



**Institute for Water
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(incl. Climate Change)**



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**UNIVERSITY INSTITUTE FOR WATER AND ENERGY SCIENCES
(incl. CLIMATE CHANGE)**

MASTER DISSERTATION

**Submitted in Partial Fulfilment of the requirement for the Master's Degree in Water
Policy**

Presented by:

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**Assessment of Water Demand and Allocation
Strategies in Kasese District, Uganda Using
Geographic Information System (GIS).**

Defended on: 21st April 2025 Before the Following Committee

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DEDICATION

I dedicate my Master's dissertation work to my family and friends who supported and cared for me throughout the process of my academic journey. In a very special way, this dissertation is dedicated to the memory of my beloved father, Mr. Joseph Mughambuli. His loyal love, hard work, and dedication to ensuring my well-being and education have left a lasting impact on my life. Even though he is no longer with us, his legacy continues to inspire me. May his soul rest in eternal peace.

DECLARATION

I, **MUHINDO Morris**, hereby declare that this dissertation report, titled “**Assessing Water Demands and Allocation Strategies in Kasese District, Uganda using GIS**” is my original work and has never been submitted for any degree or examination at any other university or institution. Any sources that have been used in this work have been duly acknowledged through proper referencing.

This dissertation is submitted in partial fulfillment of the requirements for the Master of Science in Water Policy of Pan African University-Institute for Water and Energy Sciences including Climate Change (PAUWES).

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ABBREVIATIONS AND ACRONYMS

CBOS	: Community-Based Organizations
CI	: Confidential Interval
Cu	: Copper
EWP	: Economic Water Productivity
FGDs	: Focus Group Discussions
FIEFOC	: Farm Income Enhancement and Forest Conservation Project II
GDP	: Gross Domestic Product
GIS	: Geographical Information System
GWPZs	: Ground Water Potential Zones
Hg	: Mercury
IPCC	: Intergovernmental Panel on Climate Change
IWRM	: Integrated Water Resources Management
MAAIF	: Ministry of Agriculture, Animal Industry, and Fisheries
MENA:	Middle East and North Africa
MWE	: Ministry of Water and Environment
NGOs	: Non-governmental Organizations
NRW	: Non-Revenue Water
NWSC:	National Water & Sewerage Cooperation
O.C	: Officer in Charge
Pb	: Lead
PIRI	: Pesticide Impact Rating Index
SCARD	: System for Control and Automated Remote Data.
SDGs	: Sustainable Development Goals
SHPs	: Shape Files
UBOS	: Uganda Bureau of Statistics
UN	: United Nations
UNDESA	: United Nations Department of Economic and Social Affairs
UNEP	: United Nations Environment Program
UNESCO	: United Nations Educational, Scientific and Cultural Organization.
UNICEF	: United Nations International Children's Emergency Fund
UNMA	: Uganda National Meteorological Authority
WCS	: Water Supply Committee

WHO : World Health Organization

WUE : Water Use Efficiency

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ABSTRACT

Water scarcity remains a significant global issue, particularly affecting developing areas such as Kasese District in Uganda, where it is intensified by inadequate infrastructure, weak water governance, and rising population pressures. Evaluating water demand and distribution is essential for understanding how water is allocated across sectors and regions, thereby guiding sustainable resource management. This research investigates the strategies for water demand and allocation in Kasese, with particular attention to the underlying causes of scarcity and its effects on households, agriculture, and industry.

Geographic Information Systems (GIS) were used to visualize the spatial distribution of water sources and examine access levels in different sub-counties. Primary data were gathered from 400 participants through structured questionnaires and analyzed using descriptive statistics in SPSS and Excel. Supplementary data were used to map the availability and distribution of water sources across the district.

The results show that the main contributors to water scarcity in Kasese include population expansion, changing climate conditions, and insufficient infrastructure. Households are the most affected, often traveling long distances for water, which increases exposure to waterborne diseases. In the industrial sector, inadequate water supply restricts production and raises costs, while in agriculture, limited irrigation contributes to lower crop yields.

Although Kasese has several water sources, distribution remains uneven, leading to accessibility challenges in certain areas. GIS analysis reveals notable disparities, particularly in remote sub-counties. To mitigate these issues, the study suggests expanding local water infrastructure, promoting awareness, and educating communities about water conservation. Emphasizing rainwater harvesting as a climate-resilient approach, especially for households and industries, is also recommended. Furthermore, policy adjustments should support demand-side management and implement smart metering systems.

Improving these strategies would enhance equitable water distribution and foster sustainable water resource management in the Kasese district and Uganda as a whole.

Key words:

Water scarcity, Water Demand and Allocation, Geographical Information System (GIS), Water Source, and Water Governance.

CHAPTER ONE

INTRODUCTION

1.1 Introduction and Background to the Study

More than 2 billion people around the world are dealing with water scarcity, a problem that's only getting worse due to rapid urbanization, population growth, and climate change (Adamopoulou et al., 2023). To tackle this, we need smarter ways to manage our water resources. That means developing new strategies, investing in better infrastructure, and adopting sustainable practices (Adamopoulou et al., 2023). It's not just about keeping the taps running—it's essential for protecting public health and securing a stable future.

In Sub-Saharan Africa, water scarcity is a growing crisis, made worse by weak infrastructure, poor governance, and unpredictable climate patterns (Jehan Gulamussen et al., 2019). Many areas face irregular rainfall, frequent droughts, and sudden floods, all of which throw off water supplies and deepen social and economic hardships. Countries like Uganda highlight just how tough these challenges can be, as communities struggle to access reliable, safe water in the face of these ongoing issues (Rachidi, 2014). Uganda experiences inefficient resource management and unequal water distribution while having an abundance of surface and groundwater resources from lakes, rivers, and wetlands (Nsubuga et al., 2014). Water systems are further troubled by urbanization, rapid population increase, and changed land-use patterns, which exacerbate supply-demand imbalances and regional differences in water access. Three major factors are primarily responsible for Uganda's severe water management issues: rapid urbanization, rapid population increase, and changes in land usage. For agriculture, industry, and daily life, the nation's inland water supplies, such as lakes, rivers, reservoirs, and swamps, are vital (Nalumenya et al., 2023). However, there is a discernible decline in water levels as more individuals and companies use these resources. There is an urgent need for more intelligent, sustainable approaches to water management, as evidenced by the widening imbalance between supply and demand. Ensuring equitable access to these essential resources for both local and distant groups is of utmost importance.

In Kasese District, western Uganda, the water situation is even more pressing. Nestled on the slopes of the Rwenzori Mountains, the district's rivers and streams flow into Queen Elizabeth National Park and nearby lakes like George and Edward. With a population now estimated at 702029 (UBOS, 2014) and still growing fast, the water demand is rising steeply. This puts a

strain on the already limited water resources, as households, farms, and industries all compete for their share. The surge in industrial activities, particularly mining and agro-processing, which require substantial water resources, is exacerbating the problem, intensifying the competition for access to this vital resource (Tibara et al., 2023).

Even though Kasese District has plenty of water sources, many households still depend on unimproved surface water for their daily needs. This points to gaps in both access and infrastructure. Furthermore, climate variability is exacerbating the situation. Droughts and floods are becoming more frequent and intense, making it even harder to manage water resources effectively (Tibara et al., 2023). The usual seasonal rainfall patterns are no longer reliable, and extreme weather events are not only disrupting water supply systems but also hurting agricultural productivity (Marshall, 2022). All these factors combined are putting a serious strain on the district's ability to provide clean and consistent water to its people. The impact of water scarcity hits hardest in Kasese's remote areas, where many water sources are only accessible during the rainy season. When the dry periods roll in, people, often women and children, spend countless hours and energy fetching water (Gupta, 2024). This time could be used for income-generating activities, highlighting how water shortages do not just affect health but also deepen economic struggles (Kamei, 2022). Adding to the problem, Kasese's current water allocation strategies rely on outdated, first-come, first-served systems. These don't take into account the varying needs of households, farmers, and industries, leading to unfair distribution and inefficient use of resources. To tackle this, there's a pressing need for more integrated and modern approaches that address these inequalities, consider regional differences, and promote sustainable water management across the district.

In this challenging context, Geographic Information Systems (GIS) offer a powerful, innovative solution for tackling water demand and allocation issues in the Kasese District. GIS allows for detailed spatial analysis of water resources, infrastructure, and usage patterns, making it easier to make informed, data-driven decisions in water management (Engineering et al., 2023). Unlike traditional methods, GIS can model different scenarios, whether it's shifts in population, climate changes, or new policies offering flexible and adaptive strategies for managing water resources more effectively. However, despite its potential, there's still a big gap when it comes to using advanced technologies like GIS in Kasese's water management systems. This is especially worrying given how extreme weather events are becoming more frequent and severe, worsening water-related challenges and increasing community vulnerabilities. Without

predictive tools, the district struggles with hands-on planning and adaptive management, both of which are crucial for building resilience against climate-driven water shortages.

This study aims to bridge that gap by using GIS-based methods to map and assess the distribution of different water sources in the Kasese District. By harnessing GIS technology, the research will uncover spatial patterns in water distribution, improve how resources are allocated, and support more informed, sustainable water management decisions.

1.2 Problem Statement

Globally, poor water resource management hinders sustainable development, particularly in regions experiencing water shortages. Many countries across different continents face challenges such as inefficient allocation mechanisms, weak governance, and inadequate infrastructure, which worsen existing water disasters. For example, in South Africa, poor water sector management and dependence on traditional allocation approaches caused an increase in water shortages, as evidenced by the implementation of Day Zero as a measure to address severe supply constraints in Cape Town (Mai, Thanh; M, Shahbaz; Tong, 2023). In Kenya, rapid urban expansion has deepened inequalities in water accessibility, with urban populations having better access than rural communities, which remain dependent on unreliable seasonal water sources (Nyaga et al., 2024). Similarly, in Nigeria, the combination of weak regulatory oversight, sector mismanagement, and aging infrastructure has resulted in persistent water shortages in urban and peri-urban areas (Nyaga et al., 2024). These issues underscore the need for evidence-based and data-driven strategies to promote equitable and sustainable water distribution.

Across Africa, Geographic Information Systems (GIS) have proven to be an effective tool in enhancing water resource management. In Ethiopia, GIS applications have been applied to map water demand and improve distribution systems, thereby reducing conflicts over limited water supplies in semi-arid regions (Patel & Chaudhari, 2023). Likewise, in Tanzania, spatial analysis has facilitated improved irrigation water allocation, leading to increased efficiency in agricultural water use (Komakech & van der Zaag, 2011). Despite these advancements in other African countries, Uganda—especially Kasese District—has yet to fully integrate GIS into water demand assessments and allocation planning.

Outdated allocation policies, weak institutional frameworks, and inadequate infrastructure have led to disparities in water accessibility. Some regions experience critical shortages, while others have an oversupply without clear usage frameworks (MWE (Ministry of Water & Environment), 2022). Additionally, the impacts of climate variability, including irregular

rainfall patterns and prolonged dry spells, further strain the country's water management systems, necessitating innovative approaches to enhance resilience.

Kasese District is also confronted with serious water supply challenges, mainly caused by climate change, as shown by erratic rainfall patterns, unplanned flooding, and prolonged periods of successive heat waves (Gupta, 2024). The current water allocation system, which operates on a first-come-first-served basis, does not reflect the actual real-time water resources or actual demand from the population, thus leading to unequal access across communities. In addition, the minimal use of new tools in the management of water resources, such as Geographic Information System (GIS), limits the district's capability in accurately determining demand, improving distribution efficiency, or supporting tenure in institutional structures. Considering these drawbacks, this study looks into water demand and allocation methods in Kasese District, determines inequality in the prevailing distribution system, and promotes evidence-based mapping approaches in supporting a more equitable, efficient, and effective water management system.

1.3 Research Questions

- i. What are the causes of water scarcity in Kasese District, Uganda?
- ii. What are the effects of water scarcity on the domestic, agricultural, and industrial sectors in Kasese District, Uganda?
- iii. How can GIS be used to map and analyze the water distribution network across Kasese District, Uganda?
- iv. What practical and sustainable solutions (Policy measures) can enhance water resources management in Kasese District, Uganda?

1.4 Aim and Objectives of the Study

1.4.1 Aim

The study aimed to assess water demand and allocation strategies and propose practical solutions to support sustainable water resource management in the Kasese District, Uganda.

1.4.2 Specific Objectives

- i. To identify the Causes of water scarcity in Kasese District, Uganda.
- ii. To evaluate the effects of water scarcity on domestic, agricultural, and industrial sectors in Kasese district, Uganda.

- iii. To utilize GIS techniques to map the various water sources distribution networks and accessibility in Kasese district, Uganda.
- iv. To propose practical solutions to address water scarcity in Kasese district, Uganda.

1.5 Scope of the Study

The three main classes of the study scope included geographical scope, thematic emphasis, and time horizon.

1.5.1 Geographical Scope

The research was carried out in Kasese District in western Uganda. The district has diversified topography with highlands along the Rwenzori Mountain range and diverse water resources. The region, though, experiences recurrent hydrological and socio-economic problems, particularly recurrent flooding and inadequate water accessibility. The research encompasses urban and rural environments, with a particular focus on areas engaged in agricultural and industrial activities where water availability and management are critical concerns.

1.5.2 Thematic/content Scope

The study analyzes water demand among domestic, agricultural, and industrial consumption in the Kasese District. The research explores why water is scarce, the variations of water source distribution spatially, and the challenges of governing and managing water. The research utilizes Geographic Information Systems (GIS) to identify and analyze water sources' accessibility by various consumers. Furthermore, it examines existing water allocation strategies and practices and identifies planning and decision-making gaps. Based on this, the study recommends viable and evidence-based approaches towards better and more sustainable and fair water resource management.

1.5.3 Time Scope

The study was conducted between December 2024 and March 2025, a period of four months. With a focus on climate variability and earlier evaluations of the district's water demand, it incorporates both primary and secondary data, including historical records from official sources.

1.6 Significance of the study

This study has a fundamental role to play in contributing towards Sustainable Development Goal 6 (SDG 6)—"Ensure the availability and sustainable management of water and sanitation

for all." It contributes directly to Goal 6.4, which aims at enhancing water-use efficiency, and Goal 6.5, which encourages integrated water resource management. Through the utilization of GIS in simulating water demand and distribution in Kasese District based on different climates and populations, the research provides actionable answers for water use optimization and addressing water shortages in the area. In addition to SDG 6, the research is in line with Uganda's Vision 2040 to achieve 100% coverage in water and sanitation and Africa's Water Vision 2025 to realize equitable access to safe water resources on the African continent. Through its focus on Kasese's specific socioeconomic and environmental circumstances, this project addresses key water management concerns, including how to balance the rival demands of industry, agriculture, and domestic households amidst the stresses of climate variability and population growth.

Besides these practical benefits, the research enhances both the theoretical and applied knowledge of water resource management. The results have important implications for policymakers, researchers, and practitioners, particularly in the developing world, and present a replicable model for water allocation optimization in similar environments with the application of GIS technology. This strategy not only enhances sustainable water governance in Kasese District but can also impact water management policies throughout Uganda and East Africa, helping to build more resilient and equitable water systems in the region.

1.7 Dissertation structure

The dissertation has been organized into five main chapters as follows:

Chapter One (1): Introduction

1.1 Introduction and Background to the Study

1.2 Problem statement

1.3 Research questions and study hypothesis

1.4 Aim and objectives

1.5 Scope of the study

1.6 Significance of the study

1.7 Dissertation structure

Chapter Two (2): Literature review

2. Operational definitions

2.1 Introduction to water Scarcity across the globe

2.2 The root causes of water scarcity

2.3 Effects of Water Scarcity on Key Sectors (Domestic, Industries, and Agriculture)

2.4 Water governance and stakeholder participation for sustainable water management

2.5 Geographic Information System (GIS) and Allocation Assessment

2.6 Research Gap

Chapter Three (3): Study Methodology

3.1 Research design

3.2 Description of the study area.

3.3 The study population

3.4 Sample size determination and Sampling techniques

3.5 Types and Sources of Data

3.6 Methods of Data Collection

3.7 Methods of Data Analysis

3.8 Ethical considerations

3.9 Work Plan

Chapter Four (4): Results and Discussion

4.1 Data Analysis, interpretation, and presentation

4.2 Discussion of the study results/findings

Chapter Five (5): Conclusion and Recommendations

5.1. Conclusion

5.2. Recommendation

CHAPTER TWO

LITERATURE REVIEW

2.1 Operational definitions

2.1.1 Water Demand and Allocation

Water demand refers to the quantity of water used by residential, commercial, government agencies, and industrial consumers (Ahmîni, 2015).

Water allocation refers to the systematic distribution of a limited water supply among various users, including households, industries, and the agricultural sector. This process is governed by established regulations that define access, usage limits, and timing. It considers factors such as water availability, environmental sustainability, and social equity to ensure a fair and efficient distribution of water resources (Vichete et al., 2023).

2.1.2 Water supply and consumption

Water supply denotes the volume of water provided by one economic unit to another or released into the environment. It entails both waters distributed within the economy and allocated for ecological purposes (UBOS, 2021). On the other hand, water consumption refers to the portion of water used that is not returned to its source. This includes water incorporated into products, consumed by households or livestock, or lost through evaporation and distribution inefficiencies, such as leaks or unauthorized usage. It is calculated as the difference between total water use and total water supply (Grubert & Sanders, 2018).

2.1.3 Water use

Water use refers to the total volume of water withdrawn by an economic unit, encompassing water obtained from other monetary units and directly from natural sources. Water use within the economy: Water is obtained from one economic unit by another, such as industrial facilities receiving water from municipal suppliers (Agrawal et al., 2022).

Water use within the economy refers to water obtained from one economic unit by another, such as industrial facilities receiving water from municipal suppliers, whereas water use from the environment is the Water that is directly extracted from natural sources, including surface water, groundwater, oceans, and precipitation, such as in rain-fed agriculture (Agrawal et al., 2022).

2.1.4 Water abstraction and Geographic Information System (GIS)

Water abstraction is the process of extracting water from natural sources, either temporarily or permanently, for consumption or production activities. This includes water withdrawn for domestic, agricultural, and industrial purposes, as well as for hydroelectric power generation. Water abstraction is classified based on source types, such as rivers, lakes, groundwater, or seawater, and intended use, for example, irrigation, manufacturing, or energy production (Younis & Davies, 2024).

Geographic Information Systems (GIS) in water resource management is a digital tool designed to collect, process, manage, and analyze spatial data related to water resources (Rata et al., 2014).

2.2 Introduction to Water Scarcity and Allocation

More than 2 billion people live in countries facing water scarcity, and twice that number experience shortages for at least one month each year (Rich et al., 2023). This crisis threatens global health, well-being, and economic growth, with climate change making the situation even worse (Rich et al., 2023). By 2050, global freshwater demand is expected to rise by 55%, driven by population growth, urban expansion, and climate change. A study by Liu et al. (2024) found that between 2015 and 2050, 88.8% to 99.7% of major cities are expected to experience growing water risks. This is mainly due to rising water demand fueled by population growth and climate change, further worsening global water scarcity. Rapid urbanization, population growth, and climate change are making the problem even worse, underscoring the need for innovative desalination solutions (Liu et al., 2024).

In China, there's a sharp contrast between the north and south—northern regions struggle with severe water scarcity due to limited resources (Wu et al., 2023). Similarly, the western United States faces water shortages, especially in urban areas, with climate change and extreme weather making the problem even worse (Adams, 2023). Many western U.S. states are facing severe or exceptional drought, leading to widespread water shortages and emergency conditions. Climate change, rising temperatures, and extreme weather are making water shortages worse, putting even more pressure on existing supplies (Dehghani et al., 2024) Cities like Los Angeles and Las Vegas are feeling the strain, highlighting the urgent need for sustainable water solutions. These persistent dry spells are straining resources and intensifying concerns about long-term water availability (Adams, 2023)..

Africa is especially hard-hit, facing severe water shortages due to unpredictable rainfall, poor governance, and a lack of infrastructure (Jahura et al., 2024). Water scarcity is a critical challenge in the Middle East and North Africa (MENA) region, exacerbated by low water use efficiency in irrigated agriculture, which stands at approximately 40% (Tropp & Jägerskog, 2006). More than half of MENA countries rank in the lowest 10% globally for annual per capita renewable water availability. As a result, nearly all renewable water resources are fully utilized, leading many nations to rely on non-renewable sources for agricultural, industrial, and domestic needs (Droogers et al., 2012). While this rate is higher than in Latin America, it remains lower than in South Asia. Countries such as Kuwait, Libya, Bahrain, Jordan, and the United Arab Emirates face extreme water shortages (Tropp & Jägerskog, 2006). According to the World Water Development Report, Kenya faces severe water shortages driven by rapid urbanization and pollution. However, effective water management strategies can help meet the growing urban demand (Droogers et al., 2012). Urban areas in Malawi experience frequent water supply disruptions, forcing many residents to rely on expensive or unsafe alternative sources, increasing their risk of waterborne diseases (Mpakati-Gama & Mkandawire, 2018). Inefficiencies in water utility infrastructure are a major contributing factor, highlighting the urgent need for improvements to mitigate health risks and economic hardship (Mpakati-Gama & Mkandawire, 2018).

Uganda faces unevenly distributed water resources, with rainfall variability affecting availability. Economic constraints further hinder equitable access, impacting domestic use, agriculture, and livestock. These challenges exacerbate both physical and economic water scarcity, highlighting the need for sustainable water management solutions (Nsubuga et al., 2014). In Uganda, around 80% of the population resides in rural areas, where access to potable water remains limited. In contrast, approximately 71% of urban residents have access to safe drinking water, primarily supplied by the National Water and Sewerage Corporation (Nayebare et al., 2014)

In Uganda's Kasese District, access to clean water remains a significant challenge, with availability varying by sub-county. Water scarcity in the region is exacerbated by population growth, deteriorating infrastructure, and climate change (Tibara et al., 2021). Access rates differ significantly, with Ihandiro Sub-County at 95%, while Mukunyu, Kyondo, and Kitswamba Sub-Counties have much lower rates at 21%, 18%, and 36%, respectively (Gupta, 2024).

Addressing these challenges requires advanced tools such as Geographic Information Systems (GIS) to analyze water demand, distribution, and resource efficiency, ensuring more effective water management in the district.

2.3 The drivers of Water Scarcity across the globe

Water scarcity, a crucial issue affecting worldwide populations, is caused by a complex interplay of environmental, economic, and geopolitical causes that vary by region (Mukasa et al., 2020). Although governments and humanitarian organizations have helped many people living in water-stressed areas acquire access in recent years, the problem is expected to worsen as a result of global warming and population expansion.

2.3.1 Climate Change and Variability

Climate change is one of the primary causes of the worldwide water issue. Climate change has a greater impact on water-stressed areas, such as Somalia's drought and Bangladesh's harsh monsoons (Sundin & Lindblad, 2015). As the climate situation worsens, these resources become increasingly scarce. In Sub-Saharan Africa, for example, climate-related droughts have caused soil deterioration in 80% of agriculture (Niang et al., 2014). On the other end of the scale, rising sea levels are salination of freshwater supplies, rendering them unfit for human use. Climate change has significantly altered global hydrological cycles, leading to prolonged droughts, unpredictable rainfall, and rising temperatures that exacerbate water shortages (MacAlister et al., 2023).

