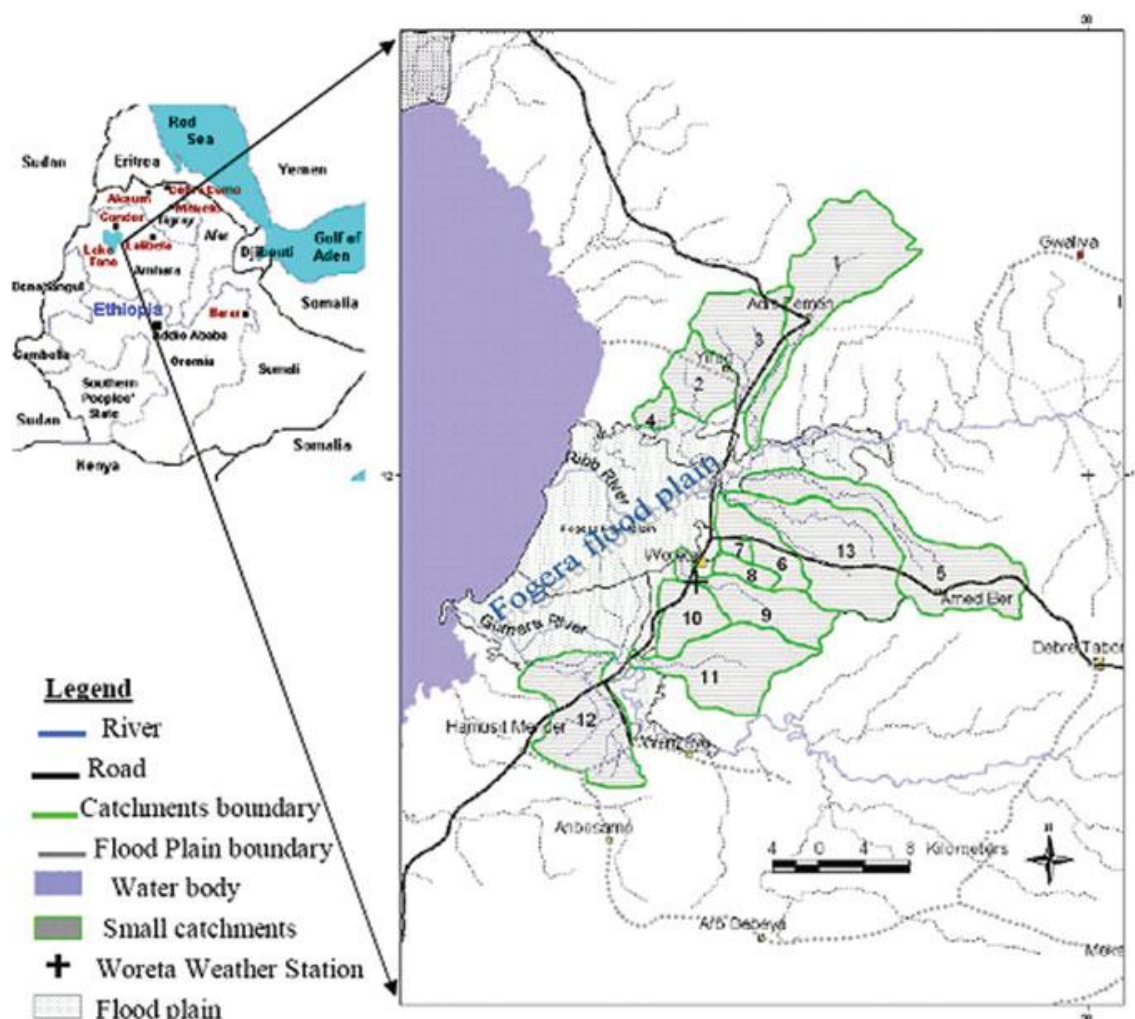


Figure 1. Maps of Fogera plain.