Climate change has increased the frequency and intensity of droughts and altered precipitation patterns, resulting in decreased water availability and quality (Millán & Rodrigo, 2014). Droughts have lowered river flows in Africa's Sahel area, affecting agricultural output and domestic water use (Niang et al., 2014). Similarly, rising temperatures and decreased rainfall in the Middle East and North Africa (MENA) have increased water stress, with regional estimates predicting a 30–50% decline in freshwater availability by 2050 (Lange, 2019). Increasing temperatures and erratic rainfall patterns further strain water resources, necessitating urgent reforms in water management (Pandya & Sharma, 2023).

In sub-Saharan Africa, climate variability has caused shifts in precipitation patterns, reducing water availability for domestic, agricultural, and industrial use (Mwebaze et al., 2021). Studies in Uganda indicate that increasing temperatures have intensified evapotranspiration rates, reducing surface and groundwater levels (Nsubuga et al., 2014).

2.3.2 Population Growth and Urbanization

Rapid population growth raises water demand, especially in metropolitan areas with limited water resources. Sub-Saharan Africa, for example, is projected to experience a population explosion, with urban populations doubling by 2050 (Cleland & Machiyama, 2017). This expansion exacerbates water scarcity in areas such as Nairobi, Addis Ababa, and Kampala, among others in the global south, where infrastructure and resource allocation are already under substantial strain. According to the United Nations Department of Economic and Social Affairs (UNDESA), Africa's population is expected to reach 2.5 billion by 2050, with urban centers experiencing the fastest growth (MacAlister et al., 2023). Human activities have a significant impact on surface water quality, especially as we rely on it for water supply. Surface water quality is predicted to vary in the future due to changes in pollution loadings, surface water withdrawals, and hydrological regimes, which are influenced by socioeconomic trends (Masereka et al., 2022). Improper waste disposal from agricultural, domestic, and industrial operations endangers water quality and strains the limited supply of clean, fresh water needed for human consumption.

Water contamination and quality degradation are serious problems aggravated by growing development, particularly in China (Zhang et al., 2023) and parts of Latin America (Guzmán Sánchez et al., 2024). Over 70% of China's rivers and lakes are contaminated, making them unfit for human use, and similar trends may be seen in Brazil due to industrial runoff. This condition jeopardizes freshwater availability (Sun et al., 2024).

In Uganda, Kasese District's population is expanding rapidly, heightening water demand and creating competition among domestic, agricultural, and industrial users (UBOS, 2014).

2.3.3 Poor Water Governance and Infrastructure

Weak institutional frameworks and outdated infrastructure contribute significantly to water scarcity. A study by Rachidi, (2014) found that many African countries lack comprehensive water management policies, resulting in inefficient allocation. Meanwhile, a lack of international coordination on water security has hampered the hunt for solutions (Mukasa et al., 2020). This dilemma is particularly acute in Sub-Saharan Africa, where rapid population increases and inadequate water management systems intensify the burden on water resources (Nsubuga et al., 2014).

Water scarcity in Sub-Saharan Africa, particularly in Tanzania and Kenya, is exacerbated by inadequate governance and institutional capacity (Wangechi et al., 2023). Weak regulatory

frameworks and ineffective management approaches contribute to the excessive use of water resources, particularly groundwater (Bulengela, 2024). This issue is exacerbated by official institutions' inability to adequately manage water resources, as seen in Tanzania, where the transition from informal to formal government has had unsustainable consequences (Bulengela, 2024).

Additionally, BARBIER, (2019) demonstrated that institutional and regulatory flaws impede effective water management, resulting in unregulated extraction. According to Wangechi et al. (2023), local institutions in impoverished countries, such as Kenya, often lack the resources and power to enforce police regulations, leading to poor compliance and enforcement of water policy. This, combined with the low involvement of local people in water governance, reduces the ability to improve compliance and resource management, as demonstrated in several developing nations, which accelerates limited water resources available to diverse users (Wangechi et al., 2023).

Despite these problems, Bulengela (2024) suggests that decentralized governance systems that engage local stakeholders and adapt to uncertainties could pave the way for better water management in the region. Recognizing and integrating traditional water management techniques can lead to better governance outcomes (Nyika & Dinka, 2023).

Local politics in certain places of the world contribute to water scarcity. Local politics and inequitable water distribution exacerbate the situation, limiting efficient policy administration and execution in places such as Pakistan (Farooq, 2023). Transboundary water conflicts, which arise when water sources are shared across political lines, frequently result in water distribution issues (Dai & Liu, 2023), exacerbating scarcity (Utari, 2021). The Nile River basin, shared by eleven countries, shows this, with downstream Egypt and Sudan competing for limited resources while upstream Ethiopia works on the Grand Ethiopian Renaissance Dam project (Goldberg, 2023).

Inadequate infrastructure, such as outdated pipelines and storage facilities, contributes to high water loss rates (Mahlknecht et al., 2015). In Latin America, 40–50% of piped water is lost due to leaks caused by outdated infrastructure, as observed in Mexico City, where water scarcity continues despite appropriate supply levels (Silva Rodríguez de San Miguel et al., 2018). In Sub-Saharan Africa, poor water facility maintenance has resulted in significant non-revenue water losses, further reducing effective water distribution (Shushu et al., 2021).

In Uganda, water governance challenges include inadequate funding, corruption, and poor stakeholder coordination, particularly at the local government level (Kanyamurwa, 2016). In Kasese, inadequate water infrastructure has led to frequent shortages, limiting access to clean water for residents and industries (Nayebare et al., 2014).

These global and regional problems pave the way for Kasese District, where uneven water distribution, climate-induced instability, and governance defects make long-term water access challenging (Mukasa et al., 2020). Kasese District presents unique challenges caused by a complex combination of natural and manmade forces, making it especially sensitive to water scarcity. The region's reliance on agriculture, along with rapid population growth and industrial expansion, places further strain on already restricted water supplies (Tibara et al., 2021). Climate change intensifies these issues by altering rainfall patterns, which in turn leads to both prolonged droughts and severe flooding, destabilizing the local water availability and infrastructure (Tibara et al., 2021). Thus, understanding these local and regional drivers of water scarcity is essential for proposing sustainable water management strategies that address Kasese's unique conditions

2.3.4 Agricultural and Industrial Water Demands

Agriculture is the largest consumer of freshwater globally, accounting for nearly 70% of withdrawals (Andrianova et al., 2022). In Uganda, more than 68% of farming is rain-fed, making it highly vulnerable to climate-induced water shortages (Babyenda et al., 2023). Additionally, industrial expansion in Kasese, particularly mining activities, has increased water demand, creating conflicts between domestic users and industries.

The Subsidies on water and power for irrigation encourage excessive consumption, resulting in plummeting groundwater levels, which are falling by more than 1 meter per year in some locations. According to Singla et al. (2024), groundwater levels in Punjab have declined dramatically, by 0.50 m per year post-monsoon and 0.43 m pre-monsoon. Furthermore, Singla et al. (2024) demonstrated that the main paddy-wheat cropping pattern exacerbates water stress since paddy requires extensive irrigation, resulting in over-extraction of groundwater in the region. Mitra et al. (2023) also found that low or zero pricing for water and energy encourages farmers to over-extract groundwater, adding to aquifer depletion. Larger farms have higher water use efficiency (WUE) and economic water productivity (EWP), demonstrating that scale is critical for optimizing water usage (Bhatia & Singh, 2024).

Agricultural water use is a serious issue, accounting for over 70% of total freshwater demand (Pandya & Sharma, 2023). Mismanagement and inefficiency in irrigation systems worsen water scarcity, particularly in Pakistan and the Aral Sea basin (Farooq, 2023). In Pakistan, traditional irrigation systems waste a lot of water, and the Indus River system is inefficient. The Aral Sea has lost more than 80% of its volume due to unsustainable irrigation for cotton farming, indicating serious environmental repercussions (Novitskiy et al., 2024).

2.3.5 Economic limitations and inefficient pricing strategies

Economic limitations and inefficient pricing strategies frequently limit water availability, especially in low-income communities (Benavides-Muñoz et al., 2024). In South Asia, water is frequently underpriced, resulting in misuse and waste (Akbar et al., 2022). This problem is compounded by subsidized water in agriculture (Singla et al., 2024a).

2.4 The effects of Water Scarcity on the Key Sectors (Domestic, Agricultural, and Industrial)

Water scarcity poses a serious concern both locally, regionally, and internationally, affecting important sectors such as agriculture, industry, and home life while endangering lives and social stability.

2.4.1 Challenges in Household Water Supply

The inadequate availability of clean water presents systemic risks to human health, food production, and energy generation that adversely affect the well-being of given societies. Water scarcity has a major impact on access to clean water for drinking, cooking, and sanitation, leading to serious health risks and economic struggles. In areas with inadequate water resources, households frequently rely on dangerous or remote water sources, exposing persons, particularly children, to waterborne infections and reducing productivity owing to time spent collecting water (UNEP, 2024). Some families in drought-prone areas or regions have used contaminated water sources for domestic purposes, contributing to an increase in sickness, particularly water-related illnesses (Jahura et al., 2023).

Water scarcity in Indonesia dramatically impairs domestic and societal livelihoods by interrupting agronomic activities, food production, and security, resulting in extended suffering and increased vulnerability among famine-affected populations (Jahura et al., 2024). According to Aromolaran et al.(2019), in places like Ogun State, Nigeria, various households travel long distances for water, which takes an average of 24 minutes and disrupts daily routines. Furthermore, Jahura et al. (2023) discovered that reliance on groundwater is increasing,

resulting in water depletion and rising shortages, depriving communities of the right to safe, clean water for human consumption.

Water scarcity has a negative influence on domestic livelihoods by raising water acquisition costs and lowering agricultural production, hence affecting overall community well-being and financial stability (Aromolaran et al., 2019). Similarly, Goswami & Ghosal, (2022) Found that household water shortage considerably impairs socioeconomic capability, resulting in moderate to high multifunctional water poverty and negatively impacting livelihoods and human development in the Purulia district of eastern India.

According to Zimmermann et al. (2023), more than 40% of people living in rural Uganda don't have access to safe, clean drinking water. This forces many communities to rely on sources that are often unreliable and contaminated, putting their health at serious risk and making it harder to maintain sustainable living conditions. In Kasese, frequent water shortages have pushed residents to use unprotected wells, increasing the risk of waterborne diseases like cholera and typhoid (Tibara et al., 2023). Water scarcity leads to severe health impacts, economic decline, and increased vulnerability, particularly in developing countries.

2.4.2 Effects on Agriculture and Food Security

Water scarcity is an acute global problem that has a substantial influence on agriculture, the world's largest consumer of fresh water. The combination of rising water demand owing to population development, climate change, and ineffective water management techniques exacerbates this problem. (AbdulHasan & M. Hanafiah, 2017). Agriculture accounts for more than 70% of global freshwater withdrawals (Rosa et al., 2020), making water shortages a critical issue for ensuring food security and sustainable agricultural practice (AbdulHasan & M. Hanafiah, 2017).

Water scarcity has a significant impact on the global agricultural business, affecting food security, economic development, and rural life. Water scarcity has the potential to reduce agricultural productivity and contribute less to GDP (Alrwis et al., 2021). According to Alrwis et al. (2021), water scarcity affects cultivated areas and agricultural productivity, hence compromising food security and economic development, particularly in locations such as Iraq. Reduced agricultural productivity owing to water shortages can result in severe economic losses, hurting not just farmers but also downstream sectors that rely on agricultural products.

Reduced water results in a major drop in agricultural productivity, whereas excessive water withdrawal causes erosion and salt intrusion, both of which have a negative influence on

agricultural production (“Informing Water Policies South Asia,” 2018) In some places of the world, ongoing water scarcity makes some land unsustainable and unfit for agricultural activities (Ingrao et al., 2023).

Drought conditions, according to studies in the United States and Australia, exacerbate water scarcity, resulting in reduced crop yields and increased salt in irrigation water (Thorslund et al., 2022). Heat and drought have been proven to worsen water scarcity, especially in irrigated agriculture, which relies largely on a constant water supply (Thorslund et al., 2022). Similarly, in developing nations like Pakistan, variable rainfall patterns and groundwater depletion present significant challenges to farmers, jeopardizing agricultural output stability (Kumari et al., 2023). Northern Mexico's acute water scarcity, notably in Chihuahua, has a substantial impact on staple crops like maize and beans. Insufficient water supplies can cause farmers to quit their land, resulting in a 30% drop in productivity (Escamilla et al., 2023).

The agricultural landscape of South Asia, notably India, is under increasing threat from altered monsoon patterns and groundwater depletion, both of which are crucial for rice and wheat production (Mishra et al., 2024). Groundwater is a primary water supply, particularly in Punjab and Haryana, where over-extraction has resulted in plummeting water tables. Mishra et al. (2024) found that groundwater levels in North India decreased by 1.5 cm per year between 2002 and 2021, resulting in a net loss of 450 km². The World Bank predicts a 6% drop in India's agricultural GDP by 2050 owing to worsening water scarcity.

The impact of water scarcity is clear in South Africa. Where agricultural commerce acts as a method for transferring water resources and improving efficiency in food production, which benefits the economy (Dalin & Conway, 2016). However, South Africa remains one of the places with considerable yield gaps due to restricted water and nutrient inputs, particularly during the dry season in the region's drier areas (Dalin & Conway, 2016). Furthermore, (Kativhu et al., 2020) Point out that smallholder farmers in Limpopo Province are especially sensitive to water access disparities, which can exacerbate poverty and impair agricultural resilience.

Musse, (2021) noticed a similar situation in most parts of West Africa, with water scarcity threatening food security and agricultural output. Farmers' reliance on rain-fed agriculture renders them particularly vulnerable to rainfall fluctuations, resulting in irregular crop yields and increased food insecurity. Promoting water-efficient agriculture techniques and implementing integrated water resource management methods are critical to tackling these concerns (Musse, 2021).

Droughts in Southern Africa and East Africa have reduced maize production by up to 50%, resulting in food insecurity (Arenas-Calle et al., 2024). The 2016 drought in Ethiopia affected cereal production, resulting in an estimated \$1.1 billion in economic losses (Tofu, 2024).

Farmers in dryland areas of Homa Bay County in Kenya face enormous challenges in maintaining their herds, resulting in a cycle of poverty and reduced adaptive potential to climate change (Ogenga & Mugalavai, 2019). In Kasese, unpredictable rainfall and prolonged droughts have led to crop failures, declining livestock productivity, and worsening food shortages (MWE (Ministry of Water & Environment), 2022). Lowered river flows in Africa's Sahel area have affected agricultural output and domestic water use (Niang et al., 2014).

2.4.3 Industrial and Economic Consequences

Water scarcity, for example, can diminish agricultural production, resulting in higher prices for raw materials used in industry, raising operational costs, and decreasing profit margins (Schmitz et al., 2013). This relationship demonstrates how water scarcity in one industry can have a ripple effect throughout the economy. In Europe, the industrial sector has responded to water constraints by implementing water reclamation technologies. Jehan Gulamussen et al. (2019) observe that breakthroughs in water reclamation for industrial use have been accomplished in areas where water shortage is extreme, such as Australia and the Mediterranean (Jehan Gulamussen et al., 2019).

Water shortage has a substantial impact on the industrial sector, notably in the Middle East and South Asia, resulting in reduced GDP and cascading consequences on water-intensive businesses (Nechifor & Winning, 2018). Limited water re-allocation exacerbates these issues, harming industries that rely on industrial water supply, such as thermal power and manufacturing industries (Nechifor & Winning, 2018).

Water scarcity has a particularly strong impact on South Africa's industrial sector. Briand et al. (2023) Anticipated that a 17% increase in water scarcity will result in a 0.34% loss in GDP by 2030, with water-intensive sectors bearing the brunt of the impact. This circumstance emphasizes the critical need for appropriate water management methods to safeguard the long-term viability of industrial operations in the face of increasing water scarcity (Briand et al., 2023).

Water shortages have a significant negative impact on productivity in East African manufacturing facilities, particularly in Uganda and Zambia. The limited supply of water has a

significant impact on industries such as food and agriculture, chemicals and pharmaceuticals, building, and metallurgy; thus, water infrastructure must be improved (Moyo, 2011).

Industries need a steady water supply for essential operations like cooling, processing, and cleaning. According to a World Bank (2022) report, water shortages in East Africa have caused declines in industrial productivity, higher operational costs, and job losses. In Kasese, industries such as mining rely heavily on water, putting additional pressure on an already limited supply (Katusiime & Schütt, 2020). Competing national interests provide a considerable danger of conflict, which might derail cooperative resource management initiatives (Dai & Liu, 2023).

2.5 Water Governance and Stakeholder Participation for Sustainable Water Management.

Water governance refers to the processes and organizations that manage and allocate water resources while taking into account the complexities of sociopolitical and environmental issues (Woodhouse & Muller, 2017). Well-structured governance models are critical in resolving water scarcity and ensuring equal access, especially in resource-constrained countries (Chandrasekara et al., 2021). Effective governance frameworks, such as participatory approaches, improve water management by incorporating local knowledge and harmonizing policies with stakeholders' different requirements. Additionally, involving diverse actors and equitable allocation is crucial for addressing competition and disputes over water, ultimately promoting social cohesion and investment, which aligns with the principles of participatory governance models in water management (Woodhouse & Muller, 2017).

On a global scale, well-organized systems of governance have played an important role in minimizing water scarcity and fostering equitable access, especially in areas with high demand and restricted resources. For instance, in the Western Cape of South Africa, a participatory water governance strategy successfully included local water users in planning and allocation decisions, enhancing water usage efficiency and public support for conservation programs. (Gleick, 2018). Such frameworks typically boost water management performance by incorporating local knowledge and ensuring that policies are matched with the demands of multiple sectors, including agriculture, industry, and residential use (Loucks & van Beek, 2017).

On the contrary, Uganda's water governance has traditionally been centralized, restricting the involvement of district and community stakeholders and impeding efficient local management. In Kasese, a district severely hit by seasonal water scarcity and infrastructure constraints, the lack of localized governance institutions adds to water usage conflicts, aggravating the issues

associated with equitable distribution and resource sustainability. Adopting a more inclusive, district-oriented strategy could strengthen governance and reduce conflict by customizing management approaches to local needs.

Engaging stakeholders in water management not only fosters community trust but it also increases the relevance and robustness of water policies. Case studies from Kenya's Mara River Basin show that inclusive water governance in which local farmers, industry, and conservationists participate in water allocation leads to more equitable and sustainable resource usage (George Marcellus Metobwa, 2018). This participatory approach addresses both pressing needs and long-term environmental health, guaranteeing that policies represent the different interests of water users while avoiding water-allocation conflicts (Mourad et al., 2018).

Stakeholder participation also promotes a sense of ownership over water resources, allowing communities to adopt sustainable practices and support conservation efforts. In Kasese, where agriculture, home needs, and expanding industry compete for water, a participatory framework with local participation can result in policies that are both practical and broadly supported. Evidence from other locations, such as Tanzania's Pangani Basin, where local users were included in water management, shows that stakeholder participation improves policy implementation and compliance, hence contributing to long-term sustainability. (Badham et al., 2019).

Kasese's effective governance should be strengthened by policy initiatives that promote water efficiency, prioritize vital uses, and incorporate local perspectives. Water prices regulated abstraction licenses, and incentives for water-saving technologies have proven effective in regions such as Namibia, where they have lowered water demand in the face of scarcity. (Iindombo et al., 2023). Such policies not only balance demand but also align with sustainable growth goals, promoting equal water access across sectors. Kasese believes that enacting similar rules might help regulate rising demand and guarantee that agricultural, industrial, and home needs are addressed sustainably.

Furthermore, forming district-level water user associations or committees would promote collaboration among local stakeholders, resulting in more responsive decision-making and conflict resolution. Uganda's neighbors, especially Kenya, have seen positive results from community-led water management frameworks that allow local actors to participate in water planning, conservation, and policy input (Mourad et al., 2018). These groups could provide a

formal forum for Kasese's different water users to discuss and resolve water allocation issues, establishing a shared commitment to sustainable practices.

2.6 Geographical Information System (GIS) in Water Demand and Allocation

Assessments

2.6.1 Overview of GIS Applications in Water Resource Management

Geographic Information Systems (GIS) are essential to water resources management, offering analytical functions, visualization potential, and decision support. GIS incorporation into the different dimensions of water management assists in improving efficiency, sustainability, and responsiveness to climatic challenges like drought and floods (Prema Kaira et al., 2024).

In watershed management, GIS is fundamental in the assessment of geomorphological characteristics and thus facilitates the efficient development of management strategies. Through the combination of land use data, topography, and drainage, GIS facilitates the determination of areas that are appropriate for water harvesting structure installation. (Prema Kaira et al., 2024). Spatial analysis further improves water quality assessment and management of traditional water sources, and thus more sustainable water management of watersheds (Prema Kaira et al., 2024).

Some of the uses of Geographic Information Systems (GIS) for water resource management are mapping spatial data on water sources and water distribution systems. GIS assists in the optimization of infrastructure design and layout, and it also improves decision-making (Engineering et al., 2023). It also supports real-time monitoring and control of water systems that make water supply management more efficient, reliable, and sustainable. GIS is also used in surface hydrology and groundwater modeling, and water supply and sewer system design. Additionally, it is involved in stormwater and nonpoint source pollution modeling for urban and agricultural lands, among other related uses.

A study by Dongare et al. (2024) Used GIS to analyze and design water distribution systems in Bota town. By leveraging satellite images and hydrological data, the study helped identify weaknesses in the network and improved water delivery through better planning and infrastructure development.

For the management of water resources, GIS offers strong tools. Water resource mapping, rainfall and runoff measurements, flood forecasting, irrigation system management, and water quality monitoring are just a few of the activities it facilitates. We can enhance resilience and

make better judgments about the use and preservation of our water resources by integrating GIS with technology such as the modeling of water and artificial intelligence (Engineering et al., 2023). GIS technology is an effective way of improving water management efficiency through enabling holistic analysis and problem-solving to be undertaken. GIS enables the creation of water tourism systems, facilitating access for potential tourists and optimizing the flow of tourists in regions like Yakutia (Andreev & Makarova, 2022).

2.6.2 Case Studies of GIS-Based Water Demand Assessment

Geographic Information Systems (GIS) have been widely used in managing water resources around the world. Many studies from various countries have shown how effective GIS can be in improving water resource management, including examples from;

i. Nigeria:

In their 2023 study, “Distribution and Access to Public Pipe-Borne Water in the Ilorin-West Local Government Area, Nigeria,” Olanrewaju et al. used Geographic Information System (GIS) techniques to analyze the spatial distribution of 146 public pipe-borne water points in Ilorin West. Their findings showed that these water points were randomly distributed, with a nearest-neighbor ratio of 1.2 (Olanrewaju et al., 2023). This suggested that the placement of water points didn’t align with the distribution of housing units, leading to issues like reduced productivity and missed business opportunities for residents. Based on these insights, the study recommended developing and implementing a house-to-point policy to improve water access in the area (Olanrewaju et al., 2023).

ii. Ethiopia

Tessema et al. (2023), a study titled "Hydro-chemical Characterization and Water Quality Assessment for Drinking and Irrigation Purposes Using WQI and GIS Techniques in Upper Omo River Basin (Southern Ethiopia) conducted to evaluate groundwater quality by collecting 58 water samples and analyzing them in GIS technology, revealed that three water quality index zones were identified: excellent (58.82%), good (35.29%), and poor (5.88%). Furthermore, in this study, the majority of the water samples were found to be drinkable (with few of them exceeding the standards of the World Health Organization and Ethiopian drinking water quality standards). In addition, electrical conductivity, sodium adsorption ratio, and permeability index data showed that most of the water samples were suitable for irrigation, except for three samples. (Tessema et al., 2023).

iii. **India:**

Meanwhile, Sharma (2023) modelled water demand trends in urban centers and assessed urbanization's implications on the water cycle using GIS in Bhopal City, India, showing GIS z-maps from 1991 to 2009. It detects changes in drainage patterns and calls out urban development complaints like water shortage and urban flash floods. Their research was all about improving the efficiency of the city's water network through the analysis of both spatial and temporal patterns of water use. So, Sharma (2023) showed where water is in demand and potentially where infrastructure can be improved to distribute water efficiently (Sharma, 2023).

In the above case studies, a glimpse into the use of GIS helped through three case studies that emphasize the importance of water resources assessment and management in different parts of the world, it highlights the community's livelihood and infrastructure development.

2.6.3 GIS Strengths and Limitations in Water Allocation

When it comes to water demand and allocation, the role of Geographic Information Systems (GIS) In addition to several strengths, the use of GIS also comes with some limitations. Besides this knowledge resource, maps can be used for effective management of water resources, but there are challenges in the use of GIS in water resource management, which need to be overcome by a new policy framework. GIS helps to improve the data-driven decision-making process related to water resource management tasks.

2.6.3.1 Strengths of GIS in Water Allocation

GIS & Remote Sensing optimization of water resources. GIS techniques add significant value to obtaining and managing geospatial data. The erosion and accretion patterns can also be easily identified using remote sensing. Finding groundwater potential zones (GWPZs) in the Gorezen watershed, Ethiopia, GIS attained a high accuracy of 0.87 (87%) (Mulu et al., 2024). These strengths include the ability to manage the data and perform spatial analysis, contributing to enhanced decision support systems as they pertain to water demand and allocation. GIS capabilities for water supply and allocation include spatial analysis, visualization of management strategies, and integration of diverse data sources (Aryastana et al., 2020).

2.6.3.2 The Limitations of GIS in Water Demand and Allocation

Limitations include difficulties in applying to more complicated regional assessments, as well as incorporating models such as the Pesticide Impact Rating Index (PIRI) that are less adept at processing spatially distributed input data. These limitations are related to data accuracy,

modeling complexity, and the requirement of trained personnel to effectively use the system (Wu et al., 2003). Furthermore, the Euclidean distance that GIS relies on is not always accurate as it fails to consider boundaries and obstacles, which in turn would lead to misplaced demand distributions in many cases of complex environments (Guth & Klingel, 2012).

2.7 Research Gaps

Similar studies have been carried out where Sharma (2023) developed the water demand trends in urban areas and the hydrological significance of urbanization through GIS in Bhopal City, India, which displayed GIS z-maps from 1991-2009 with little attention on urbanization concerning groundwater quality and, therefore, affecting the aquatic biodiversity.

While numerous studies highlight water scarcity causes and impacts, limited research has focused on GIS-based water allocation in Uganda, particularly in the Kasese District. This study bridges that gap by using GIS to assess water demand, identify distribution inefficiencies, and propose data-driven allocation strategies for sustainable management.

CHAPTER THREE:

STUDY METHODOLOGY

3.1 Research Design

The study employed a mixed-methods approach, combining qualitative and quantitative techniques to examine water demand and distribution in Kasese District. This study involved use of administering semi-structured questionnaires to the selected 400 respondents. This framework was chosen to address the multifaceted nature of water management by integrating statistical data with insights from key stakeholders. The research includes both descriptive and analytical elements to characterize the study area, facilitating a well-rounded understanding of the water demand patterns and allocation strategies in Kasese District, Uganda.

Quantitative methods were utilized to assess the socio-demographic characteristics of respondents and various study variables. This included analyzing primary household water collectors, different water sources, daily household water consumption, and meteorological factors such as precipitation and temperature using statistical software like SPSS and Excel. In contrast, qualitative methods focused on capturing key stakeholders' insights regarding the causes and effects of water scarcity, particularly issues related to water governance. Furthermore, GIS mapping was used to illustrate the spatial distribution of water sources throughout Kasese district in Uganda. By integrating these methods, the study achieved triangulation, thereby enhancing both the reliability and validity of the findings.

3.2 Study Area Description

Kasese District is located in western Uganda, at about latitude 0.2° N and longitude 30.1° E. It shares borders with the Rubirizi District to the southwest, Kamwenge District to the south, and the Democratic Republic of the Congo (DRC) to the west. The district is 3,389.8 square kilometers in size, with 68.8 square kilometers of marshes and wetlands, 407.7 square kilometers of open water, and 2,911.3 square kilometers of dry land. Notably, 1,834.6 square kilometers have been set aside for the preservation of species and the environment. A variety of water sources, including groundwater and surface water, define the district. From the Rwenzori Mountains, major rivers, including Nyamwamba, Rwimi, Mubuku, Nyamugasa, and Lhubirigha, feed into neighboring lakes like Lake Edward, Lake George, and Lake Katwe, all of which are part of Queen Elizabeth National Park. These sources of water are essential to the socioeconomic activities of the district, especially fishing and farming.

Kasese has an equatorial climate, with daily highs of 23°C to 30°C and occasionally higher, particularly when the sun is directly overhead in the Kasese Municipality. The district has a bimodal rainfall pattern, with May, August, and November seeing the most rain. Heavy rainfall in mountainous areas frequently causes flooding throughout river systems (Tibara et al., 2023). Even though the district has an abundance of water sources, it nevertheless faces issues like unequal water distribution, inadequate infrastructure, and the negative effects of climate change. Among these are more frequent floods and droughts, which have an impact on the amount of water available for industrial, agricultural, and residential uses (Tibara et al., 2021). Kasese District was chosen as the research location because of its representative qualities, which make it perfect for examining water management in areas with comparable natural and socioeconomic dynamics.

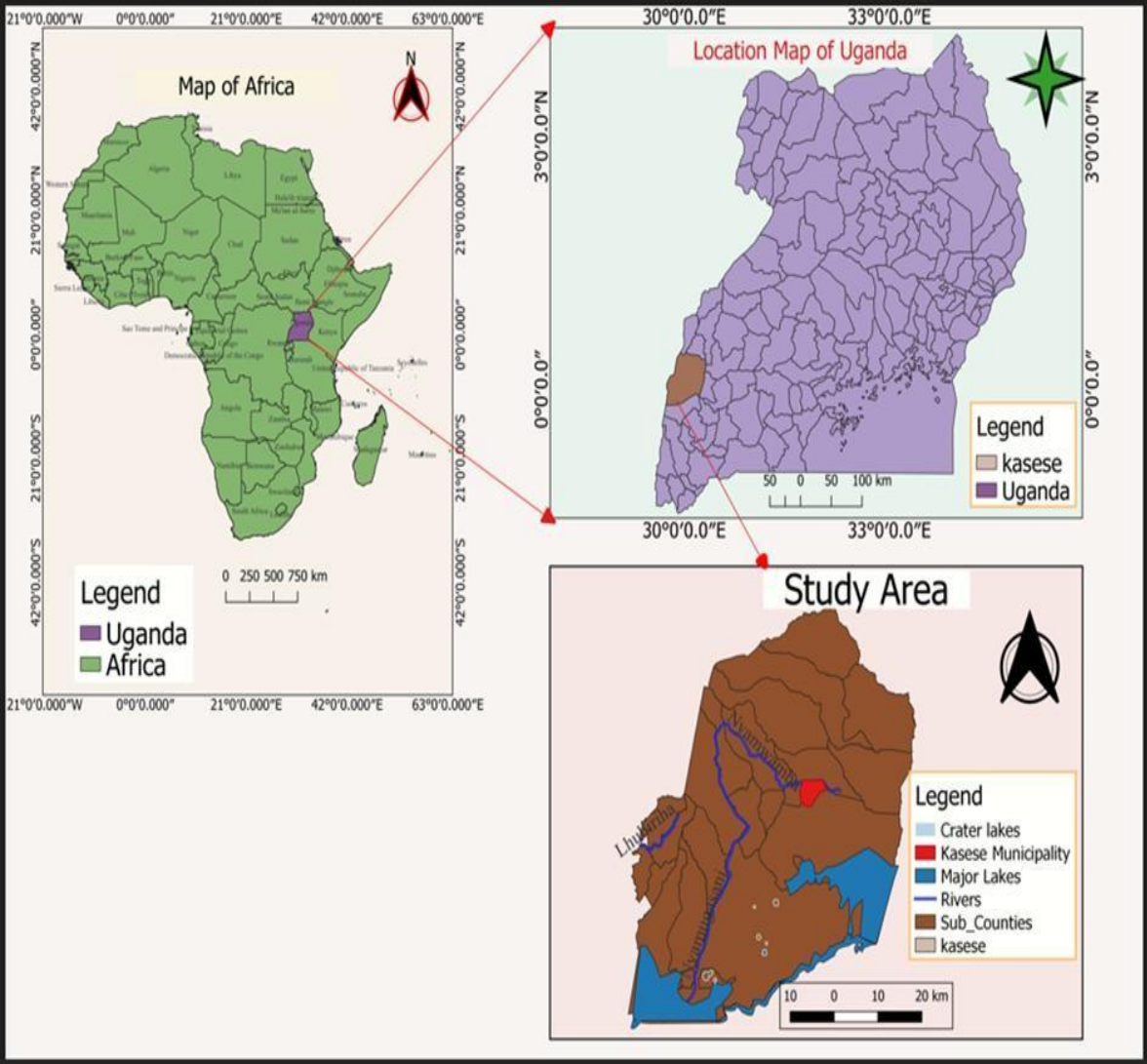


Figure 3.1: The location Map of the Kasese District in Western Uganda

Source: (Author’s Work, 2025).

3.3 Study population

According to the Uganda Bureau of Statistics (UBOS) of 2014, Kasese District has an estimated total population of 702,029 people, with 338,796 (48.3%) males and 363,233 (51.7%) females. A majority of 529,976 people (75.5%) live in rural areas, while 172,053 people (24.5%) live in urban areas (UBOS, 2014). The population figure has been utilized to calculate the sample size for the participants targeted for this study. The study population, sourced from the entirety of Kasese’s demographic, was categorized into the following groups: household representatives, farmers, representatives from water supply institutions (NWSC, MWE), local leaders, religious leaders, sub-county and parish chiefs, health workers, and officials from the Kasese district local government, specifically from the water and natural resources department, planning unit, and agriculture (production) department.

3.4 Sampling techniques and sample size determination

3.4.1 Sampling Techniques (Procedures)

In order to capture the various interests of household heads, agricultural, and industrial water users, the survey participants were carefully selected through a simple random sampling technique to represent the population at large. Non-probability sampling (Purposive) was also used to choose specialists in the water sector, including those from the Ministry of Water and Environment (MWE), National Water and Sewerage Cooperation (NWSC), Irrigation Scheme, Natural Resources and Environment in Kasese district, and health personnel who were important for detailed informative provision.

3.4.2 Sample Size Determination

To attain statistical significance, Yamane’s formula determined the sample size (Adam, 2020), considering the population size and the estimated water use variability. The appropriate sample size was determined and derived from Yamen’s formula (Eq... 1), which states that;

$$n = \frac{N}{1+Ne^2} \dots\dots\dots \text{Equation 1}$$

Where;

- *n = the sample size determined for the study*
- *N = the total population size of the study area*
- *e = the Margin of error ((Level of precision) (C.I = 95≈0.05 at 5%))*

Given that, $N = 702,029$, $e = 0.05$, n is calculated as follows;

$$\begin{aligned} n &= \frac{702,029}{1+702,029 (0.05)^2} \\ &= 399.999 \approx 400 \text{ Participants/Respondents} \end{aligned}$$

This study engaged a total sample size of 400 respondents from all the counties of Kasese district.

3.5 Types and Sources of Data

The study utilized both primary and secondary data sources. Primary data included firsthand information collected directly from study participants through various methods, such as field visits, questionnaires, focus group discussions, interviews, and personal observations. Secondary data, on the other hand, was obtained by reviewing government reports and online databases from international organizations. Additionally, Geographic Information System (GIS) shapefiles (Shp) datasets were employed to supplement data collection. The integration of these diverse data sources ensured a comprehensive approach, enabling the researcher to effectively address the study objectives.

3.6 Data Collection Methods

3.6.1 Primary Data Collection

The study employed various primary data collection techniques to collect the primary data types, and these include;

Surveys & Questionnaires—The surveys and questionnaires were conducted with household heads, farmers, and local leaders to assess water access, demand, and allocation challenges.

Interviews and focus group discussions. The researcher conducted interviews and Focus Group Discussions (FGDs) with key stakeholders, such as officials from the Ministry of Water and Environment (MWE), water agencies (NWSC), district officials, and industrial managers, to understand the governance and policy implications of water scarcity.

Field (Personal) Observations— The researcher utilized field observation by using his eyes to examine water collection points, infrastructure conditions, and spatial distribution disparities, validating the respondents' answers regarding these variables.

3.6.2 Secondary Data Collection

The study also used secondary data collection methods to acquire data such as Geographic Information System (GIS) shapefile (ShP) data, along with government reports, journals, and online databases.

The Geographic Information System (GIS) data included a series of GIS shapefiles that outlined different water sources located within sub-county regions of the Kasese district. The performance indicators obtained from governmental and institutional water sectors included measures for safe water access across all sub-counties of the Kasese district, as well as demographic data provided by the Uganda Bureau of Statistics (UBOS) and climatic data provided by the Uganda National Meteorological Authority (UNMA). Further, urban water demand data was obtained through the National Water and Sewerage Corporation (NWSC). The complete dataset sought to improve the understanding of water demand variability and water access disparities within the district.

3.7 Methods of Data Analysis

3.7.1 Spatial Analysis Using GIS

The water resources mapping process was carried out to assess water source spatial distribution, accessibility, and disparities involved with respect to the main water sources accessed by Kasese District residents for domestic, agricultural, and manufacturing purposes. The exercise involved mapping a range of water sources and related infrastructure, including boreholes, wells, springs, public stand posts (PSPs), gravity flow setups, rivers (symbolizing surface water), yard taps, and water kiosks. The use of heat maps helped to understand levels of accessibility for these scattered water sources within specified sub-counties. The spatial examination provided an overall understanding of existing water resources and levels of accessibility, thus helping to identify regions with priority water needs and aid future planning and resource distribution initiatives.

3.7.2 Statistical Analysis

Descriptive statistics were used to summarize survey responses related to water demand issues and the efficiency of existing water infrastructure. Descriptive statistics included; frequency distribution tables and graphical presentation to visualize and explore respondents' responses on the different variables like primary household water collectors. This approach provided

insights into how these factors interact and influence water resource management in the Kasese district.

3.8 Ethical considerations

An official letter of introduction for data collection was obtained by the researcher from the Pan African University Institute of Water and Energy Sciences (PAUWES). This letter was presented to the appropriate authorities in the study area to gain official authorization to carry out the research. The researcher also made use of his institutional identification to foster credibility and build trust with local officials and other relevant stakeholders throughout the fieldwork.

Before engaging participants, the researcher ensured that each respondent was thoroughly informed about the nature and objectives of the study, the procedures involved, and their rights as participants. These rights included voluntary participation and the freedom to withdraw from the study at any time without any adverse consequences. Informed consent was sought and obtained, confirming that participation was based on a clear understanding of the research and a willingness to take part.

Throughout the data collection process, the academic intent of the research was consistently communicated, and the importance of the participants' involvement was highlighted. Participants were explicitly informed that their participation would not be accompanied by any form of financial or material reward.

To maintain ethical integrity, the researcher implemented rigorous confidentiality measures. All personal identifiers were removed from the collected data to ensure participant anonymity and protect their privacy. The research was guided by core ethical principles, including respect, honesty, and transparency, with a steadfast commitment to safeguarding the rights and well-being of all participants throughout the study

3.9 Work Plan

The research was conducted over approximately four months, separated into major phases:

1. Initial Scoping and Data Collection (December).

This step involves identifying key stakeholders, obtaining necessary permits, and carrying out preliminary data collection activities.

2. Data collection, coding, and analysis (January and February).

The data collected was coded (cleaned) and then later subjected to both qualitative and quantitative analysis techniques, including interpretation and validation of the study results.

3. Final report writing and submissions (March).

During the last phase, the researcher compiled the findings into a detailed report and planned submissions to the concerned persons and stakeholders to inform them of the key study findings.

Throughout the research process, regular progress assessments were done to ensure that the study stayed on track and could adapt to any new obstacles that arose.

CHAPTER FOUR:

DATA ANALYSIS, INTERPRETATION, PRESENTATION, AND DISCUSSION

4.1 Introduction

This chapter presents the study findings, organized into two main parts: the study respondents' socio-demographic characteristics and results relevant to the study-specific objectives include determining the causes of water scarcity in Kasese District, assessing water scarcity effects on residential, agricultural, and industrial sectors, and using Geographic Information System (GIS) to map the spatial distribution of water sources and analyze their accessibility in different sub-counties of Kasese District, Uganda. Furthermore, practical policy recommendations are made based on the key study findings. The results are based on data gathered from 400 participants using a detailed methodological approach that consists of surveys, semi-structured questionnaires, interviews, focus group discussions (FGDs), and personal observations. The results are presented systematically, using descriptive statistics, tables, plates (pictures), and figures to facilitate an in-depth understanding of the underlying challenges.

4.2 The Socio-Demographic Characteristics of the Study Respondents

This study explores key demographic variables, including age group, gender (sex), educational background, occupation, the primary household water collectors, accessibility to different water sources, and the household size, based on a sample of 400 respondents. These factors significantly impact water needs across different sectors, including domestic use, agriculture, and industry, thereby affecting the sustainability of water resource utilisation. Variations in age distribution can indicate differing levels of water dependency.

A systematic analysis of these demographic variables establishes a strong empirical basis for assessing inequalities in water access and infrastructure development. The insights gained would contribute to a data-driven discourse on water resource management while informing policy recommendations tailored to address specific challenges. These findings would be instrumental in designing sustainable water governance strategies that promote equitable distribution and strengthen resilience to water scarcity issues in the Kasese District.

4.2.1 Age, Gender, and Education

A considerable percentage of the respondents (36.8%) fell within the 31–40 age group, which is typically regarded as the most economically productive age group. Women made up 56.5% (N = 226) of the study participants, highlighting their essential involvement in household water management and water collection activities (Table 4.2)

Regarding education levels, the highest proportion of respondents (39%, N = 156) had attained secondary education, indicating a moderate literacy rate in Kasese District. This level of educational attainment can influence the extent to which individuals are aware of, and can effectively implement, water management and conservation strategies (Table 4.2).

4.2.2 Occupation and Household Size

Agriculture was the main occupation, with 37.8% (N = 151) of the participants being farmers, thus emphasizing the huge water demand created by irrigation as well as livestock. Moreover, most families, representing 52.3% (N = 209), consist of 6 to 8 members (Table 4.2), thus increasing the water usage rates per day and exacerbating competition for the available water resources.

Table 4.2: The Socio-Demographic Characteristics of the Study Respondents

Variables		Frequency (N)	Percentage (%)
Age of Respondent	Under 20 years	20	5.0%
	21-30 years	54	13.5%
	31-40 years	147	36.8%
	41-50 years	97	24.3%
	Above 50 years	82	20.5%
Gender of Respondent	Female	226	56.5%
	Male	174	43.5%
Education Level	Non-formal education	19	4.8%
	Primary	149	37.3%
	Secondary	156	39.0%
	Tertiary/University	76	19.0%
Main Occupation	Business	115	28.7%
	Civil servant	54	13.5%
	Farmer	151	37.8%
	Local leader	35	8.8%
	Student	45	11.3%
Household Size	Less than 3 people	39	9.8%
	3-5 people	108	27.0%
	6-8 people	209	52.3%
	More than 8 people	44	11.0%

Source: (Author's Work, 2025)

4.2.3 The primary household water collectors

The results indicate that water collection for domestic purposes is primarily undertaken by female members of the household. Women represented the highest percentage of individuals responsible for this task, comprising 46.75% (N = 187), followed by girls at 31.75% (N = 127). In comparison, boys accounted for only 13% (N = 52), and men 8.5% (N = 34). These figures

highlight the disproportionate involvement of females in household water collection, reflecting a clear gender imbalance (Table 4.2.3) (Figure 4.2.3).

Table 4.1.3. *The Primary Household Water Collectors*

Household Water Collectors		Frequency (N)	Percentage (%)
Variables	Women	187	46.75
	Girls	127	31.75
	Men	34	8.5
	Boys	52	13.0
	Total	400	100.0

Source: (Author’s Work, 2025)

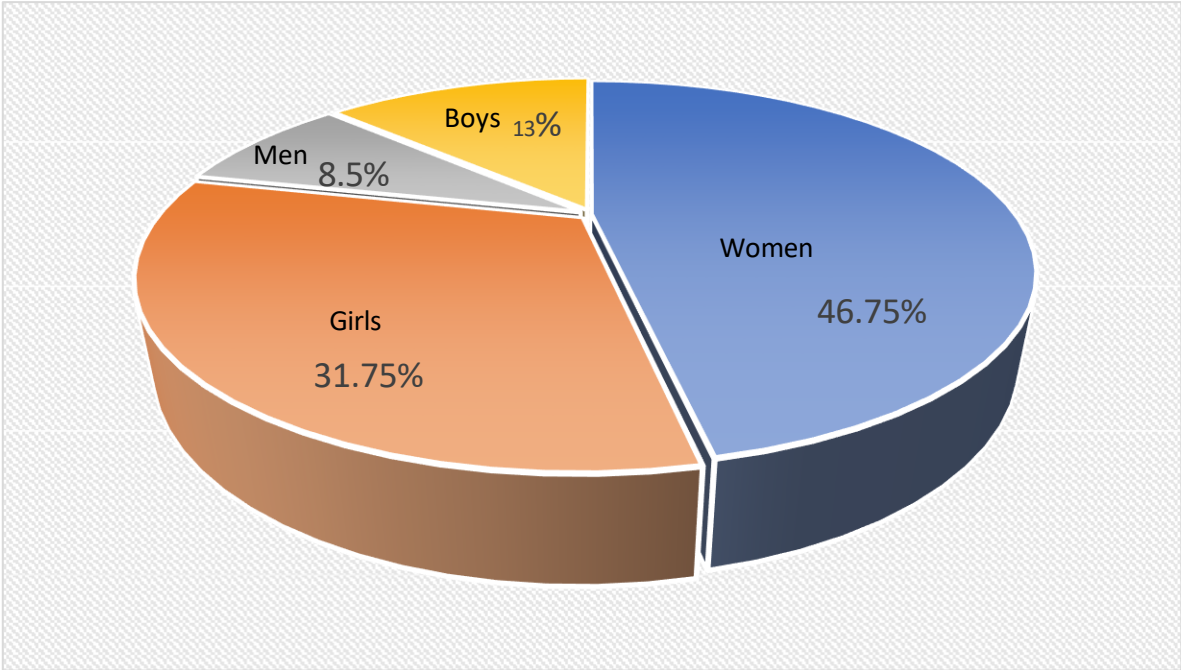


Figure 4.2.3 *Primary Household Water Collectors*

Source: (Author’s Work, 2025)

This finding aligns with MacAlister et al. (2023), who reported that in many developing nations, cultural norms and gender roles designate women as the main providers of water for essential domestic functions such as drinking, cooking, and maintaining hygiene.