2.3. Data Sources

Data were collected through various methods to ensure the comprehensiveness and validity of the findings. The study utilizes both primary and secondary data sources:

2.3.1. Primary Data

The data was collected through household surveys, focus group discussions, key informant interviews, and field ob-

servations. Surveys were conducted among smallholder farmers involved in irrigated agriculture in selected irrigation potential kebele in Fogera. These kebeles were selected because they represent irrigation practices. A structured questionnaire was designed to gather information on irrigation methods, crop yield, water use efficiency, and the challenges faced by farmers. Semi-structured interviews were held with key stakeholders, including farmers, irrigation scheme managers, local government officials, and agricultural extension officers. The survey aimed to gather quantitative data on

demographic information (age, education level, and household size), Sources of irrigation (surface and groundwater), Crop types and yield levels, Perceptions of water scarcity and challenges faced in irrigation, and other data were collected. Focus group discussions provided qualitative insights into the community's perception of irrigation, water management challenges, and the institutional support available to them.

2.3.2. Secondary Data

Data was collected from published literature, government documents, research reports, and other sources. This includes hydrological data, irrigation system performance, agricultural productivity records, and others. Sources such as the Fogera Woreda Irrigation and Lowland Office, Fgera Woreda Agricultural Office, and the Central Statistical Agency (CSA), and academic studies on Ethiopian irrigation systems, provided critical insights. This secondary data helped in understanding the current trends and challenges in the irrigation sector.

2.4. Sampling Technique

A stratified random sampling method was used to select farmers across different irrigation systems (traditional, modern, small-scale, and large-scale irrigation). Farmers were further stratified by geographic location (upstream vs. downstream) to capture variations in water access and usage. The sample size was determined based on the population size using Cochran's formula, ensuring statistical reliability [20]. A purposive sampling technique was used to select 150 respondents across the major irrigated kebeles.

2.5. Data Analysis

Quantitative data from the surveys were analyzed using statistical methods such as descriptive statistics to summarize findings related to crop yield, water usage, and farmer income. Qualitative data from interviews were analyzed using thematic analysis to identify recurring themes, such as technical challenges, institutional weaknesses, and environmental impacts. For quantitative Analysis, SPSS Statistical tools were used to analyze survey data, focusing on descriptive statistics and inferential statistics to identify relationships between irrigation practices and productivity [21]. For qualitative Analysis, Thematic analysis is applied to qualitative data from FGDs and, identifying key challenges [22]. Data were coded and organized into categories such as water management issues, institutional barriers, and environmental impacts.

3. Results and Discussion

3.1. Current Status of Irrigated Agriculture in Fogera

Irrigated agriculture in Fogera district plays a significant

role in enhancing food security and rural livelihoods. The current status of irrigated agriculture in Fogera highlights its critical role in local food security and economic development while facing challenges related to water scarcity and resource management. The major irrigation practices focus on furrow irrigation. Approximately 20% of Fogera's arable land is currently under irrigation, contributing to increased productivity and diversification of farming systems. Small-scale irrigation dominates the landscape, with farmers primarily using traditional methods such as furrow and canal irrigation. Despite the country's vast water resources, regional disparities in water availability and poor irrigation infrastructure limit the expansion of irrigated farming [23]. The majority of Fogera's irrigation schemes are small-scale and are often managed by individual farmers. These schemes are primarily located along rivers and streams and serve subsistence farmers growing staple crops like maize, wheat, and teff. Farmers predominantly use surface irrigation, which involves flooding the fields or diverting river water. This method, while inexpensive, is inefficient, with significant water losses due to evaporation and seepage. More efficient technologies like drip and sprinkler systems were not used due to their high costs and lack of technical expertise.

3.2. Irrigation Water Sources in Fogera

Fogera Woreda is endowed with substantial potential for both surface and groundwater resources, making it a promising area for irrigation development. This abundance of water resources is a key factor in the region's agricultural productivity and economic development. Fogera Woreda's significant potential for surface and groundwater resources makes it a critical area for agricultural development, particularly through irrigation. To harness this potential effectively, a balanced approach that integrates water resource management, infrastructure investment, and sustainable practices is essential. These efforts would not only improve agricultural yields but also enhance the livelihoods of the local population and contribute to food security in the region [24].

3.2.1. Surface Water

Fogera, a region renowned for its agricultural potential, has a significant number of surface water sources, totaling 352. These include 77 rivers and 275 springs, which are vital for irrigation and other agricultural activities. However, a critical aspect of these water sources is their flow characteristics, as only 2 of the 77 rivers have permanent flow, meaning they provide water year-round. The remaining rivers and springs have seasonal flow, primarily dependent on rainfall patterns. These two permanent flow rivers are the Ribb and Gumara. The primary source of irrigation water is the Gumara and Ribb Rivers and other tributaries that flow into Lake Tana. These rivers are essential for supporting agricultural productivity and ensuring food security in the face of climate variability [25]. These river systems, which are part of the Lake Tana

sub-basin in the Upper Blue Nile Basin, play a crucial role in the socioeconomic stability of rural communities. However, increasing agricultural activities, coupled with environmental challenges, raise questions about the sustainability of irrigation practices in these basins [26]. This study highlights both its benefits and challenges and offers insights into sustainable water management practices. Farmers reported varying access to surface water, with seasonal fluctuations affecting availability. Seasonal rivers generally provide adequate water during the rainy season but become less reliable during dry months, leading to water scarcity. Water availability fluctuates seasonally, with the rivers experiencing high flow during the rainy season and reduced flow in the dry season [27]. Climate change, along with increased agricultural demand, has altered traditional water availability patterns, posing challenges for water resource management and necessitating

more sustainable irrigation solutions.

The expansion of irrigated agriculture in the rivers and springs has provided critical benefits in terms of food security and economic resilience. However, this expansion has also increased water resource stress, created soil degradation issues, and threatened biodiversity. Intensified water extraction has reduced the dry-season flow of the Ribb and Gumara rivers, which affects not only agricultural productivity but also the ecological health of downstream areas and Lake Tana [27]. In some areas, this has led to reduced water availability for domestic and livestock use, creating conflicts over water access [28]. Sustainable water management practices, efficient irrigation methods, and community engagement in water governance are essential for preserving the basins' ecological and socio-economic stability.

Table 1. Water sources wells, and water pumps in Fogera.

Year	Total Irrigated Land (ha)	Irrigable Land (ha)	Number of Rivers	Number of Springs	seasonal flow	Perma- nent flow	Number of Wells	Number of Water Pumps	No. solar pump
2019	8882	8882	77	275	350	2	25252	2606	
2020	9127	9127	77	275	350	2	28973	3058	
2021	9263	9127.5	77	275	350	2	25165	3066	
2022	9304	9304	77	275	350	2	19442	4508	5
2023	10573	10573	77	275	350	2	28211	5051	47



Figure 2. Surface water in Fogera, Gumara River during rainy (a) and dry (b) seasons.

3.2.2. Groundwater

In addition to surface water, Fogera Woreda has significant potential for groundwater, which is particularly valuable in addressing the limitations posed by the seasonal nature of surface water. Groundwater serves as a reliable supplementary resource, enhancing water availability during periods of low rainfall or seasonal river flow. Groundwater can be tapped through shallow and deep wells to support irrigation, especially during dry periods. However, Proper groundwater management is crucial to avoid over-extraction and ensure long-term availability. Groundwater also plays a significant role in Fogera, particularly as a more stable water source during dry seasons. Extraction methods such as manually operated and motorized pumps are utilized to access shallow groundwater.

Groundwater is accessed through wells and boreholes, particularly during the dry season. However, over-extraction has led to declining water tables in some areas, posing risks to long-term sustainability [29]. In areas near rivers and lakes, groundwater potential is high, with shallow water tables supporting hand-dug wells [30]. Moderate to low potential areas are found farther from water bodies, where water tables are deeper, and yields may decline during dry seasons [31]. The study found that 40% of respondents reported difficulties in accessing groundwater due to declining water levels. Aquifers in the plain include unconfined and confined types, with hand-dug wells accessing the former and shallow boreholes reaching the latter [32]. Groundwater resources in the Fogera Plain face challenges, including over-extraction, seasonal water table fluctuations, and contamination risks from agri-

cultural practices [33]. Effective management is needed to sustain these resources, especially as demand increases [30]. To improve sustainability, community-based groundwater management initiatives can promote sustainable practices and prevent overuse [34].

Hand-dug wells in the Fogera Plain are typically 5 to 15 meters deep, primarily tapping shallow unconfined aquifers. Due to their accessibility, these wells are widely used but are vulnerable to seasonal depletion and contamination, especially from agricultural runoff [35]. Regular maintenance is essential to ensure water quality and structural integrity, as hand-dug wells can collapse if not lined [36].