The results of the study, complemented by direct field observations, highlight a pronounced gender disparity in responsibilities related to household water collection. Although the quantitative data demonstrated that females predominantly undertake this task, qualitative insights gathered during site visits further substantiated and contextualised this pattern. Women

and girls were consistently seen moving long distances to access water, often from unprotected and potentially hazardous sources, thereby facing heightened exposure to waterborne illnesses (Plate 4.2.3). Reliance on such unsafe water points underscores broader structural challenges in equitable water access. Additionally, the physical strain imposed on young girls, who frequently carry jerrycans heavier than their body weight, raises serious health implications (Plate 4.2.3). These outcomes point to a pressing need for the implementation of gender-responsive strategies in the planning and provision of water services within the district.



Plate 4.2.3: *Female gender (Women & Girls) collecting water from unhygienic sources/points*
Source: (Author’s Work, 2025)

4.2.4 Household Daily Water Consumption (Liters per Day)

The study revealed significant variation in daily household water consumption among respondents in the Kasese District. Most households (32.5%) reported using between 200 and 299 liters per day, while 26.3% consumed less than 200 liters. A further 21.0% indicated daily usage ranging from 300 to 399 liters, 15.8% consumed between 400 and 499 liters, and only 4.5% of households reported consuming 500 liters or more per day (Table 4.2.4).

Table 4.2.4: *The Household Daily Water Consumption (Liters per Day)*

Amount of water consumed (Liters/day)	Frequency (N)	Percent (%)
<200L	105	26.3
200-299L	130	32.5
300-399L	84	21.0
400-499L	63	15.8
500+L	18	4.5
Total	400	100.0

Source: (Author’s Work, 2025)

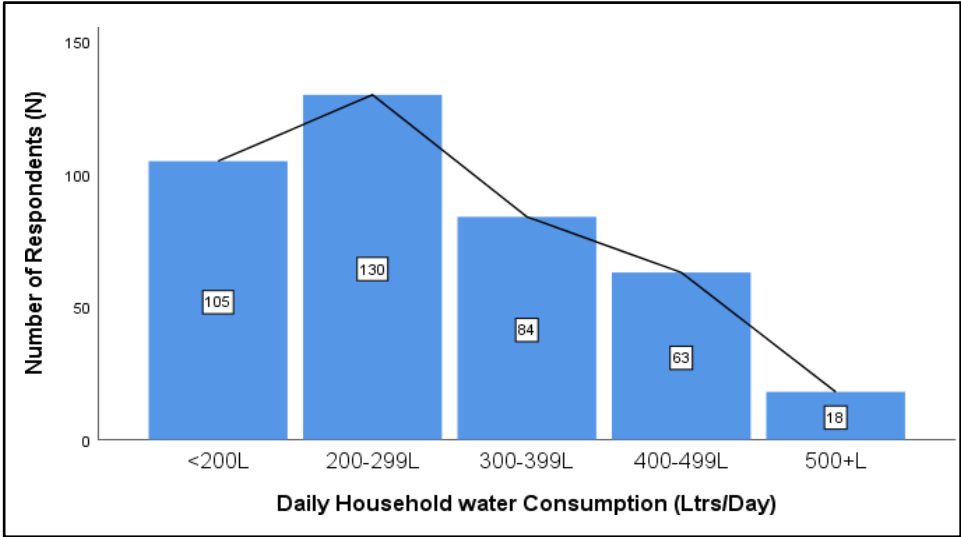


Figure 4.2.4: *Household Water Consumption*
Source: (Author’s Work, 2025)

These findings indicate that the majority of households (58.8%) utilize less than 300 litres of water per day (Fig. 4.2.4). Considering that the average household size in the study area ranges between 6 to 8 members, these consumption levels fall significantly below the minimum daily water requirements recommended by the World Health Organization (WHO), which suggests 50–100 litres per person per day to meet basic needs such as drinking, cooking, hygiene, and sanitation. Ideally, such households would require between 300 and 800 litres per day to maintain adequate health and hygiene standards. The observed shortfall in water usage could be due to limited access to sufficient water sources in the Kasese district.

These findings support the study by Kanyesigye et al. (2021), which reported similarly low per capita water consumption in water-stressed regions of western Uganda, citing both infrastructural limitations and long distances to water sources as contributing factors. Furthermore, they align with MacAlister et al. (2023), who emphasized the disproportionate burden faced by women and children in water-scarce communities, often resulting in reduced water usage due to physical and time constraints. The extremely low proportion of households (4.5%) consuming over 500 litres per day could reflect geographical proximity to improved water sources or a relatively higher socioeconomic status of only a few families in the study area, enabling more frequent or reliable access.

Consequently, these findings underscore an urgent requirement for infrastructure enhancement, especially in neglected sub-counties, in conjunction with community-oriented water resource management and policy reforms designed to augment access to safe and adequate water. Additionally, fostering household-level water conservation technologies, such as rainwater harvesting, and enhancing public awareness of water management practices may alleviate the detrimental impacts of water scarcity identified in the study area.

4.2.5 Access Rate to safe water in Kasese District.

The availability of safe water in Kasese District remains a significant challenge, with an access rate of 56%, which is considerably lower than the national average of 74%. Data from the Kasese District Water Department

(<https://www.kasese.go.ug/departments/engineering/water-and-sanitation/>) retrieved on 31st January 2025 indicate substantial disparities among sub-counties, with Kyondo Sub-county recording the lowest access at 17%, while Ihandiro Sub-county reports the highest at 75% (Table 4.2.5). It was indicated that the district has 3,510 domestic water points serving 516,413 residents, yet a significant portion (344,406 people in rural areas) remains inadequately served, including 177 boreholes and 1,932 gravity flow Scheme (GFS) taps. However, their uneven distribution exacerbates water scarcity, particularly in rural communities.

Table 2.2.5: Access Rate to Safe Water in Kasese District.

N/s	Sub-counties	Safe Water Access Rate (%)
1.	Ihandiro	75%
2.	Munkunyu	21%
3.	Kyondo	17%
4.	Maliba	41%
5.	Kyarumba	31%
6.	Bwesumbu	43%
7.	Buhuhira	42%
8.	Nyakabingo	60%
9.	Kitabu	59%
10.	Karusandara	56%

Source: (Kasese District Local Government-Water Department website, <https://www.kasese.go.ug/departments/engineering/water-and-sanitation/>)-31/01/2025.

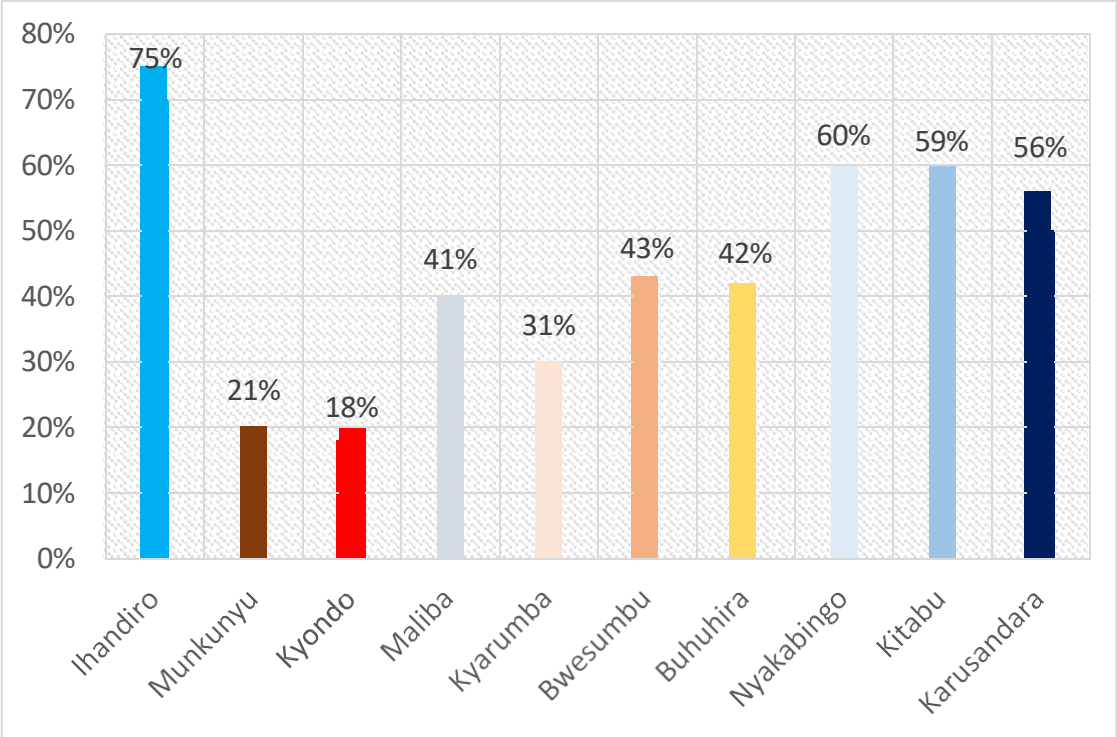


Figure 3.2.5: Access Rate to safe water in Kasese District (Source: Kasese District Local Government-Water Department website, <https://www.kasese.go.ug/departments/engineering/water-and-sanitation/>)

Marked differences in water supply between urban and rural areas, especially in sub-counties like Kyondo, have heightened the exposure of rural communities to waterborne illnesses, inadequate sanitation, and reduced economic output due to the considerable time spent collecting water. This finding supports MacAlister (2023), who highlights how restricted access to water negatively affects rural livelihoods. In many parts of Kasese District, insufficient water infrastructure limits individuals' capacity to meet daily water needs, thereby infringing on their fundamental right to safe water and sanitation. As a result, these challenges hinder progress toward the realization of Sustainable Development Goal (SDG) 6, Target 6.4, and the aspirations of Uganda's Vision 2040, both of which advocate for universal and equitable access to safe water and sanitation services. Addressing this challenge requires urgent and strategic investment in alternative water supply solutions, including rainwater harvesting, borehole drilling, and the construction of water treatment plants in poorly served sub-counties like Kyondo. The region's limited access to safe water is primarily due to inadequate water infrastructure, which contributes to resource competition, potential water-related conflicts, and rising water prices. These elevated costs disproportionately affect the most economically disadvantaged households, thereby exacerbating existing socio-economic disparities, a concern echoed by Adamopoulou et al. (2023).

4.3. The Causes of Water Scarcity in Kasese District (*Objective i*)

4.3.1 Poor Water Infrastructure

A notable 60% of participants identified outdated and inadequate water infrastructure as a primary factor contributing to water scarcity within their communities. This view is reflected in the water sources available in the study area, many of which rely on aging systems with limited maintenance. For instance, 45% of respondents depend on public stand posts, which are frequently affected by structural defects and unreliable service. Additionally, 35% access water from surface sources such as rivers and streams that often lack regulation and proper treatment, increasing risks to both health and environmental sustainability. Boreholes, used by 5% of households, tend to have low output or face mechanical breakdowns due to insufficient upkeep, while 15% rely on yard taps that are prone to supply interruptions from damaged pipelines or pressure inconsistencies. These patterns are consistent with findings by MacAlister et al. (2023), who noted that inadequate infrastructure significantly limits water access and heightens health vulnerabilities in underserved regions. Likewise, Adamopoulou et al. (2023) emphasized the crucial role of infrastructure investment in ensuring equitable and sustainable access to safe

water. Consequently, improving the state and reliability of water infrastructure in Kasese District is essential for enhancing water security and achieving the targets of Sustainable Development Goal 6 (Table 4.3.1).

Table 4.3.1: *The different Water Sources Accessed by respondents in Kasese District*

<i>Inadequate Water Infrastructure</i>		
Accessible Water Points/Sources	Frequency (N)	Percentage (%)
Public Standpipes (PSP)	180	45
Surface Water (Rivers & Streams)	140	35
Piped Water/Yard Taps (YT)	60	15
Boreholes	20	5
Total	400	100

Source: (Author’s Work, 2025)

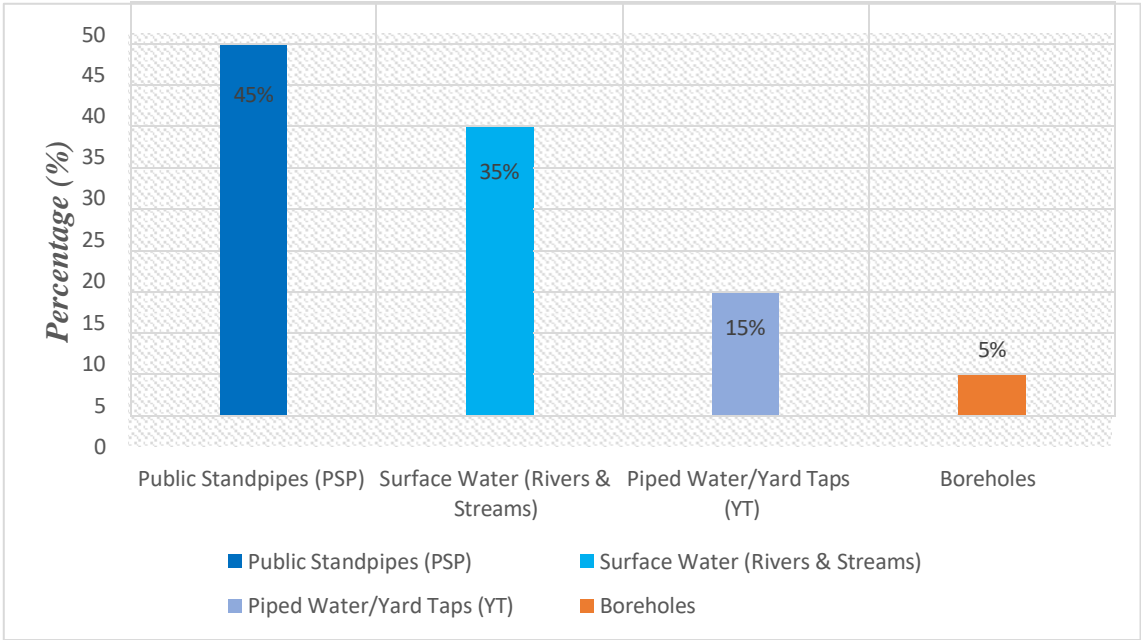


Figure 4.3.1: *The different Accessible Water points*

Source: (Author’s Work, 2025)

4.3.1.1 Stakeholder Interview (Perspective)

Theme 1: Deteriorating infrastructure as a root cause of unreliable water supply.

Question: What has caused the prevalence of aging water infrastructure in your society?

Several water experts (Technicians) cited that “most of the water systems, especially in rural areas, were constructed decades ago with little to no maintenance. This has led to frequent pipe bursts, leakages, and dry standposts. Infrastructure breakdowns contribute to inconsistent supply and water loss. Moreover, insufficient budgetary allocations to the water department have hindered its capacity to effectively support Village Water User Committees in maintaining and rehabilitating existing water infrastructure”.

This limitation was confirmed through the researcher’s direct observations during multiple field visits to various water points within the study area. The researcher identified several malfunctioning and abandoned facilities, including boreholes, public standposts, and yard taps, which underscore the deteriorating condition of the water infrastructure and highlight the pressing need for systematic repair and maintenance interventions (Plate 4.3.1).



Plate 4.3.1.1: *The broken (Malfunctioning) Water systems in different communities of Kasese*
Source: (Author’s Work, 2025)

Moreover, on-site observations during field visits revealed extended queues at the limited number of functional public stand posts in Kasese Municipality (Plate 4.3.1.2). When questioned about the duration required to collect water, most respondents indicated that they often wait for more than an hour during each trip.



Plate 4.3.1.2: *The long queues at operational public stand posts during different time intervals*
 Source: (Author's Work, 2025)

Water service providers noted that the deteriorating state of the water distribution infrastructure, coupled with the slow adoption of new technologies, significantly impairs their ability to meet the growing demand for water within the district. A major issue identified was the lack of sophisticated monitoring tools, particularly the System for Control and Automated Remote Data (SCARD). This system, which operates based on Supervisory Control and Data Acquisition (SCADA) frameworks, is intended to support real-time system monitoring, enhance operational performance, and ensure timely detection and resolution of leakages throughout the network.

Theme 2. The consequences of poor infrastructure

Qn. How does insufficient or poor infrastructure affect your operations and your society?

Water managers indicated that *“in the absence of such technology, levels of non-revenue water (NRW) remain high. NRW refers to water that is supplied but not accounted for through billing due to factors like leakage, unauthorized consumption, or faulty metering. This not only reduces the amount of water accessible to users but also weakens the financial stability of water utilities by curbing their revenue streams. As a result, there are limited resources available for critical maintenance and upgrades of the infrastructure. These challenges highlight the pressing need for technological advancement and strategic investment in the water sector to strengthen service delivery, transparency, and long-term sustainability”*.

Key stakeholders from marginalized sub-counties reported that *“the inadequacy of water infrastructure severely limits residents' access to safe and consistent water sources. As a result,*

many households are forced to depend on unsafe alternatives such as unprotected springs, polluted streams, and contaminated wells". According to a Village Health Team (VHT) representative, *"this reliance increases the incidence of waterborne diseases and disproportionately burdens women and children with the physically demanding task of water collection. This gendered labor division not only impedes educational attainment and economic participation but also reinforces existing socio-economic inequalities within already disadvantaged communities"*. These findings underscore the urgent need for targeted interventions to improve water supply infrastructure in the Kasese District. Addressing these challenges requires a comprehensive strategy, including investment in pipeline expansion, adoption of advanced leak detection systems, and policy reforms aimed at promoting equitable water distribution. Implementing these measures would enhance water accessibility and efficiency while also strengthening the district's resilience to future challenges, such as population growth and climate variability.

4.3.2 Increasing Population Growth

Kasese District's steady annual population growth rate of 2.9% has emerged as a fundamental driver of rising water demand across domestic, agricultural, and industrial sectors. This demographic expansion is rapidly outpacing the development of water infrastructure, thereby deepening the strain on the district's finite water resources and widening the gap between supply and demand.

Urban areas, particularly the Central and Nyamwamba Divisions within Kasese Municipality, have witnessed sharp increases in water demand due to both natural population growth and internal migration. However, the existing water infrastructure is insufficient to meet this demand, resulting in intermittent supply. Survey data indicate that approximately 58% of urban households encounter regular shortages, especially during dry periods, prompting the enforcement of supply rationing by utility providers.

The growing population has also placed considerable stress on agricultural water use. In response to increasing food demand, many residents have turned to small-scale irrigation farming. Officials managing irrigation schemes report that over 64% of major water sources have experienced significant depletion, largely due to unregulated water abstraction and diversion. This issue is particularly acute in sub-counties like Karusandara, where irrigation needs have intensified alongside unpredictable climatic patterns. This aligns with Kato (2024),

water stress. Nonetheless, even less densely populated regions, dependent on gravity flow systems or poorly maintained infrastructure, are increasingly vulnerable, demonstrating that water scarcity is driven by both demographic pressure and governance inefficiencies.

To mitigate these challenges, there is an urgent need for strategic investments in water infrastructure, the implementation of effective regulatory mechanisms, and the adoption of integrated water resource management approaches. Without these interventions, the district risks escalating shortages that could jeopardize public health, agricultural productivity, and economic development.

4.3.3 Climate Variability and Seasonal Shortage

The climate data obtained from the Uganda National Meteorological Authority (UNMA) for Kasese District presents significant temporal variability across several climatic parameters. This variability plays a critical role in understanding the underlying causes of water scarcity within the district.

Kasese District experiences significant seasonal water shortages due to variations in rainfall patterns and rising temperatures. The district's average monthly temperatures range between 23.3°C in November and 25.8°C in February (Table 4.3.3), with the highest recorded temperatures occurring in January (29.7°C) and February (30.7°C) (Table 4.3.3). These high temperatures accelerate evaporation, leading to a decline in surface water levels in key rivers such as Nyamwamba, Nyamugasani, and Mubuku. As a result, the availability of water for agriculture, domestic use, and industrial activities is significantly affected during dry periods.

Although rainfall remains moderate in January (456 mm) and February (361 mm), the most critical water shortages occur in July (112 mm) and August (202 mm), overlapping with humidity levels dropping to 56% in July and 62% in August (Table 4.3.3).

Table 4.3.3: The Monthly Average Climate Variability in Kasese District.

Months	Jan	Feb	Mar	Apr	Ma	Jun	July	Aug	Sept	Oct	Nov	Dec
Avg. Temp (°C)	25.1	25.8	24.9	24.2	24.2	24.3	24.5	24.2	24.1	23.8	23.3	24
(°F)	77.2	78.5	76.8	75.6	75.6	75.8	76.1	75.5	75.4	74.8	74	75.3
Min. Temp (°C)	20.6	21.1	20.8	21.1	21.2	20.7	20.5	20.5	20.1	19.9	19.5	19.9
(°F)	69.1	70	69.4	69.9	70.2	69.2	68.9	68.9	68.1	67.8	67.1	67.8
Max. Temp(°C)	29.7	30.7	29.4	28.2	28	28.5	29	28.6	28.8	28.3	27.6	28.5
(°F)	85.5	87.3	84.9	82.7	82.5	83.3	84.1	83.4	83.8	82.9	81.6	83.2
Rainfall (mm)	456	361	497	458	383	204	112	202	253	366	538	606
Humidity (%)	59%	55%	63%	68%	67%	61%	56%	62%	63%	67%	70%	65%
Rainy days (d)	18	16	20	19	18	12	9	14	15	19	20	20
Avg. Sun hours	8.8	9.2	8.6	8.5	8.7	8.9	9.2	9.1	9.2	8.8	8.2	8.2

Source: (Uganda National Meteorological Authority-Kasese, Met Datasets, 2024).