Shallow boreholes, generally 15 to 30 meters deep, offer a more stable water source. Boreholes are usually more expensive but provide higher yields and better water quality, as they are less prone to contamination. Seasonal water table drops impact boreholes less severely, making them a reliable source for both drinking water and irrigation [37]. Both hand-dug wells and shallow boreholes are essential for meeting household and agricultural water needs, with boreholes generally used as community water points due to their reliability [38]. Small motorized pumps extract water from rivers, lakes, and shallow wells. This method allows farmers to access water independently of natural flow but requires investment in pumps and fuel, which can be a limiting factor. Farmers often dig wells or tap into local springs to secure water for irrigation. These wells support small-scale vegetable production, especially during the dry season, though they are susceptible to drying out or contamination during droughts.

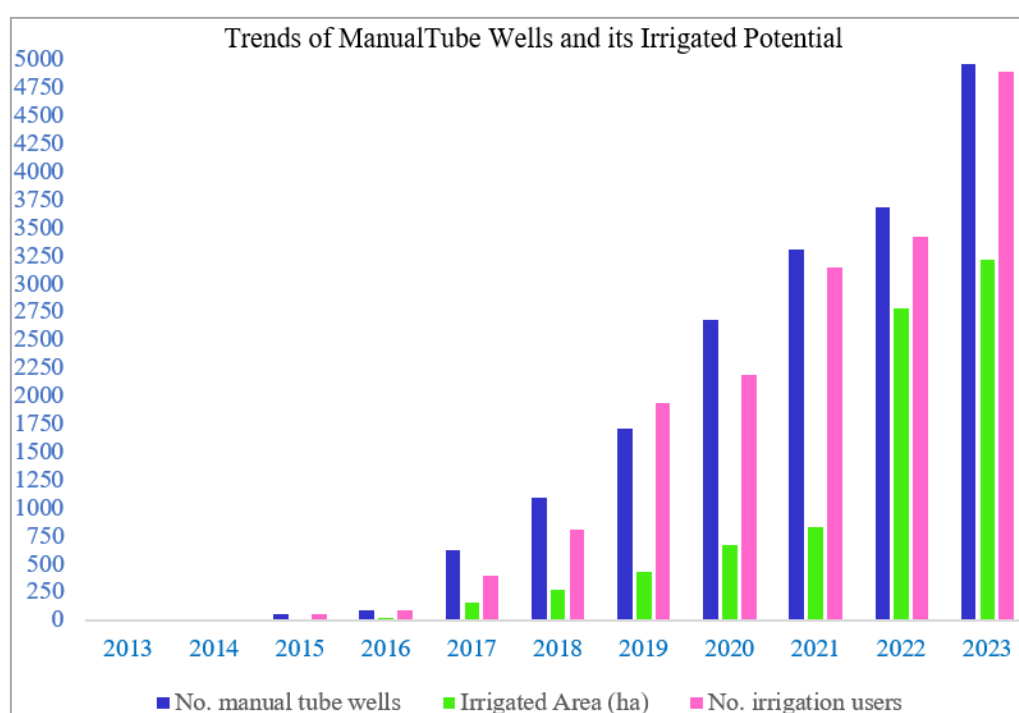


Figure 3. Groundwater source and irrigation users.

Table 2. Manual tube well, irrigated land, and irrigation users in Fogera Woreda.

Year	No. manual tube wells	Irrigated Land (ha)	No. irrigation users
2013	2	0.25	2
2014	14	4	14
2015	56	5.2	56
2016	90	22.5	90
2017	623	155.75	396
2018	1096	274	810
2019	1712	428	1935
2020	2682	670.5	2192
2021	3306	826.5	3145
2022	3689	2786.5	3423
2023	4965	3212.25	4893

**Figure 4.** Groundwater source (Hand-dug wells and Shallow boreholes) in Fogera.

3.3. Major Irrigated Crops in Fogera

Farmers in Fogera predominantly cultivate teff, maize, and vegetables like onion and tomato using irrigation. Major irrigated crops in Fogera were onion, tomatoes, maize, teff, and other horticultural and cereal crops. Irrigation has transformed farming in Fogera from subsistence to market-oriented agriculture. Farmers can grow high-value crops that get better prices, improving livelihoods. Increased production of staples and vegetables reduces dependency on imports and stabilizes food availability. Maize is widely grown under both rainfed and irrigated conditions. Irrigation ensures better yields and resilience against inconsistent rainfall. Vegetable Crops like onions, garlic, and tomatoes are common under irrigation. These high-value crops are increasingly cultivated to meet market demands. Wheat and Barley are produced particularly in areas with access to modern irrigation techniques. It helps bridge gaps in food security during dry seasons. Pulses Crops such as chickpeas and lentils are grown with irrigation to enhance productivity. Teff Although traditionally a rainfed crop, irrigation is being used to increase teff production in

Fogera areas. The availability of irrigation infrastructure, including small-scale water pumps and canals, has been instrumental in diversifying crop production and improving agricultural productivity in Fogera.