February, July, and September, the driest months, also record prolonged sunshine exposure (9.2 hours daily), further accelerating water loss through evaporation from rivers and reservoirs. Additionally, groundwater recharge is minimal during these months, reducing borehole and well water availability and increasing reliance on alternative water sources such as rainwater harvesting and water trucking.

In contrast, the March-May and September-December rainy seasons (Table 4.3.3) enhance water availability.

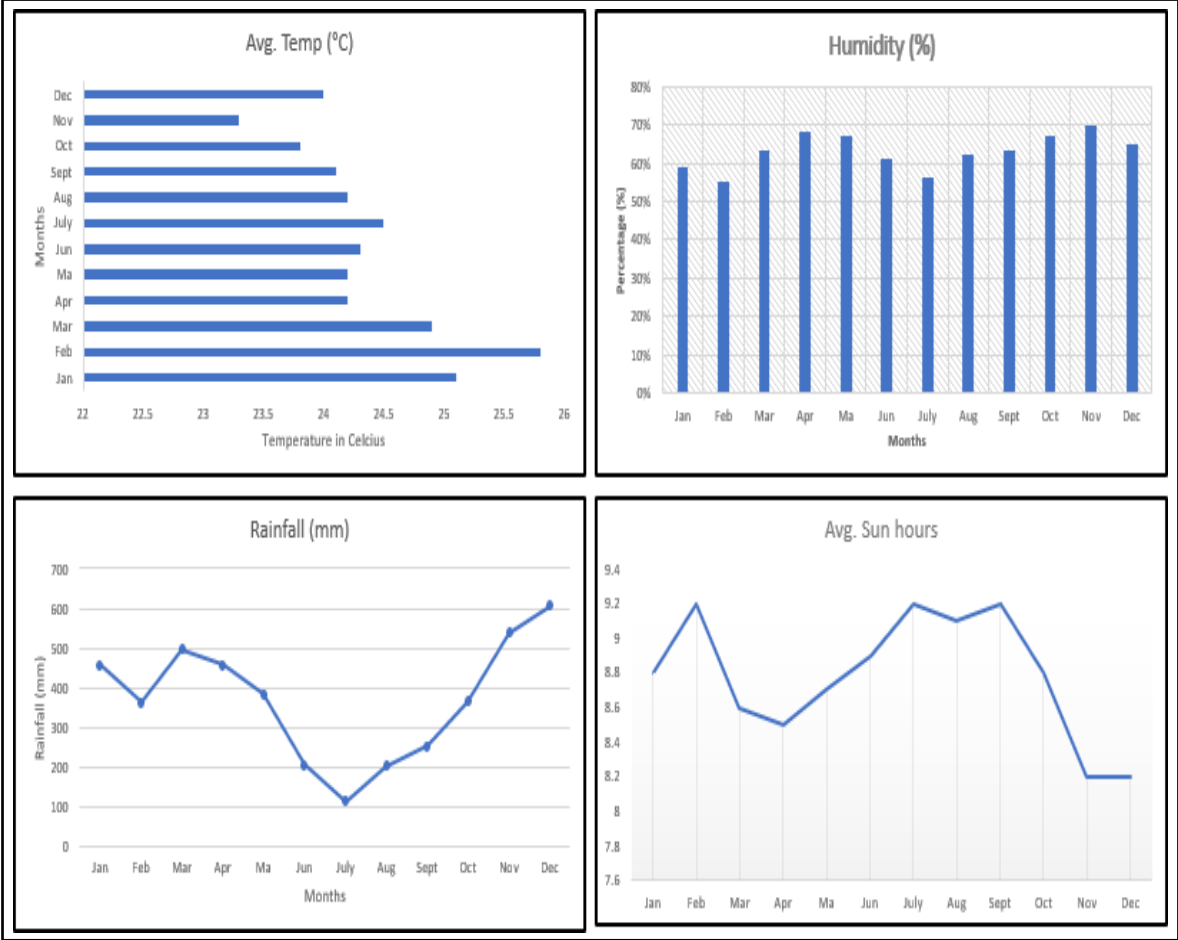


Figure 4.3.3: The Monthly Average Climate Variability in Kasese District.

Source: (Uganda National Meteorological Authority-Kasese, Met Datasets, 2024).

However, these periods are also characterized by flooding, soil erosion, and water contamination. November (538 mm) and December (606 mm) receive the highest rainfall amounts, posing risks of infrastructure damage and increased sediment deposition in rivers. Humidity levels fluctuate significantly throughout the year, reaching their lowest in February (55%) and highest in November (70%), affecting both evapotranspiration and soil moisture retention.

Therefore, as adaptation strategies to climate change impacts on water availability, some households and institutions, such as health centers, have embraced the integration of rainwater harvesting infrastructure into their buildings to help capture and store rainwater for future use during the drought season (Plate 4.3.3).



Plate 1.3.3: *The Rainwater Harvest tanks are installed in household & institutions' buildings*
Source: (Author's Work, 2025)

4.4 Effects of Water Scarcity in Kasese District (Objective (ii))

4.4.1 Domestic and Livelihood Impacts

The issue of water scarcity in Kasese District has profoundly affected household well-being, contributing to a significant decline in the quality of life. A structured questionnaire survey involving 400 respondents revealed that the most pressing challenge is inadequate access to clean drinking water, reported by 41.25% of participants. This is followed by concerns related to poor sanitation and hygiene (27.5%), extended time spent collecting water (18.75%), and increasing water costs (12.5%) (Table 4.4.1).

Table 4.4.1: *The effects of Water Scarcity on the Domestic sector in the Kasese district.*

Effects of Water Scarcity	Number of Respondents (N)	Percentage (%)
Lack of clean drinking water	165	41.25
Poor sanitation and hygiene	110	27.5
Increased time fetching water	75	18.75
Rising water costs	50	12.5
Total	400	100

Source: (Author's Work, 2025)

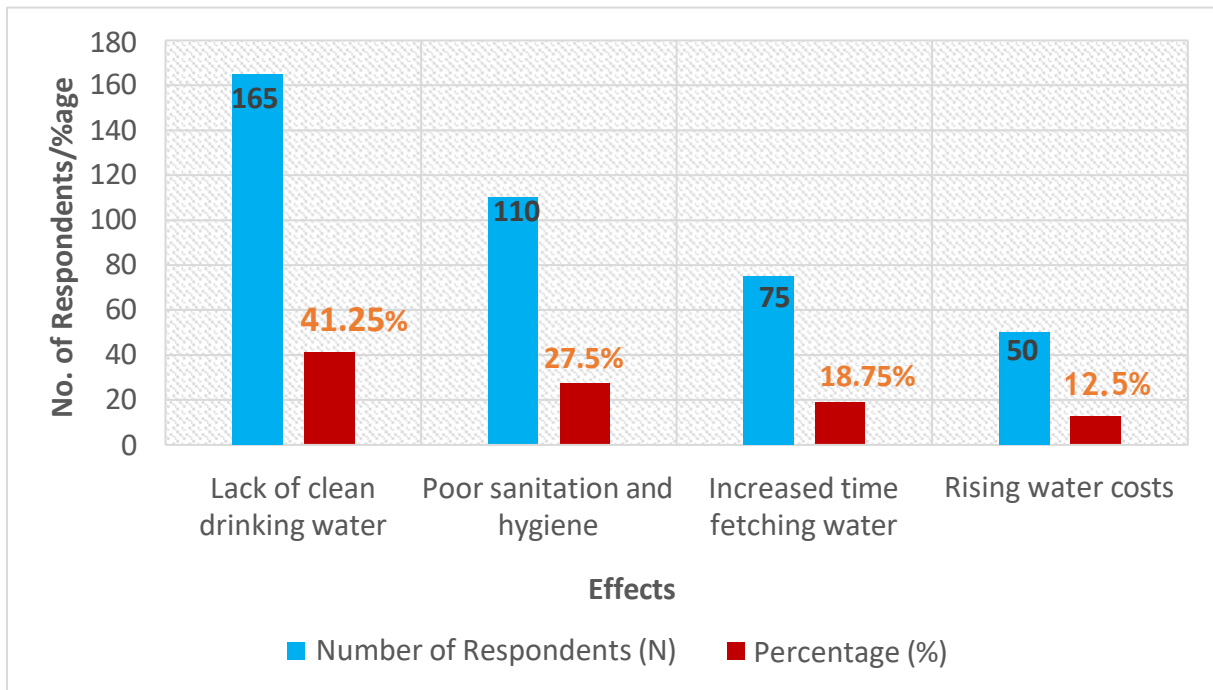


Figure 4.4.1: *The Effects of Water Scarcity on the Domestic Sector in Kasese District Source: (Author's Work, 2025)*

Findings from interviews and focus group discussions with elderly residents, household heads, Water Users Association representatives, local authorities, and religious leaders indicate that nearly 60% of households experience water shortages at least four times a week. The Chairperson of the Kizungu Cell Women's Association highlighted that frequent breakdowns of water taps compel women to travel long distances, often to the Nyamwamba River, in search of water. These prolonged trips not only expose them to risks such as gender-based violence but also contribute to domestic conflicts, as partners grow suspicious of the time spent away from home fetching water.

Women and children dedicate an estimated 1.5 to 2 hours daily to collecting water, which reduces opportunities for income-generating activities and negatively impacts children's school attendance. Furthermore, focus group discussions pointed to an increase in disputes over water access, especially in densely populated areas where multiple households depend on a single water point. On the other hand, medical records from local health centers further highlight the impact of water scarcity on public health, with approximately 35% of reported illnesses attributed to waterborne diseases such as typhoid and cholera. Additionally, field observations and surveys confirm that women and girls experience higher rates of musculoskeletal conditions, including neck, chest, and back pain, due to the physical burden of carrying heavy water containers over long distances. These findings underscore the urgent need for

interventions to enhance water supply infrastructure, improve resource management, and ensure equitable access to safe water sources

4.4.2 Agricultural Effects

Table 4.4.2: *The effects of Water Scarcity on the Agricultural practices in Kasese district*

Water Shortage Effects on Farming Practices	Number of Respondents (N)	Percentage (%)
Reduced Crop Yield	160	40.00%
Increased Prevalence of Crop Pests and Diseases	85	21.25%
Limited Livestock Watering Opportunities	70	17.50%
Soil Degradation and Loss of Soil Fertility	50	12.50%
Increased Irrigation Expenses	35	8.75%
Total	400	100%

Source: (Author's Work, 2025)

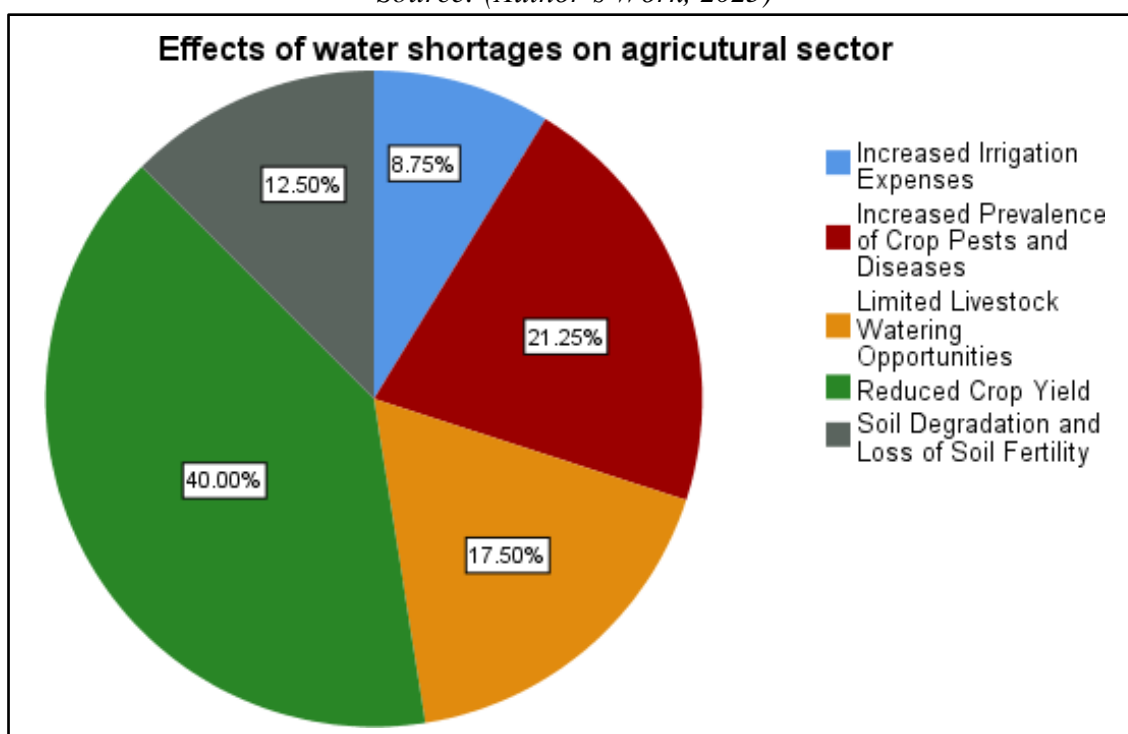


Figure 4.4.2: *The Effects of Water Scarcity on Agricultural Practices in Kasese District Source: (Author's Work, 2025)*

Water scarcity has profoundly impacted agricultural productivity in the Kasese District, disrupting both crop farming and livestock rearing. Research findings indicate that 40% of

respondents identified a decline in crop yields as the most severe consequence, highlighting the adverse effects of prolonged droughts and inadequate irrigation systems on food production. Additionally, 21.25% of respondents noted an increase in crop pests and diseases, suggesting that water-stressed plants become more vulnerable to infestations and infections due to weakened resistance.

Another critical challenge associated with limited water availability is the difficulty in providing sufficient water for livestock, which was reported by 17.5% of respondents. This issue not only jeopardizes animal health but also threatens the sustainability of dairy farming and livestock-based livelihoods. Soil degradation and declining soil fertility were also prominent concerns, with 12.5% of respondents attributing these issues to insufficient water supply. Reduced moisture levels accelerate soil erosion and nutrient depletion, ultimately compromising long-term agricultural productivity. Additionally, 8.75% of respondents pointed out the rising costs of irrigation, indicating that farmers are increasingly reliant on expensive alternative water sources to maintain crop production (Table 4.4.2).

Observations at the Mubuku Irrigation Scheme further highlighted the challenges posed by water scarcity. Findings revealed that irrigation water is drawn from River Nyamwamba, a distant source requiring extensive infrastructure for distribution (Plate 4.4.2). However, concerns raised by the Ministry of Water and Environment and the Kasese District Local Government emphasize the risks associated with this water source. Recent flooding incidents have led to contamination with heavy metals and copper, posing potential hazards to both agricultural produce and human health. Addressing these challenges requires urgent interventions, including the development of improved irrigation infrastructure to enhance water distribution, the implementation of effective water governance strategies to ensure equitable resource allocation, and measures to mitigate water pollution and soil degradation. Strengthening these areas will be crucial in minimizing the adverse effects of water scarcity and fostering sustainable agricultural practices in the Kasese District.



Plate 4.4.2: A field visit to the diverted River Nsebwe into the Mubuku irrigation Scheme Source: (Author's Work, 2025)

It is clear from the results that Kasese District's agricultural productivity suffers from water constraints. The results of the study showed that there is a significant variation in the ways that water constraints impact many facets of agriculture in the Kasese district. The wide range of answers demonstrates that different farmers encounter water scarcity in different ways, with crop yield loss being the most frequent consequence.

4.4.3 Industrial Impacts

Industries and businesses in Kasese District rely heavily on water for their daily operations, yet persistent water shortages continue to impede productivity and economic performance. Key examples of industries, including agro-processing, manufacturing, and mining, are facing serious operational disruptions due to inadequate water supply, which limits production capacity, escalates operational costs, and reduces overall efficiency. An interview with the hospitality industry marketing managers revealed that *“manufacturing industries have experienced a 15% reduction in water supply, compelling many factories to reduce production hours as an adaptive measure”*. This decline in operational output not only lowers profit margins but also weakens the district's industrial competitiveness and economic resilience.

Additionally, the Maize Millers Processing Company managers highlighted that “*rising operational expenses are a direct result of the company’s reliance on private water tankers to meet production demands*”. This alternative supply method has significantly driven up maize processing costs, which in turn have led to higher retail prices for consumers. These financial burdens are particularly challenging for small and medium-sized enterprises (SMEs), which have limited financial capacity to absorb the increased costs. Water scarcity has also had a severe impact on the hospitality industry, where hotels and restaurants have recorded a 23% increase in water costs. This added financial strain makes it difficult for businesses to maintain service quality, which in turn affects customer satisfaction and overall profitability. These findings align with Olanrewaju et-al. (2023)

Beyond the rising costs, industries are also struggling with regulatory and operational constraints as the municipal water supply remains unreliable. Many factories rely on public water systems, which are frequently rationed due to increasing demand and limited supply capacity. Consequently, industrial stakeholders are advocating for water efficiency measures, including wastewater recycling, improved treatment systems, and the adoption of water-saving technologies to maximize available resources. However, the high cost of implementing these interventions remains a significant challenge, especially for businesses in manufacturing and agro-processing, where water is an essential component of production.

Addressing these challenges requires comprehensive industrial water management strategies, including investment in infrastructure expansion, diversification of water supply sources, and the adoption of sustainable water use practices. Strengthening policy frameworks to encourage industries to implement cost-effective water conservation technologies will be critical in mitigating the impact of water shortages. Without long-term solutions, continued water scarcity will undermine industrial growth, limit employment opportunities, and weaken Kasere District’s economic stability. Therefore, prioritizing water security initiatives is not only vital for business sustainability but also a key factor in ensuring long-term economic development in the region

4.4.4 Insights from Stakeholder Interviews on climate change and water scarcity

Qn: Has the district experienced decreased river flow quantities due to climate impacts?

The District Senior Water experts explained that “*watercourses like the Kabiiri River in Bukonzo East, the Mubuku River in Busongora County, and the Nyambyea River—particularly in sub-counties like Nyakasanga Lower, Kanyangeya, and Nyambyea West—have recorded low flow rates during dry seasons and longer dry seasons*”. According to them, “*this is an indication*

of heightened climate variability, exacerbated by water scarcity throughout the Kasese District”.

Question: What steps have been taken to put in place, and which challenges deter some of these interventions?

Emphasis was put on *“the need for such interventions as improving water storage capacity, conserving watersheds, and supporting climate-resilient agricultural practices”.*

The district water policy experts explained that *“while sensitization campaigns to promote rainwater harvesting have been initiated, uptake remains low due to financial constraints among the population. Nonetheless, some of the residents are starting to adopt the practice, and public institutions like health centers have begun to install rainwater harvesting facilities. They added that “Additional initiatives like riverbank restoration and protection to reduce siltation in river courses—a significant contributor to river flooding. These floods inflict damage on infrastructure and worsen the deficit of available water in the region”.*

Qn: On what grounds does the district distribute water among sub-counties?

“Water allocations largely depend on the proportion of safe water coverage per sub-county”. However, the District Water Department officials explained that *“the effective allocation decisions are based on approval by the District Council Committee, which must approve a sub-county before conducting feasibility studies”.*

4.5 GIS Mapping of various water source distributions and Demand in Kasese District

(Objective (iii))

The application of Geographic Information Systems (GIS) facilitated the generation of distribution density and heat maps to analyze the spatial distribution of water sources across various sub-counties in Kasese District. The heat maps aided in providing critical insights into water accessibility and the concentration patterns throughout the district. i.e., the heat maps illustrate variations in water type, density, and overall accessibility in specific locations. While distribution density maps depict the volume and number of different water sources within each sub-county. The water sources mapped in this study included rivers and lakes (open water networks), boreholes, protected springs, water kiosks, shallow wells, stand posts, yard taps, and rainwater harvesting systems. Each of these sources plays a significant role in supporting domestic, agricultural, and industrial water needs across the district.

A GIS water mapping approach was adopted to enhance the understanding of the distribution of point water sources in Kasese District. The maps provided a comprehensive visual representation of the sub-counties' water source locations, effectively showcasing their spatial

patterns and identified densities (Fig. 4.5). By utilizing geospatial analysis, it helps identify differences in water availability, assess accessibility, and facilitate informed decision-making for equitable and efficient water resource management.