3.4. Challenges of Irrigated Agriculture in Fogera

The surface and groundwater resources in Fogera Woreda highlight the critical role of irrigation in supporting agriculture and livelihoods. However, significant challenges related to water scarcity, infrastructure limitations, water resource management issues, limited access to modern irrigation technologies, fuel availability and shortage, and inadequate institutional support for extension services and market linkages. These challenges often hinder the full utilization of irrigation potential, and inadequate institutional support threatens the sustainability of irrigated agriculture. Addressing these challenges is crucial for enhancing agricultural productivity and ensuring food security in the region.

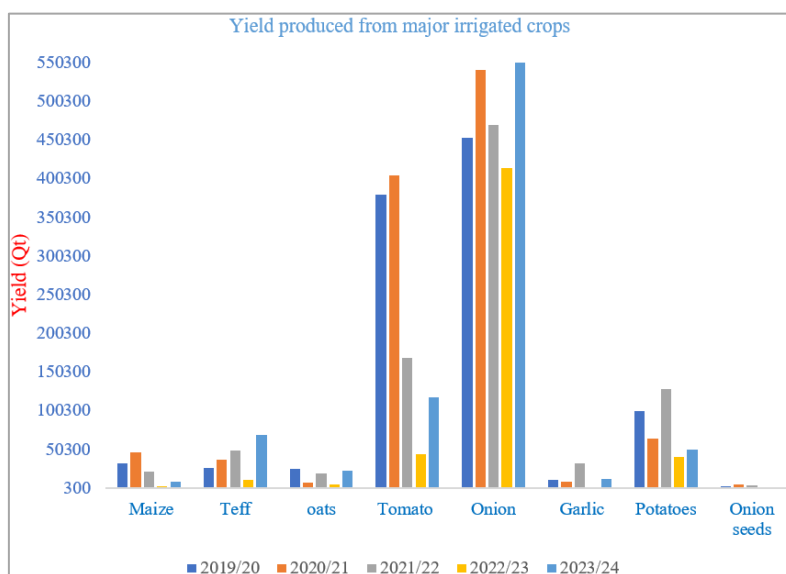
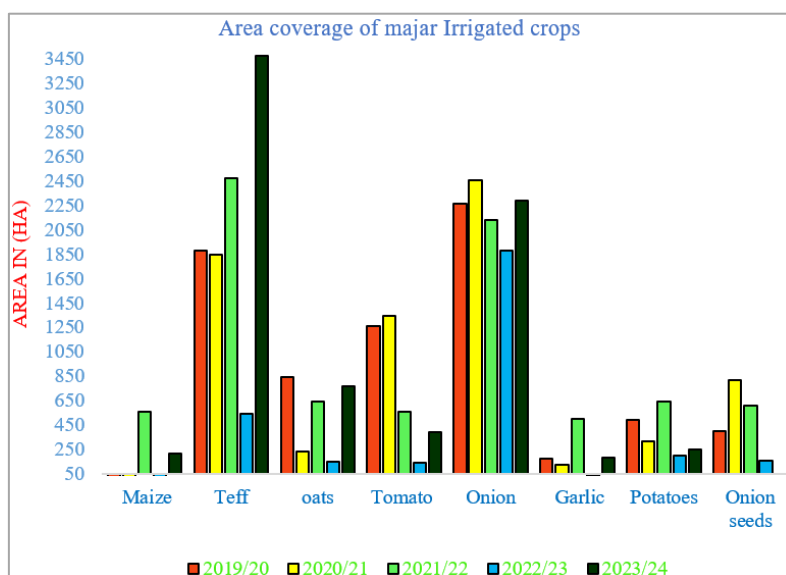
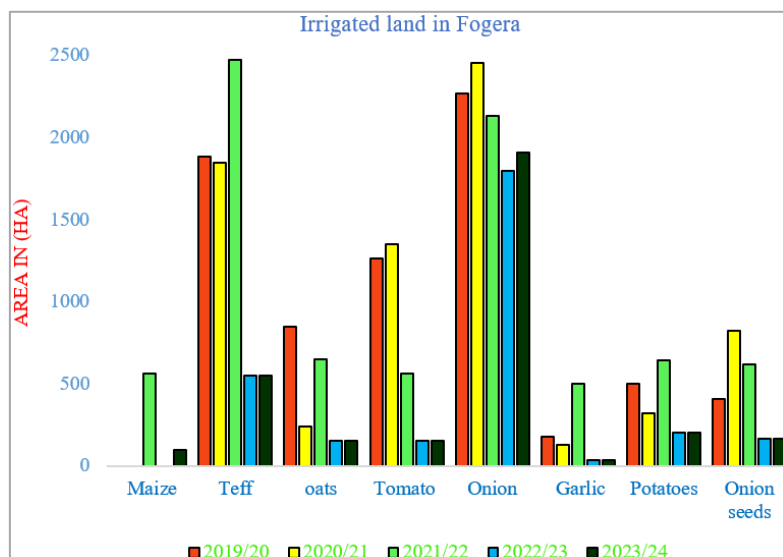


Figure 5. Major irrigated crops and their production in Fogera.

3.4.1. Water Scarcity in Fogera

The expansion of irrigated agriculture in Fogera has provided critical benefits in terms of food security and economic resilience. However, this expansion has also increased water resource stress, created soil degradation issues, and threatened biodiversity. Intensified water extraction has reduced the dry-season flow of the Ribb and Gumara rivers, which affects not only agricultural productivity but also the ecological health of downstream areas and Lake Tana [27]. In some areas, this has led to reduced water availability for domestic and livestock use, creating conflicts over water access [28]. Competition for water resources among various users, especially during dry seasons. Seasonal drying of rivers impacts crop yield, which is vital for local diets and income, and affects fish species reliant on wetland habitats [25]. Sustainable water management practices, efficient irrigation methods, and community engagement in water governance are essential for preserving the basins' ecological and socio-economic stability.

Ethiopia's water resources are unevenly distributed across the country, with some regions experiencing chronic water shortages. During the dry seasons, competition for water intensifies, often leading to conflicts among users. Moreover, poorly maintained irrigation infrastructure leads to inefficient water distribution and wastage [29]. Weak governance structures, insufficient policy coordination, and a lack of clear water rights hinder the sustainable management of irrigation schemes. Many irrigation projects lack proper oversight, leading to poor water management practices and low system performance [39]. Poor water management and excessive irrigation have led to environmental problems, including soil salinization and waterlogging in some irrigated areas. These issues reduce land productivity and threaten the long-term sustainability of irrigation [29].

Poor Design and Planning and incorrect predictions about water availability or demand can lead to under design or overdesign of irrigation systems, causing inefficient water use.

Infrastructure that doesn't account for population growth, agricultural expansion, and changing climate conditions can fail to meet future demands. Insufficient maintenance due to budget constraints, lack of expertise, and uneven water distribution can cause certain areas to suffer from water shortages while others may face over-irrigation. Overuse of groundwater or surface water sources can lead to depletion, causing water scarcity to provide adequate irrigation capacity. Excessive use of groundwater for irrigation can lead to a lowering of water tables, affecting the ability to water. Uncontrolled extraction or theft of water from canals can lead to water shortages.

In the Fogera region and other nearby areas, water scarcity challenges are impacting agricultural productivity. The primary issues include irrigation water shortages due to seasonal variances, over-pumping of groundwater, and unregulated water extraction from aquifers. Without enough available surface water, farmers rely more heavily on groundwater, straining these resources further. Due to increased water demand for irrigation, over-pumping of groundwater is common. This practice significantly lowers the water table, which not only impacts the availability of groundwater but also increases the risk of wells running dry. This issue is compounded by the use of outdated irrigation techniques and a lack of sustainable water management policies. In the Fogera area, there is often a lack of strict policies governing water abstraction. The lack of regulatory frameworks leads to unsustainable practices like over-abstraction, which lowers groundwater levels at a faster rate than natural replenishment. This situation is common in areas with hydrogeological complex aquifers, where water availability is already limited. Persistent water scarcity forces farmers to use groundwater unsustainably to maintain crop yields. Without better water management and policies, the aquifers may reach critical depletion levels, which would threaten long-term agricultural productivity in the region.