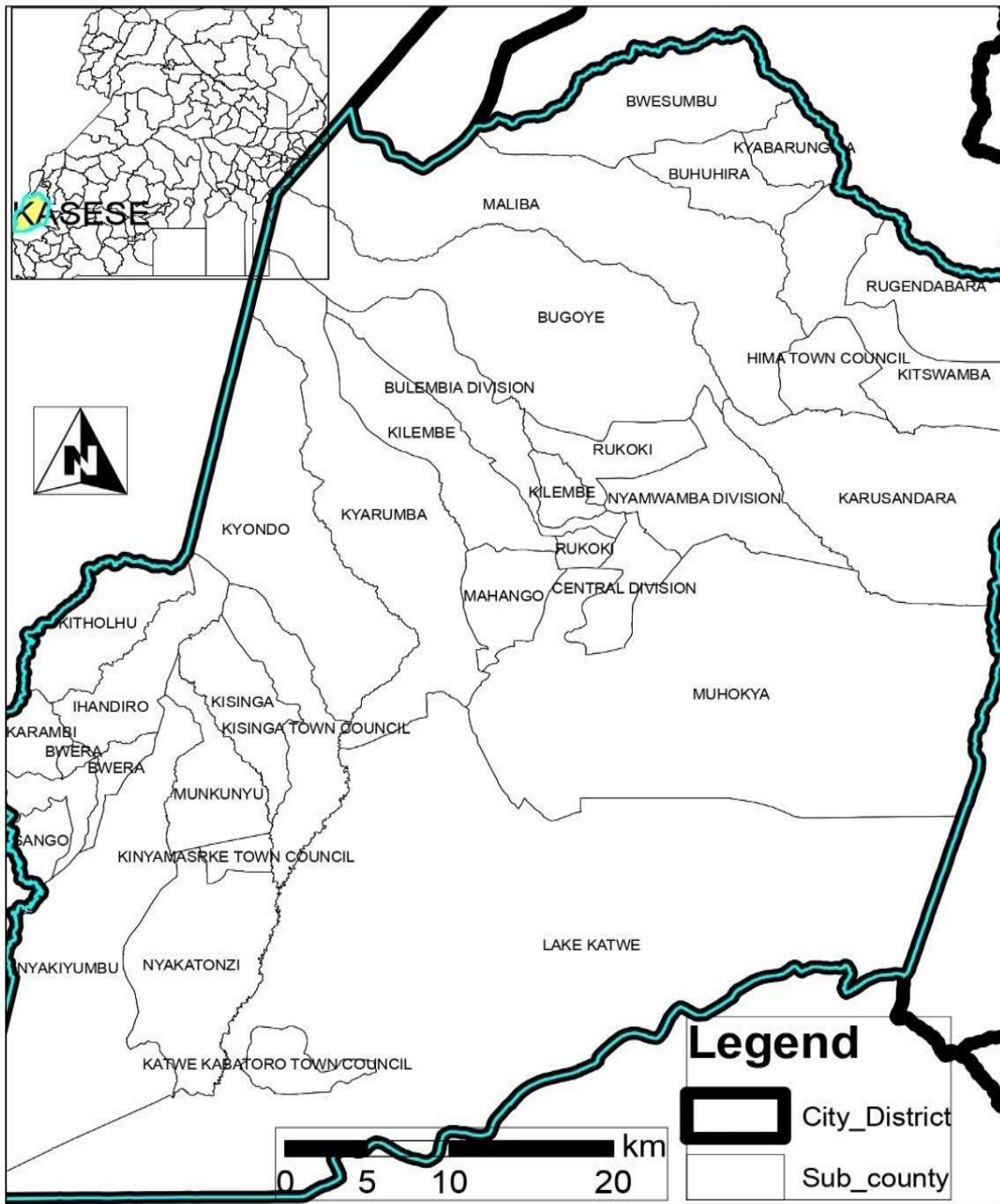


Figure 4.5: A location Map of Sub-counties in Kasese District -Uganda
 Source: (Author's Work, 2025)

4.5.1 Water Distribution and River Network Analysis in Kasese District

The heat map (Fig. 4.5.1) offers a spatial representation of the river network in Kasese District, providing valuable insights into areas with adequate water availability, locations experiencing severe shortages, and potential zones for water infrastructure development. Identifying these

spatial trends are essential for enhancing water distribution strategies, improving resource allocation, and guiding infrastructure investments. By leveraging GIS-based mapping, authorities can develop a data-driven approach to water management, enabling them to design and implement effective policies and targeted interventions to improve water accessibility and long-term sustainability within the district

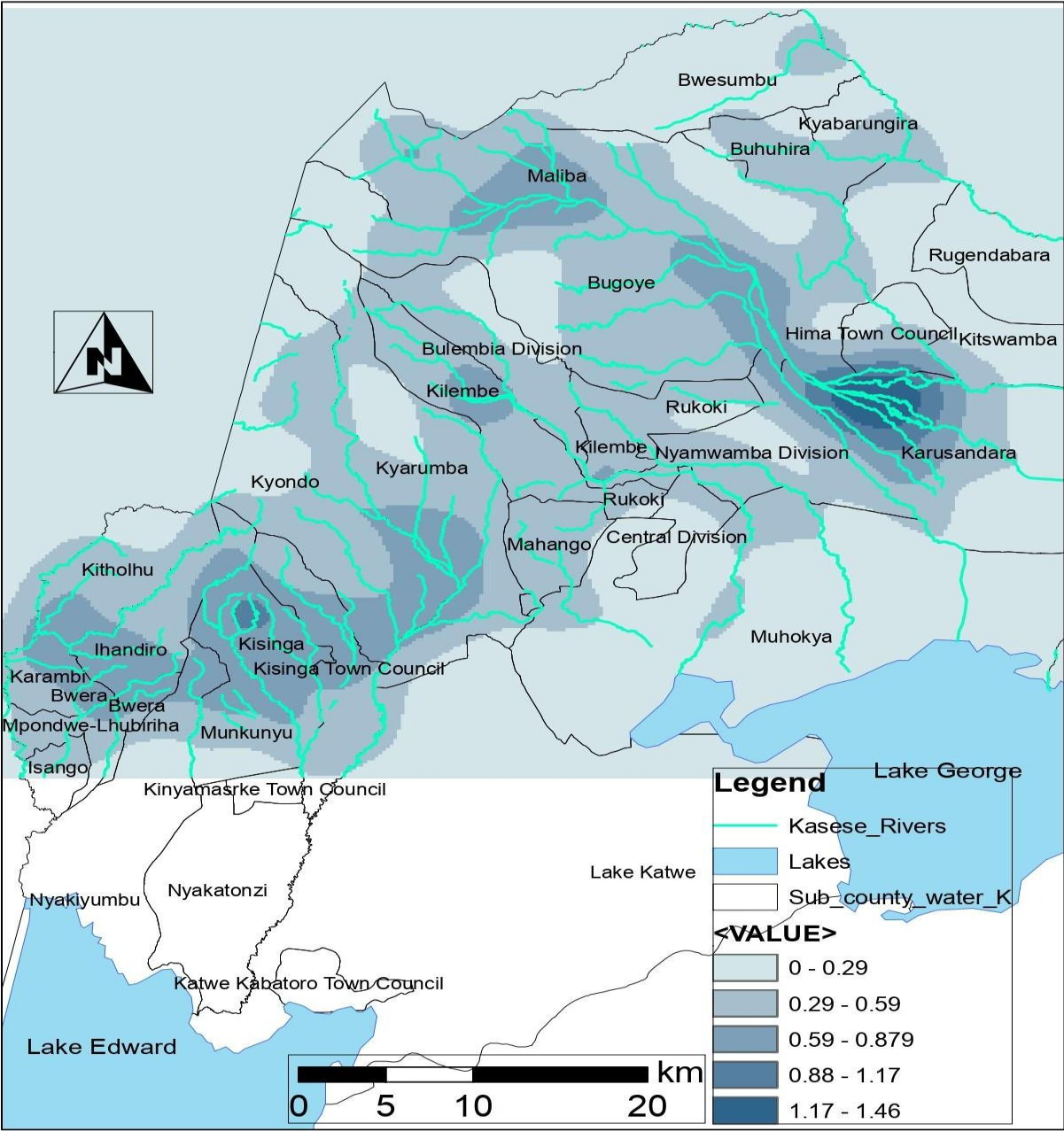


Figure 4.5.1: A Distribution density and Heat map of the river network in Kasese district Source: (Author’s Work, 2025)

Areas shown with darker shades indicate regions with an extensive river network, whereas lighter shades signify zones with limited river network and water accessibility. Understanding these spatial patterns is crucial for evaluating water demand and resource allocation strategies, as river systems play a fundamental role in determining water accessibility and distribution. The findings underscore the importance of a hydrological assessment-based approach to water management, ensuring fair and efficient allocation of resources to meet the growing demand.

The study highlights notable disparities in river-water distribution, with some sub-counties benefiting from proximity to major rivers while others experience persistent shortages due to geographical and climatic constraints. Areas such as Kilembe, Kyarumba, Kisinga, and Karusandara enjoy high water availability, primarily due to their close connection to the Rwenzori Mountain range, which acts as a natural water catchment. The presence of multiple tributaries in these areas makes them ideal for irrigation, domestic consumption, and industrial use, reducing reliance on alternative sources like boreholes and rainwater harvesting.

On the other hand, sub-counties such as Nyakatonzi, Muhokya, Nyakiyumbu, and Katwe-Kabatoro Town Council have a limited number of river networks due to their geographical locations. Being at the lowlands far from the mountain ranges, these places have limited river supply, thus facing limited water supply and severe water scarcity. Additionally, these places experience high temperatures due to their proximity to the equator line, which accelerates evaporation. Although Katwe-Kabatoro is located close to Lake Edward, the lack of alternative surface water sources restricts access to clean and safe water, posing additional challenges for local communities. As a result, residents in these areas heavily rely on boreholes, groundwater extraction, and seasonal rainwater harvesting, which may not be adequate to meet the rising water demand.

A deeper examination of the heat map reveals that the southern and eastern parts of Kasese District have little to no river networks, leaving these communities highly susceptible to seasonal fluctuations in water availability (Fig 4.5.1). The increasing impact of climate change further worsens this issue, as unpredictable rainfall patterns, prolonged droughts, and rising temperatures accelerate evaporation and reduce water retention capacity. These factors intensify the existing water shortages, reinforcing the urgent need for sustainable water resource management strategies.

The wide disparities in river network distribution across Kasese District emphasize the need for targeted interventions to improve water accessibility and management. While some regions

benefit from stable surface water sources, others require immediate investments in water infrastructure, enhanced allocation policies, and alternative supply mechanisms. To address these issues, local authorities should prioritize expanding water storage facilities, improving water distribution efficiency, and implementing climate-adaptive water management strategies. The integration of GIS-based mapping tools provides a data-driven approach to optimizing resource allocation, reducing shortages, and ensuring fair water distribution throughout the Kasese District. Strengthening policy frameworks to promote sustainable water usage, investment in irrigation efficiency, and integrated watershed management will be essential for securing long-term water availability and enhancing socio-economic stability in the district.

4.5.1 The distribution density and Heat map of the Rainwater Harvest and Boreholes across the various parts of the Kasese District.

The Geographic Information System (GIS) heat maps and distribution density maps offer a spatial representation of rainwater harvesting and borehole water sources in the Kasese District (Figs. 4.5.2a & 2b). These maps are crucial tools that help identify areas with high and low concentrations of rainwater harvesting (RWH) and boreholes. They also enhance understanding of the gaps and inequalities in water accessibility, facilitate the assessment of the suitability of water sources in various locations, and predict future trends of water scarcity amidst increasing demand and climate variability. Furthermore, they aid in decision-making for water infrastructure planning, investment, and policy interventions.

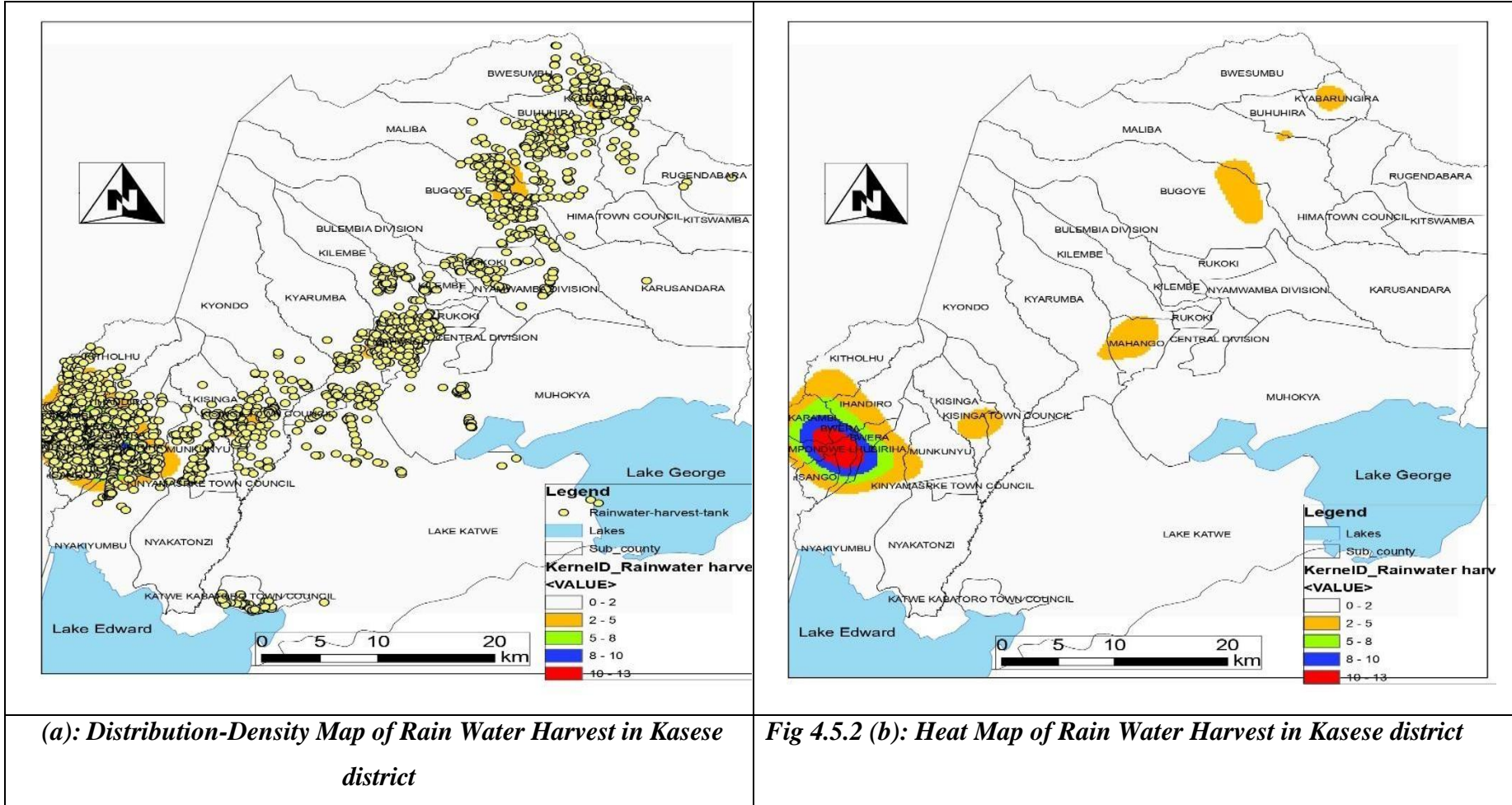


Figure 4.5.2 (a & b): The distribution density and Heat map of Rainwater Harvest in Kasese District
 Source: (Author's Work, 2025)

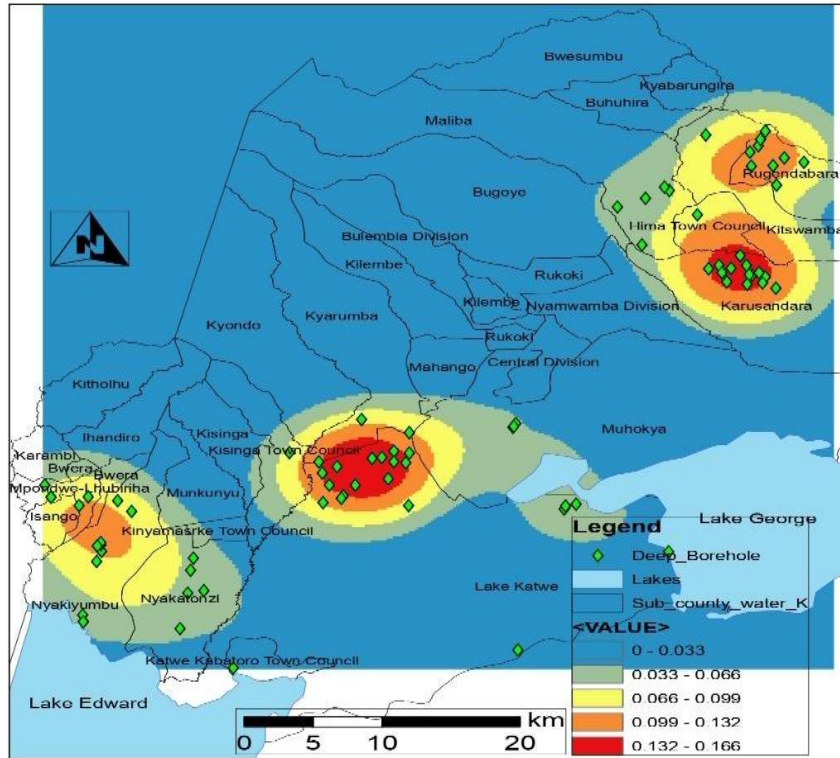


Fig 4.5.2 (c): A Distribution-Density and Heat Map of Boreholes in Kasese District

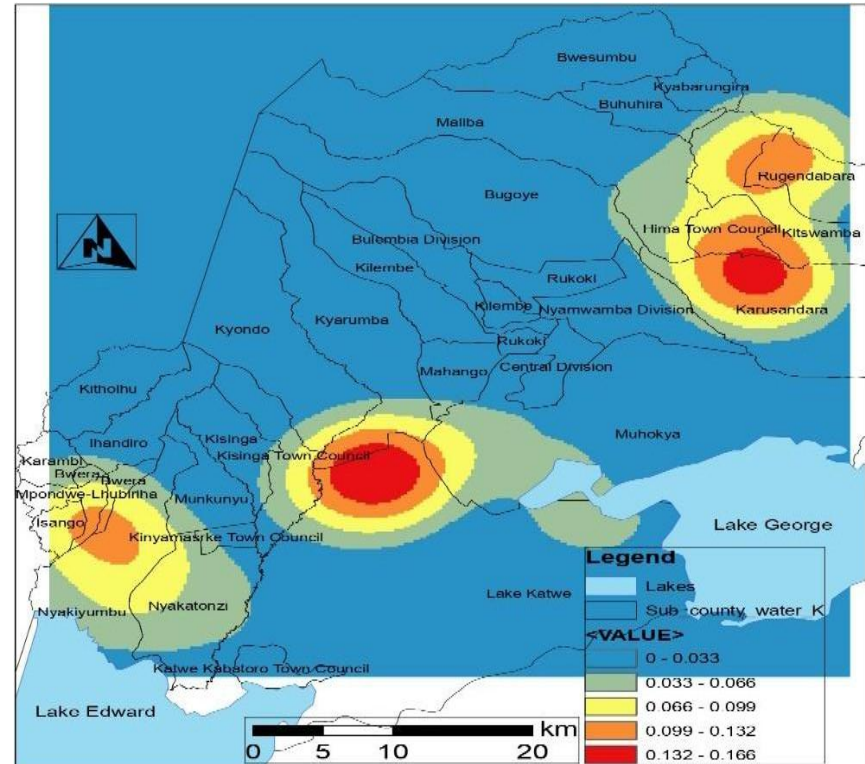


Fig 4.5.2(d): A Heat Map of Boreholes in Kasese district

Figure 4.5.2 (c & d): The Distribution-Density and Heat Maps of Boreholes in Kasese district
 Source: (Author's Work, 2025)

Analysis of Rainwater Harvesting (RWH) Distribution A high concentration of rainwater harvesting systems is observed in sub-counties such as Bwera, Kilembe, and Hima regions, indicating a strong reliance on RWH (Figures 4.5.2a and 4.5.2b). These areas experience relatively high rainfall and have established practices for RWH. Sub-counties like Kyarumba, Maliba, and Kisinga show moderate availability of rainwater harvesting, suggesting a variety of water sources, including groundwater. Conversely, Figures 4.5.2a,.2b indicates that sub-counties such as Nyakatonzi, Katwe-Kabatoro, Muhokya, and parts of the eastern region have very few rainwater harvesting systems or none at all. These areas face low rainfall and high evaporation rates, making rainwater harvesting unreliable without improved storage solutions.

The future water scarcity trends in RWH—the increasing population and climate change, rainfall variability—will make rainwater harvesting less reliable in water-scarce areas like Nyakatonzi and Muhokya. Therefore, future planning should focus on increasing storage capacity and implementing alternative water sources. In certain parts of the district where the piped water supply is unreliable (Figure 4.5.2), rainwater harvesting has been adopted as an alternative water source. However, its large-scale implementation remains hindered by significant policy shortcomings, such as weak enforcement structures, inadequate regulatory measures, and a lack of financial incentives. While many survey respondents recognize the advantages of rainwater harvesting, only 22% of households reported having fully functional storage systems, highlighting the ongoing issue of ineffective policy execution. Enhancing regulatory enforcement and establishing targeted financial support mechanisms could greatly improve the adoption of rainwater harvesting, ultimately strengthening water security and resilience across the district.

Analysis of Borehole Distribution—A high density of boreholes is found in Kyarumba, Karusandara, and parts of Hima (Figs. 4.5.2c & 4.5.2d). This indicates not only groundwater availability but also a high dependence on boreholes due to limited surface water sources. Sub-counties such as Rugendabara, Maliba, and Bwera have a moderate borehole distribution, showing mixed reliance on both groundwater and surface water sources. On the other hand, areas lacking boreholes included Nyakatonzi, Muhokya, Katwe-Kabatoro, and parts of the eastern Kasese District (Figs. 4.5.2c & 4.5.2d), having very few or no boreholes, highlighting groundwater inaccessibility. These areas may have low groundwater recharge or unsuitable hydrogeological conditions.

The Prospects for Water Scarcity in Boreholes— Over-extraction may cause groundwater levels in high-borehole-density locations (Kyarumba, Karusandara) to drop. Without the development

of alternate water sources (such as piped water or deep boreholes), the eastern and southwestern regions will experience acute shortages.

Rainwater harvesting is, therefore, ideal in places like Bwera, Kilembe, and Hima. This can be a result of the region's heavy rainfall as well as adequate and established rainwater infrastructure. On the other hand, because of their consistent groundwater recharge capability, boreholes are appropriate water sources in places like Kyarumba, Muhokya, and Karusandara. The Nyakatonzi and Katwe-Kabatoro did not exhibit boreholes or RWH compatibility. This results from poor groundwater availability and rainfall.

Generally, to effectively tackle the ongoing water scarcity challenges in Kasese District, a holistic approach that integrates improvements in rainwater harvesting (RWH), borehole development, expansion of piped water infrastructure, and GIS-based monitoring is necessary. Enhancing rainwater harvesting systems, particularly in areas experiencing severe water shortages, such as Nyakatonzi and Katwe-Kabatoro, is a crucial strategy. Establishing large-scale RWH storage facilities will strengthen water security while encouraging households to adopt RWH systems through subsidies and incentives will promote sustainable water management practices at the community level.

Beyond rainwater harvesting, strengthening borehole infrastructure and management is essential for improving groundwater access in regions with favorable hydrogeological conditions. Deep boreholes should be developed in areas like Muhokya and Rugendabara, where groundwater resources remain underutilized. Additionally, implementing groundwater recharge initiatives in Karusandara and Kyarumba will help mitigate the risks of excessive extraction and depletion, ensuring the long-term availability of water resources.

Improving access to piped water and optimizing surface water use are also critical steps in addressing water shortages. Constructing a Lake Edward Water Treatment Plant would offer a reliable source of clean water for residents of Katwe-Kabatoro and Nyakatonzi, where alternative water sources are insufficient. Moreover, extending piped water networks to underserved regions such as Maliba and parts of Kisinga will enhance equitable water distribution and accessibility.

Finally, leveraging GIS technology for continuous monitoring and predictive analysis is key to sustainable water resource management. Regularly updating GIS maps will allow for the assessment of spatial and temporal variations in water availability, facilitating timely decision-making. Additionally, GIS-based modeling should be utilized to forecast future water scarcity

trends under various climate change scenarios, enabling proactive mitigation strategies. The introduction of early warning systems in communities prone to water shortages will further enhance resilience and preparedness, ultimately contributing to the sustainable management of water resources in the Kasese District.

4.5.2 The distribution density and Heat map of the Protected Springs and Shallow wells in Kasese District.

Figures 4.5.3 (a) and (b) offer a comprehensive depiction of the spatial distribution and density of protected springs within the sub-counties of Kasese District, Uganda. Figure (a) highlights the exact locations of protected springs, providing a clear geographic reference, while Figure (b) utilizes a heat map to effectively represent their concentration levels. Similarly, Figures (c) and (d) illustrate the distribution and density of shallow wells, with Figure (c) pinpointing individual well locations and Figure (d) employing a heat map to emphasize regions with higher well concentrations.

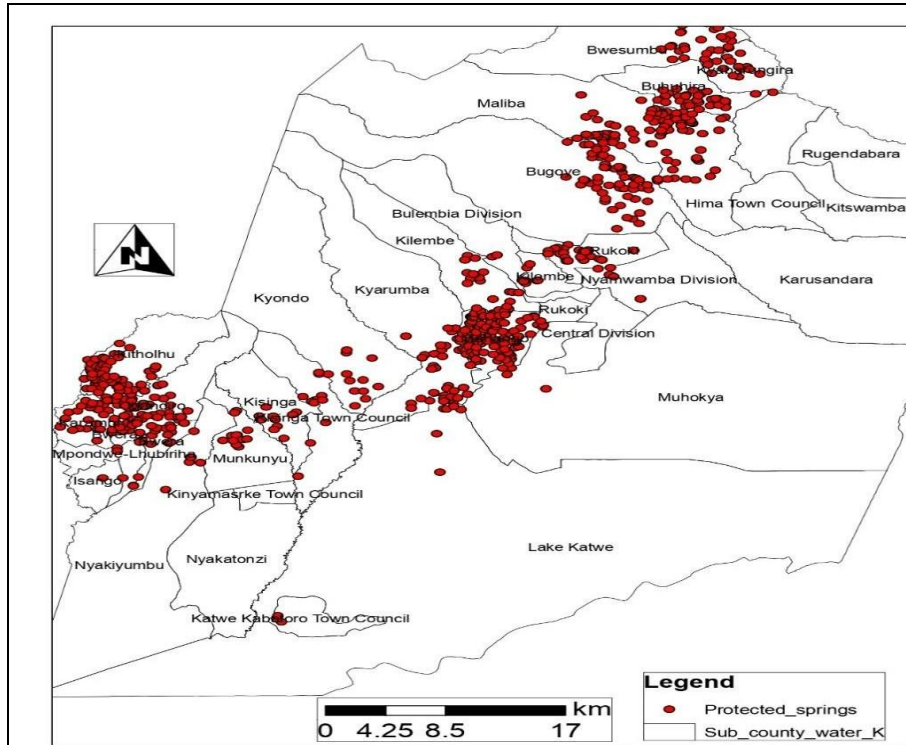


Fig 4.5.3 (a): Distribution-density of protected springs in Kasese District

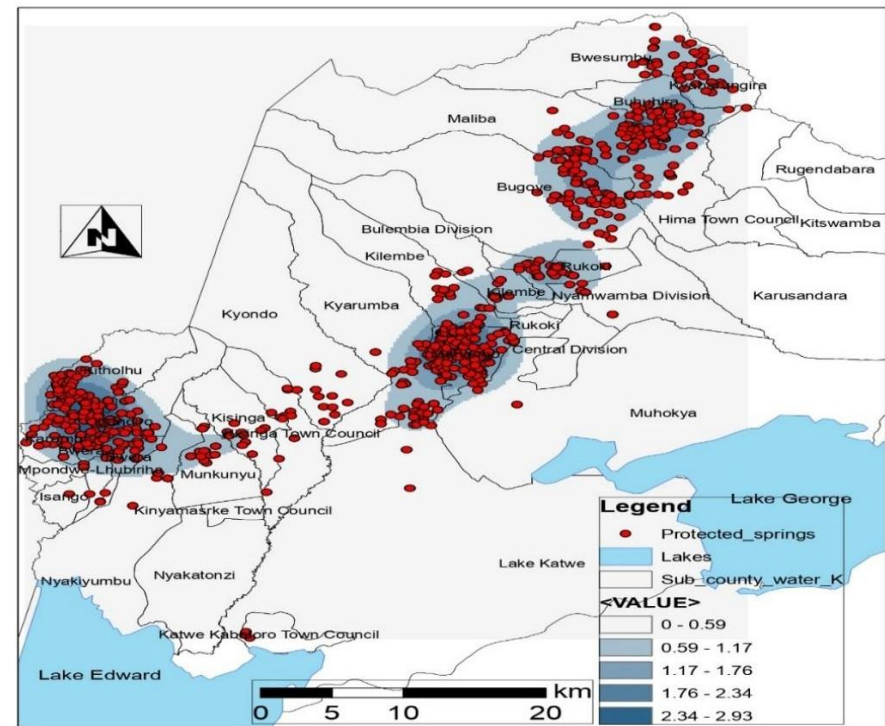


Fig 4.5.3 (b): The Heat Map of protected springs in Kasese District

Figure 4.5.3 (a & b): The distribution density and Heat Maps of Protected springs in Kasese District

Source: (Author's Work, 2025)

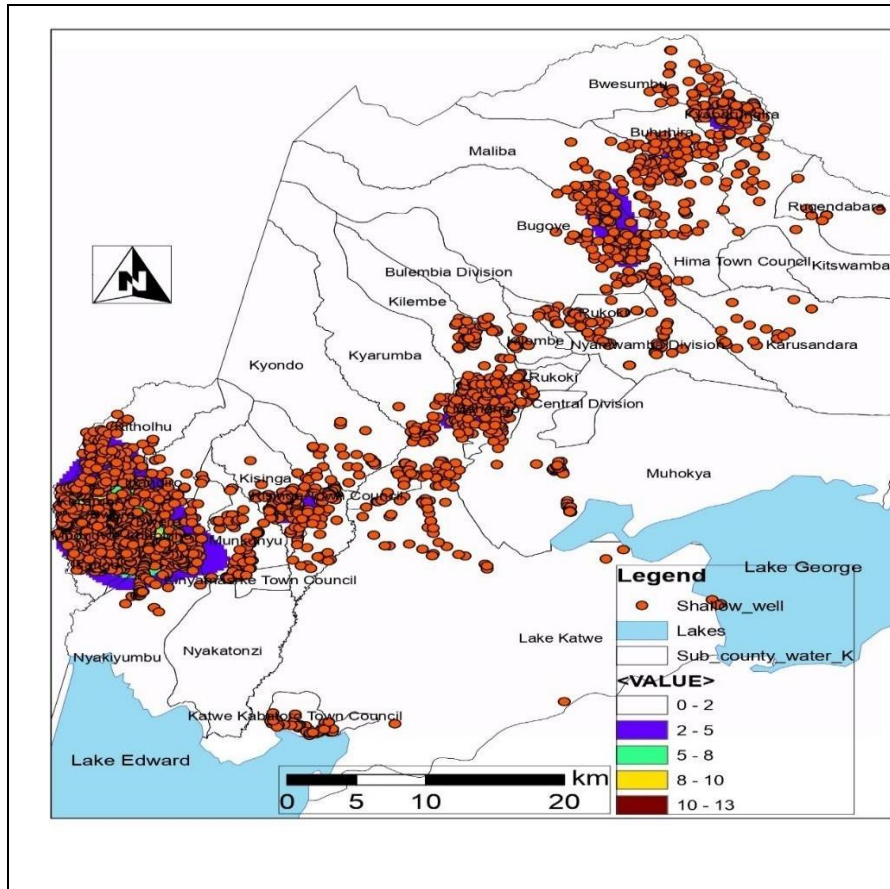


Fig 4.5.3 (c): Distribution-density & Heat Map of Shallow Wells in Kasese District

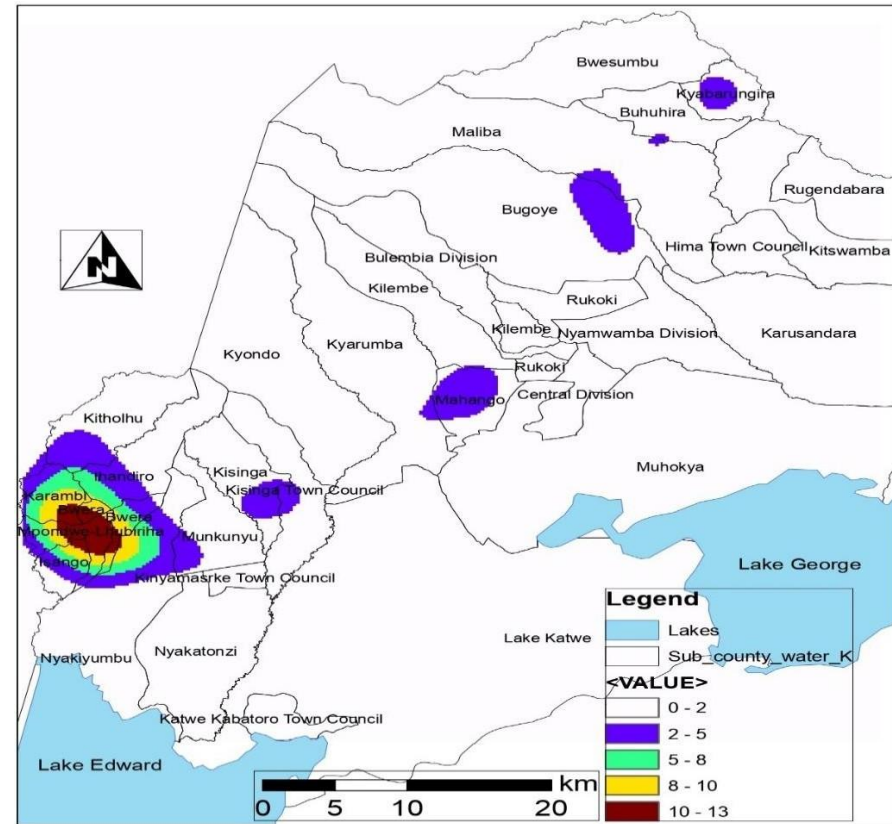


Fig 4.5.3 (d): The Heat Map of Shallow Wells in Kasese District

Figure 4.5.3: (c & d): The distribution-density and Heat Maps of Shallow Wells in the Kasese district
 Source: (Author's Work, 2025)

Spatial Distribution of Protected Springs- The distribution of protected springs in Kasese District is highly uneven, with a higher concentration observed in the central and eastern regions. Specifically, sub-counties such as Kasese Municipality (particularly the Central Division), Kilembe-Nyamwamba Division, Kitholhu, Mpondwe-Lhubiriha Town Council, Bwera, Buhuhira, Kyabarungira, Karambi, Ihandiro, and Mahango exhibit dense clusters of protected springs, as indicated by the red dots on the distribution map.

Equally, the southwestern, southern, and eastern sub-counties, including Nyakatonzi, Lake Katwe, Katwe-Kabatoro Town Council, Nyakiyumbu, Karusandara, Kitwamba, and Muhokya, have a sparse or absent presence of protected springs. This suggests a higher dependency on alternative water sources such as boreholes, rivers, and lakes. The distribution pattern is likely influenced by topographical and hydrogeological factors. The northeastern and western parts of the district, particularly those bordering the Rwenzori Mountains, exhibit a greater prevalence of springs. This can be attributed to higher rainfall levels, increased groundwater recharge, and the steep terrain, which promotes natural spring formation. In contrast, the lowland areas near Lake Edward and Lake George have fewer protected springs, possibly due to limited groundwater recharge and a greater reliance on lake water as the primary source.

Heat Map Analysis of Protected Springs (Fig. 4.5.3 a)- The heat map offers a comprehensive representation of the distribution and density of protected springs across the Kasese District. The areas marked in red signify regions with a high concentration of protected springs, reaffirming previous observations that the central and eastern parts of the district contain the most significant number of these water sources. On the contrary, the northwestern and southern regions exhibit lower densities, implying that communities in these areas may experience water shortages or depend on unprotected water sources, heightening their susceptibility to waterborne illnesses.

Notably, the highest concentration of protected springs is found in Isango, Mpondwe-Lhubiriha Town Council, Bwera, Ihandiro, and sections of Kisinga Town Council and Kyabarungira sub-counties. This trend may be linked to larger population settlements and deliberate efforts to secure water sources in these areas. On the other hand, regions near Lake Edward and Lake George exhibit minimal heat intensity, suggesting a reduced reliance on protected springs, likely due to the accessibility of alternative surface water sources such as lakes and rivers.

The uneven distribution of protected springs highlights disparities in access to safe drinking water. Areas with a high concentration of springs enjoy better water security, whereas those

with fewer protected sources may be forced to rely on untreated water, increasing the risk of diseases such as cholera and typhoid. Additionally, the presence of the Rwenzori Mountains plays a crucial role in sustaining groundwater-fed springs, contributing to their prevalence in elevated sub-counties. Socioeconomic aspects must be integrated into water resource planning. Densely populated areas often require a higher number of protected water sources to meet demand, whereas regions with low population densities may receive less investment in water infrastructure or depend on alternative water sources. Furthermore, lowland areas with sparse spring distribution may experience lower groundwater recharge and drier climatic conditions, which can hinder the formation of natural springs.

These findings highlight the need for a more balanced distribution of protected water sources throughout Kasese District, particularly in underserved areas such as the south and northwest. Future initiatives should focus on expanding water protection measures, promoting rainwater harvesting, and increasing borehole drilling to improve water security in less-covered regions. Generally, the maps illustrate significant disparities in the availability of protected springs, with the eastern and central sub-counties benefiting from greater access while other areas remain disadvantaged. Addressing these inequalities will require targeted water resource management strategies that consider the influence of topography and hydrogeology in future development plans.

The spatial analysis of shallow well distribution and density in Kasese District, as presented in the combined distribution-density map and heat map, highlights significant disparities in water accessibility across different sub-counties. These variations are influenced by factors such as topography, hydrogeological conditions, population density, and infrastructural development. The distribution-density map indicates that shallow wells are highly concentrated in areas such as Kitholhu, Kisinga, and parts of the Central Division (Fig. 4.5.3 c). This high density suggests that these areas have relatively favorable hydrogeological conditions, including shallow groundwater tables that allow for easier extraction of water. Additionally, these sub-counties likely have communities that rely heavily on groundwater sources due to the limited availability of piped water infrastructure. The heat map further supports this observation by highlighting these areas with intense red and yellow zones, indicating a high density of shallow wells (Fig. 4.5.3 d).

Sub-counties such as Karusandara, Kyabarungira, and Kyarumba exhibit moderate shallow well distribution. These areas may have moderate groundwater availability, requiring deeper well drilling or alternative sources such as surface water. The moderate distribution may also

be a result of government or non-governmental organization (NGO) interventions aimed at improving rural water supply, although infrastructural gaps persist. Given their semi-urban and rural nature, communities in these areas may rely on a mix of shallow wells and other sources, such as boreholes and rainwater harvesting systems.

Spatial mapping indicates that shallow wells are either scarce or absent in sub-counties such as Nyakatonzi and Katwe-Kabatoro. This trend is primarily attributed to semi-arid environmental conditions, limited groundwater recharge, and proximity to Lake Edward, which increases the community's dependence on surface water sources. The sparse distribution of these wells also points to limited investment in groundwater infrastructure, likely due to complex geological conditions that render drilling efforts technically and economically unviable.

Significant disparities in water access between urban and rural areas are also apparent. Urban zones like the Central Division and Hima Town Council exhibit a higher concentration of shallow wells, largely due to better-developed infrastructure and greater population density. Conversely, rural sub-counties such as Nyakatonzi and Rugendabara are less served, mainly because of poor infrastructure and unfavorable hydrogeological conditions.

These inequalities are further deepened by socioeconomic factors. Urban communities often possess the financial resources needed to construct and maintain wells, whereas rural populations generally rely on external support from governmental or donor initiatives. Moreover, shallow wells are often the primary water source in rural areas, unlike urban settings where piped water and other improved sources are more commonly available.

In summary, the uneven distribution of shallow wells in the Kasese District reflects a combination of hydrogeological challenges, infrastructural limitations, and socioeconomic disparities. Addressing these issues requires an integrated approach that combines groundwater and surface water development, promotes rainwater harvesting, and applies GIS-based tools to support equitable and sustainable water access across all regions.

4.5.3 Spatial Distribution and Density Assessment of Yard Taps and Stand Posts in Kasese District

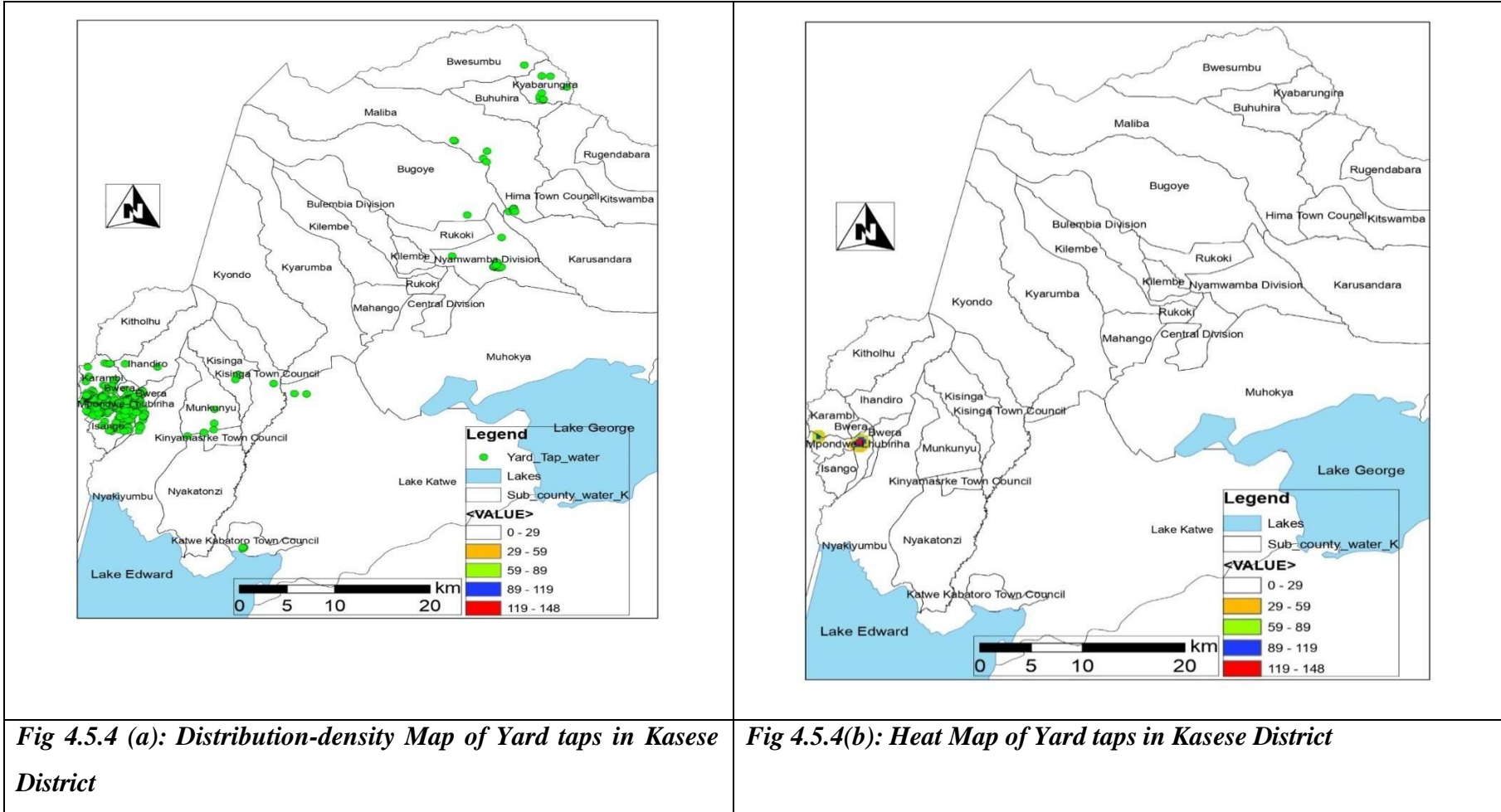


Fig 4.5.4 (a): Distribution-density Map of Yard taps in Kasese District

Fig 4.5.4(b): Heat Map of Yard taps in Kasese District

Figure 4.5.4: (a &b): The distribution density and Heat Map of Yard taps in the Kasese District
 Source: (Author's Work, 2025)

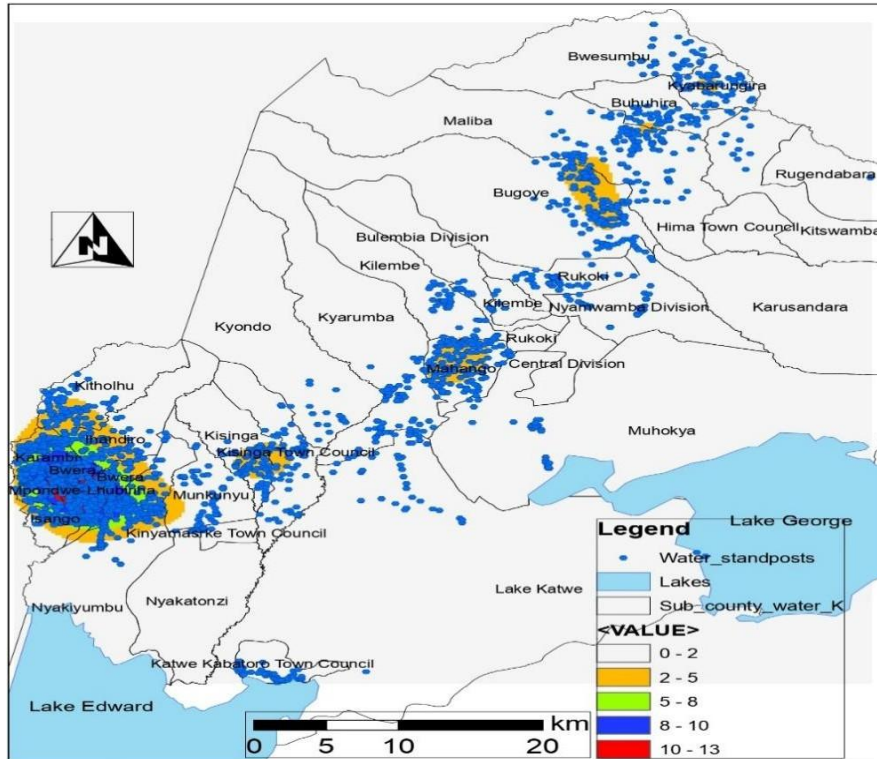


Fig 4.5.4 (c): Distribution-density Heat Map of Stand posts in Kasese District

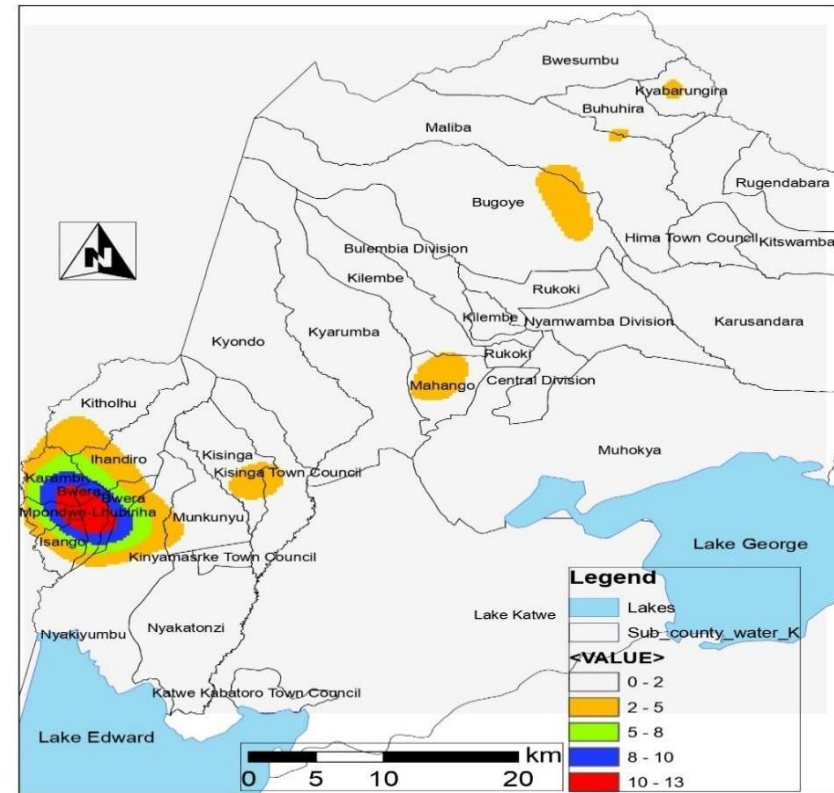


Fig 4.5.2 (d): Heat Map of Stand Posts in Kasese District

Figure 4.5.4: (c & d): The distribution density and Heat Map of Stand Posts in the Kasese District

Source: (Author's Work, 2025)

The maps presented in Figures 4.5.4 (a) and (b) illustrate the spatial distribution and density of yard taps in Kasese District, providing insight into the differences in access to piped water. These illustrations draw attention to regions where households rely on alternate water sources and areas with a high concentration of yard taps.