Figure 6. Water scarcity in Fogera due to over-pumping, Seasonal drying of rivers and wells, and crop failure.

3.4.2. Diesel/Fuel Shortage in Fogera

In Fogera, a district, fuel and diesel are critical for powering

irrigation water pumps, essential for agriculture, especially in the dry season. The availability, accessibility, and price of diesel fuel present specific challenges that impact farmers and their productivity. Diesel accessibility plays a critical role in

the productivity and profitability of irrigated agriculture, especially in regions like Fogera, where fuel-powered pumps are often essential for water delivery. Limited or inconsistent access to diesel can significantly impact agricultural output by restricting the ability of farmers to irrigate their crops effectively. Studies have shown that when diesel is scarce or priced beyond affordability, farmers are forced to reduce irrigation frequency, irrigated area, let crops dry, scale back cultivated land, or leave fields fallow, which directly decreases crop yields and farm incomes [40, 41].

In Ethiopia, the reliance on diesel fuel for irrigation is high, yet rural supply chains often struggle with transportation and availability issues, which disrupt the consistent fuel supply needed for farming operations [42]. When diesel prices rise or when fuel is unavailable, farmers experience higher production costs, which can deter investment in irrigation technology and further strain agricultural productivity [43]. This situation can contribute to food insecurity and economic vulnerability, as smallholder farmers lack the financial resilience to cope with these disruptions. Diesel for irrigation in Fogera faces challenges related to availability, accessibility, and pricing. Farmers contend with high costs and inconsistent supply, exacerbated by limited distribution and rural infrastructure. These factors contribute to high operating costs, impacting productivity and the economic viability of farming.

During the peak irrigation periods, demand for diesel rises sharply, often outstripping supply. This situation can result in delays, leaving farmers unable to irrigate their fields at crucial times. Macroeconomic factors, including inflation and currency devaluation, increase fuel prices and impact the stability of the diesel supply. When fuel prices spike, the cost of irrigation rises, reducing farmer profitability, so diesel demand

fluctuates significantly. Vendors may not stock as much fuel during the off-season, leading to shortages during peak times when all farmers need it simultaneously. Due to limited infrastructure for renewable energy like solar or wind power in rural Ethiopia, diesel remains one of the few viable options for irrigation, which increases reliance on it despite the challenges. Fogera's rural setting makes a consistent fuel supply challenging, with fuel stations sparsely distributed. Farmers may need to travel to urban centers like Bahir Dar for refueling, which is time-consuming and costly. The Ethiopian government occasionally provides fuel subsidies, but these may not always reach rural areas effectively. When subsidies are available, they can reduce diesel prices but may lead to shortages if the demand exceeds the supply.

Many farmers in Fogera are smallholders with limited storage facilities, requiring frequent refueling. They often depend on local traders who bring fuel in small amounts, sometimes at inflated prices due to transport costs. The distribution system is often unorganized, with fuel deliveries not on a set schedule, making it difficult for farmers to predict availability. Farmers must sometimes queue for long periods or even days to buy fuel. With the high cost of diesel, the operational cost of irrigation pumps becomes substantial. This can limit the amount of land that smallholder farmers can afford to irrigate, especially when diesel prices increase unexpectedly. Given the price volatility, some farmers consider switching to alternatives like solar-powered pumps. However, the high initial costs for renewable energy systems can be prohibitive for smallholders, keeping most farmers dependent on diesel despite its high costs. Solutions such as subsidized fuel access, investment in renewable energy, use solar pumps, and improved infrastructure could help mitigate some of these challenges.



Figure 7. The availability and accessibility of diesel fuel in Fogera.

3.4.3. Irrigation Infrastructure Distraction

Irrigation infrastructure failures can occur due to a variety of causes, often interrelated. These failures can lead to water shortages, crop loss, and economic damage, especially in areas reliant on agriculture. Infrastructure built in unsuitable locations, like areas with poor soil quality or where water

sources are unreliable, can face operational difficulties. Erosion of canal banks due to high water velocity or improper design can result in breaches and loss of water. The diversion structures, gates, and weirs may weaken or fail due to aging, improper construction, or lack of maintenance, allowing water to escape or flow unpredictably. If these structures are too small to handle stormwater or heavy water flow, they can get

blocked or collapse, leading to canal failure. Sediment accumulation in canals can reduce water flow and efficiency, causing water shortages and damaging diversion structures. Over time, sediment build-up can completely block the canal. Inadequate cleaning and maintenance of diversion points may lead to silt accumulation, obstructing water flow. Extreme weather, such as heavy rains or flash floods, can overwhelm canal systems. Excess water can erode banks, breach structures, or cause water diversion points to fail. Long periods of drought or reduced water flow in rivers or reservoirs can cause canals to dry up, leading to water scarcity for irrigation.

Lack of maintenance and timely repairs, such as sealing leaks, repairing cracks, and reinforcing structures, can lead to the gradual deterioration of canals and diversion works. Weeds and vegetation growing along canals can obstruct water flow, damage canal infrastructure, and increase the risk of erosion, theft of water from canals can lead to affecting the entire irrigation system, Mismanagement during the operation of gates, sluices, or other control structures can result in flooding or uneven water distribution, Canals constructed on weak or unstable soils can experience subsidence, cracking, or shifting, leading to structural damage, Soils that are prone to high infiltration rates can cause water loss through seepage, reducing the amount of water available for irrigation this are some cases of irrigation infrastructure failures. Overall, irrigation infrastructure failures are multifaceted and require comprehensive planning, investment, and ongoing management to mitigate. Effective maintenance, sustainable water management practices, and timely upgrades are key to ensuring the longevity and resilience of irrigation systems.



Figure 8. Irrigation infrastructure failures in Fogera.

3.4.4. Market Problems

In developing countries like Ethiopia, most smallholder farmers are characterized by poor market participation due to a lack of market information, price volatility related to the seasonality of supply, and poor performance of the vegetable market. The horticultural crop market in Fogera faces several challenges. These problems often arise due to production, post-harvest, and market-related issues. Here are some of the significant problems: Farmers often lack timely and accurate market information about demand, prices, and potential buy-

ers, limiting their decision-making. Limited road access and poor transportation infrastructure make it challenging for farmers to transport their crops to markets. Farmers may need to travel long distances to reach major markets, increasing costs and reducing profitability. Oversupply during peak harvest seasons leads to drastic price drops, negatively affecting farmers' incomes. The reliance on intermediaries and brokers often reduces farmers' profits, as middlemen take a significant share of the revenue. Perishable horticultural products often suffer significant losses due to the lack of cold storage or proper handling facilities. Minimal value addition and a lack of processing industries mean farmers cannot fetch better prices for their produce. Unpredictable weather conditions, such as excessive rainfall or drought, can damage crops, reduce quality, and disrupt supply chains, affecting the horticulture crop markets. To address these challenges, investing in rural infrastructure to improve transportation and reduce post-harvest losses, expand access to market information systems and financial services, and introduce value addition through processing and packaging industries.

4. Conclusion and Recommendations

4.1. Conclusion

Irrigated agriculture in Fogera Woreda is vital for food security and economic resilience, but its full potential is hindered by challenges such as water scarcity, infrastructure limitations, reliance on diesel, and market inefficiencies. Seasonal variability, over-extraction of water resources, and outdated irrigation practices threaten sustainability, while high fuel costs and poor infrastructure further strain agricultural productivity. Additionally, inadequate market linkages, transportation issues, and post-harvest losses reduce farmer profitability. Addressing these challenges is crucial to securing the region's agricultural future, improving livelihoods, and ensuring long-term food security.

4.2. Recommendations

To address the challenges in Fogera Woreda, the following summarized recommendations are proposed:

- 1) Adopt sustainable water management practices and efficient irrigation technologies; invest in renewable energy, such as solar-powered pumps, to reduce diesel dependency;
- 2) Improve irrigation infrastructure through timely maintenance and upgrades; strengthen policies on water rights and governance while enhancing institutional support for farmers;
- 3) Develop transportation infrastructure, cold storage facilities, and value-added industries to reduce post-harvest losses and improve market access;
- 4) Promote community engagement through training on modern agricultural practices and sustainable water use.

Abbreviations

SSA	Sub-Saharan Africa
GDP	Gross Domestic Product
°C	Degrees Celsius
%	Percentage
CSA	Central Statistical Agency
FGDs	Focus Group Discussions
FAO	Food and Agriculture Organization
Ha	Hectare

Author Contributions

Belachew Muche Mekonen is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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