Yard Taps' Spatial Distribution (Fig. 4.5.4 a): Yard taps are mostly found in the western and southwestern sub-counties, specifically in Kasese Municipality, Bwera, Lhubira Mpondwe Town Council, Nyakiumbu, and Mukunyu, according to the distribution map. This pattern implies that these areas have better access to piped water services and more established infrastructure. In contrast, the northern and eastern sub-counties like Bwesumbu, Bugoye, Karusandara, Buhuhira, and Maliba have fewer yard taps, which is indicative of their less extensive piped water coverage. Similarly to this, yard taps are sparsely distributed in the Lake Edward region and certain southern locations, most likely as a result of topographical limitations or a reliance on alternate sources such as surface water and shallow wells. The Yard Tap Heat Map (Fig. 4.5.4 b) shows how intensely yard taps are distributed, with Bwera, Mpondwe, and Lhubiriha Town Council having the highest concentrations (seen in red and yellow).

Due to a well-established piped water network, these areas have easier access to clean water. The absence of discernible heat zones across a large portion of the region, particularly in the east and north, emphasizes the low density of yard taps. This suggests a greater dependence on alternative resources such as protected springs, shallow wells, and surface water. Improved access to piped water is shown by the presence of yard taps in urban areas such as Kasese, Mpondwe, Lhubiriha Town Council, and Kinyamaseke Town Council. This increases water security and lessens reliance on untreated sources. However, problems with maintenance, price, and supply reliability must be addressed to ensure long-term viability. Piped water access is limited in sub-counties like Bwesumbu, Bugoye, Kyabarungira, and Maliba that have a low yard tap density, especially in the north and east. As a result, if alternate sources are not properly managed, these populations may face health hazards and water shortages. In regions where groundwater supplies are scarce, seasonal fluctuations may make the water shortage more severe. In addition, communities around Lake Edward and other lowland areas with few yard taps probably rely on lake water, which can be harmful to health if improperly managed. It is crucial to fortify water infrastructure and guarantee sustainable, safe water availability in these regions.

In general, the Kasese District's yard tap distribution shows notable disparities in piped water access. The eastern and northern regions are still underserved, whereas the western and southern sub-counties benefit from a larger density of yard taps. Achieving equal water access across the district requires improving maintenance, expanding water infrastructure, and guaranteeing affordability.

Studying the spatial distribution and density of stand posts in Kasese District is vital for understanding variations in water accessibility and ensuring equitable resource allocation. Standpipes provide an essential source of piped water, particularly in semi-urban and peri-urban settings where household water connections are limited.

Through the analysis of these heat maps, water resource planners can identify areas with high concentrations of stand posts, regions with moderate access, and those facing severe shortages. This information is crucial for guiding infrastructure investments, optimizing water service provision, and improving access to safe and reliable water for underserved communities.

The distribution-density map (Fig. 4.5.4 c) shows that stand posts are primarily concentrated in urbanized areas, particularly around Kasese Municipality, Hima, Kisinga, and Mpondwe-Lhubiriha town councils. The corresponding heat map (Fig. 4.5.4 d) further highlights these high-density zones, with the highest concentration appearing in Mpondwe Lhubiriha Town Council and its surroundings. This pattern indicates that urban areas have relatively well-developed piped water infrastructure, making standpipes a key water source for residents without direct household connections (Yard taps).

In contrast, rural and mountainous sub-counties such as Kilembe, Maliba, Kyondo, Kyarumba, and Rugendabara have a notably lower density of stand posts. The limited presence of these facilities in such areas can be attributed to the challenging topography, which makes extending piped water networks both costly and technically difficult. Additionally, in regions near Queen Elizabeth National Park, including Nyakatonzi and Lake Katwe Sub-counties, stand-post coverage remains minimal, likely due to sparse human settlement and land-use restrictions linked to conservation efforts.

The unequal distribution of stand posts reveals significant disparities in water accessibility between urban and rural communities. While urban and semi-urban areas benefit from a reasonable number of stand posts that complement household connections, their availability decreases sharply in rural areas. This situation forces residents in remote sub-counties to rely on alternative sources such as shallow wells, Springs, rainwater harvesting, and surface water,

which may be inadequate or unsafe, particularly during dry spells. The absence of stand posts in mountainous regions such as Kilembe and Maliba poses a serious challenge, as alternative sources like groundwater are not easily accessible due to the rocky terrain. Similarly, areas near conservation zones like Nyakatonzi face a shortage of stand posts, leaving residents dependent on distant or seasonal water sources, which are often unreliable.

To address these disparities, efforts should focus on expanding piped water networks to underserved rural areas such as Maliba, Rugendabara, and Kyarumba. This can be achieved through targeted investment in borehole-fed piped systems and community-managed stand post installations. Additionally, alternative water supply solutions, such as gravity-fed water schemes and rainwater harvesting in such remote sub-counties, should be prioritized. Stand-alone posts should be strategically located in accessible community hubs to efficiently serve multiple households. In protected areas like Nyakatonzi and Lake Katwe Sub-counties, where public stand post (PSP) installation is constrained, a combination of rainwater harvesting, groundwater abstraction, and small-scale piped networks can offer a sustainable solution. Regular GIS-based monitoring should also be conducted to assess changes in stand post distribution and identify emerging water-stressed areas. Additionally, predictive modeling using GIS technology can help decision-makers forecast future water demand based on population growth and climate variability. Implementing these measures will help Kasese District achieve a more balanced distribution of water resources, ensuring that rural and marginalized communities have better access to stand posts and other reliable water sources.

4.5.4 Geographic Distribution and Density Analysis of Water Kiosks in Kasese District

In this study, Water kiosks are the fixed facilities or water supply points that provide communities in Kasese district with access to clean and affordable water, typically overseen by local authorities, private entities, or community-based organizations. These kiosks are commonly situated in areas where direct household water connections are either limited or non-existent. Their operation is supported by various sources, including piped water networks, boreholes, or other alternative water supply systems, ensuring a consistent provision of safe drinking water. They play a particularly significant role in urban slums, peri-urban areas, and rural settlements where conventional water infrastructure is inadequate.

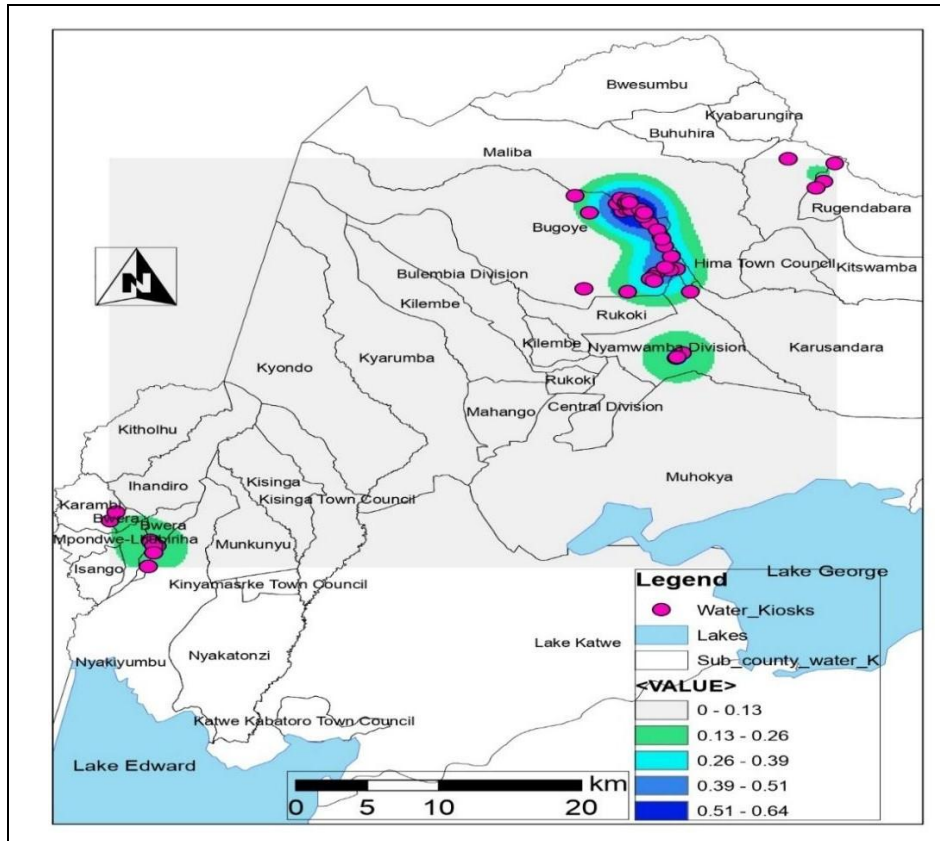


Fig 4.5.5 (a): Distribution-density Heat Map of Water Kiosks in Kasese District

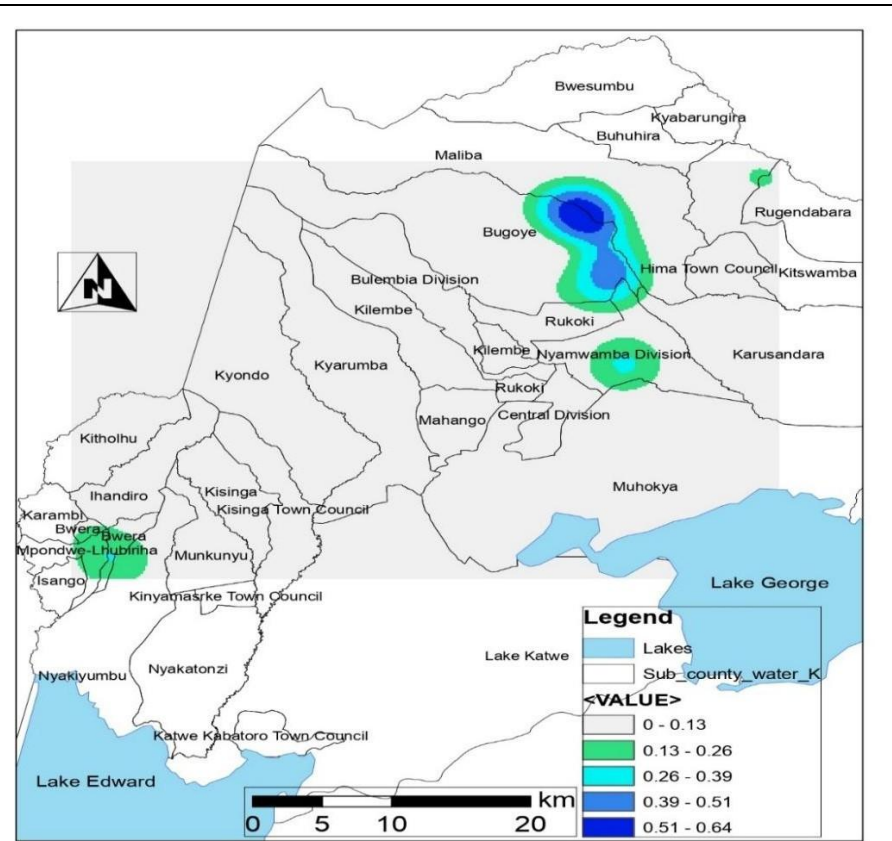


Fig 4.5.5 (b): Heat Map of Water Kiosks in Kasese District

Figure 4.5.5: (a & b): The Distribution-Density & Heat Maps of Water Kiosks in Kasese District
 Source: (Author's Work, 2025)

A nominal fee is usually required per container of water, positioning water kiosks as a critical component of water supply strategies in areas facing infrastructural challenges.

Therefore, assessing the spatial distribution and density of water kiosks in Kasese District is essential for identifying disparities in water accessibility and promoting fair resource allocation. Heat maps facilitate the identification of areas with a high concentration of kiosks, moderately covered locations, and areas experiencing severe shortages. Such insights are valuable for guiding the allocation of resources, expanding infrastructure, and ensuring that communities struggling with water access receive appropriate interventions.

The distribution-density map (Fig. 4.5.5 a) illustrates that water kiosks are predominantly clustered in Bugoye and nearby areas, with additional concentrations in parts of Bwera, Mpondwe Lhubiriha Town Council, and Hima. The heat map (Fig. 4.5.5 b) further highlights this pattern, showing the highest density of kiosks in Bugoye Sub-County. This suggests that these locations have relatively better access to water kiosks, potentially due to the presence of piped water infrastructure and demand-driven distribution. Likewise, several sub-counties, particularly those in mountainous and remote areas of the Kasese district like Maliba, Kyondo, Kyarumba, Bwesumba, Kyabarungira, Buhuhira, Kitholhu, Kisinga, Kilembe, Bulembia Division, and Mahango, exhibit a significant lack of water kiosks. This could be possibly due to challenging terrain and the high costs associated with installing piped water systems. Moreover, settlements located near protected areas such as Queen Elizabeth National Park, including Nyakatonzi and parts of Lake Katwe Sub-County, have very limited or no presence of water kiosks. This shortage can be attributed to low population density, conservation-related restrictions, and inadequate piped water infrastructure. The absence of kiosks in these locations forces residents to rely on alternative water sources, such as surface water, rainwater harvesting, or distant standpipes, which may not be sufficient, especially during dry periods. The use of alternative water sources can lead to a decreased reliance on water kiosks among residents. Additionally, economic factors play a role, as the low population density and limited commercial activities in these areas may not warrant substantial investment in kiosk infrastructure. This uneven distribution contributes to disparities in water access across different settlements. In urban centers such as Mpondwe Lhubiriha Town Council, the availability of water kiosks improves access to safe drinking water, reducing dependence on untreated sources and promoting better public health. In contrast, rural sub-counties such as Maliba, Bwesumbu, and Kyarumba, where water kiosks are scarce or absent, are more vulnerable to water shortages,

particularly during drought periods. As a result, residents frequently rely on unsafe water sources, heightening the risk of waterborne diseases.

The absence of water kiosks in most divisions of Kasese Municipality, despite being the metropolitan center of the district (Fig 4.5.5 a), can be attributed to several key factors. First, Kasese Municipality has a relatively well-developed piped water infrastructure, which supplies water directly to households, institutions, and businesses. Unlike rural and peri-urban areas, where water kiosks serve as critical alternatives due to limited household connections, residents in the municipality are more likely to have access to individual or shared piped water connections, reducing the necessity for kiosks. Additionally, the economic structure and urban planning of Kasese Municipality influence water distribution strategies. Since the municipality hosts a higher concentration of commercial activities, government offices, and residential apartments, the demand for formalized water supply services is met through centralized distribution systems managed by the National Water and sewerage Corporation (NWSC), a government water utility. Private water vendors may also supplement the municipal water supply, further reducing the need for kiosks. Moreover, the pricing and operational model of water kiosks may not be economically viable in the municipal setting. In metropolitan areas, land use regulations, commercial competition, and the higher costs of maintaining standalone kiosk infrastructure may discourage investment in such facilities. Instead, utility companies especially NWSC may prioritize expanding household connections and improving existing water networks over establishing additional kiosks.

The heat maps further highlight the disparity, with kiosks being concentrated in peri-urban and rural areas such as Bugoye, Hima, and Bwera. These locations likely experience lower household connection rates and greater reliance on communal water points. In contrast, Kasese Municipality exhibits no kiosk presence, reinforcing the assumption that alternative water supply systems, primarily piped networks, fulfill the water demand. However, while the municipality may not require water kiosks in the same manner as rural sub-counties, challenges such as intermittent supply, high water tariffs, and inequalities in household connections could still affect water accessibility. In cases where vulnerable communities within the municipality struggle with affordability or service reliability, alternative supply options, including strategically placed kiosks, could still be considered as a supplementary measure.

Addressing these inequalities necessitates well-planned interventions. Expanding piped water networks in underserved sub-counties like Maliba, Kilembe, and Rugendabara would help improve water kiosk coverage and enhance access to safe drinking water. In mountainous areas

where conventional piped infrastructure is difficult to establish, alternative solutions such as gravity-fed water systems and community-led rainwater harvesting initiatives should be prioritized. For regions near conservation zones with limited kiosk availability, a combination of groundwater extraction, small-scale piped networks, and rainwater harvesting systems could offer sustainable water access. Furthermore, incorporating GIS-based monitoring into water supply planning would enable real-time tracking of water accessibility trends, allowing policymakers to make informed decisions on infrastructure development. Implementing these measures would lead to a more equitable distribution of water kiosks across the Kasese District, ensuring that even the most vulnerable communities have reliable access to safe drinking water.

CHAPTER FIVE:

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Summary of Findings

The study's key findings and results have been aligned with the study objectives and the research questions. This study assessed water demand and allocation strategies in the Kasese District in Uganda using GIS.

Water scarcity in the district is mainly caused by climate variability, high population growth with an annual growth rate of 2.9%, and aging/poor water infrastructure development. The water scarcity has contributed to a lack of access to safe water (41.25%), reduced crop yield (40%), increased water costs (23%), and family violence. The industrial operations, particularly in the manufacturing and agro-processing sectors, experience operational disruptions due to inadequate water supply, forcing industries to depend on costly alternatives such as private water tankers.

Furthermore, significant disparities in water accessibility were identified across different sub-counties, with urban centers such as Kasese Municipality and Bwera having relatively better infrastructure, whereas rural sub-counties like Kyondo, Kyarumba, Nyakatonzi, Maliba, and Kilembe face acute water shortages. The GIS-based spatial analysis further highlighted the unequal distribution of water infrastructure, pinpointing key areas with high water demand and severe supply gaps across the district.

5.2 Conclusion

In conclusion, the study objectively assessed water demand and allocation strategies aimed at improving water resource management. The study concluded that, water scarcity in Kasese District is both structural and spatial. It is driven by rapid population growth (2.9%), large household sizes (52.3% with 6–8 members), and a high reliance on farming (37.8%).

GIS-based analysis revealed uneven spatial distribution of water sources, with some sub-counties like Ihandiro reaching 75% coverage while others like Kyondo lag at 17%. Over 60% of water infrastructure is non-functional, contributing to a 40% drop in crop yields and a 15% decline in industrial water supply. These findings underscore an urgent need for infrastructure rehabilitation, climate-resilient water planning, and community-centered water governance to achieve equitable and sustainable access.

5.3 Recommendations

Tackling water scarcity issues in Kasese District necessitates the adoption of efficient strategies and interventions. The study presents recommendations covering policy, technical knowledge, and practical approaches. The successful implementation of these recommendations will provide long-term solutions to the identified challenges.

A.3.1 Policy Recommendations

A. Household Water Access

1. Targeted Infrastructure Investment

Kasese District Local Government should prioritize sub-county-specific water infrastructure development based on geospatial data, focusing on the installation of boreholes, protected springs, and shallow wells in underserved residential areas.

2. Rainwater Harvesting Support

The district should collaborate with NGOs and microfinance institutions to establish community cooperatives that offer subsidized rainwater harvesting systems for households in low-access zones.

3. Incentivize Water-Saving Technologies

National government should introduce tax waivers or import duty reductions on certified water-efficient appliances and Water-Star products to enhance domestic water use efficiency.

4. Promote Inclusive Water Governance

Local governments should institutionalize gender-balanced water governance by ensuring at least 50% female representation in Water User Committees (WUCs) and Village Health Teams (VHTs).

B. Agricultural Water Management

1. Subsidized Irrigation Technologies

Promote access to affordable small-scale irrigation kits through farmer cooperatives and agricultural extension programs, especially for smallholder farmers.

2. Farm-Level Rainwater Harvesting

Invest in rainwater collection infrastructure for agricultural use as a climate adaptation strategy to enhance year-round food production.

3. Safe Reuse of Treated Water:

Promote the development of decentralized wastewater treatment systems to enable the safe reuse of treated water for irrigation.

4. Water Use Efficiency Campaigns

Implement multi-platform awareness campaigns—through radio, television, mobile networks, community sensitization, and agricultural extension—to promote efficient water use practices among farmers.

C. Industrial Sector

1. Establish Water Source Protection Zones (WSPZs)

Collaborate with local councils and the District Natural Resources Office to designate and enforce WSPZs around key water sources, particularly in mining-affected areas.

2. Mandatory Water Audits and Reporting

Require all industries to conduct periodic water quality testing and submit remediation plans and public compliance reports, under the supervision of the Ministry of Water and Environment.

3. Environmental Compliance Monitoring

The District Natural Resources Office should regularly inspect industrial operations for adherence to environmental and water-use regulations, applying penalties for non-compliance and offering technical support where necessary.

5.3.2 Technical Recommendations

1. Adopt Smart Water Management Technologies

The government should invest in modern water management tools such as GIS-based monitoring, smart metering, SCARDA systems, and automated leak detection to enhance water distribution efficiency and reduce non-revenue water.

5.3.3 General Recommendations

1. Promote Research and Innovation in Water Management

Support universities and research institutions to co-develop localized water solutions, including demand forecasting tools, alternative water sourcing technologies, and climate resilience strategies, while integrating GIS and sustainability modules into water-related academic curricula.

2. Integrate Geospatial Data into Planning

District and national water planning units should institutionalize the use of spatial water access data and GIS justifications in all infrastructure budgeting and decision-making processes to promote equity and efficient resource allocation.

5.4 Final Thoughts

Ensuring sustainable water access in Kasese District requires a comprehensive approach that integrates policy reforms, infrastructure development, research advancements, and expert-driven solutions. The successful implementation of these recommendations will enhance water security, support economic growth, and improve the livelihoods of communities across the district. Moving forward, continuous research and collaboration among stakeholders, including government agencies, academic institutions, technical experts, and local communities, will be essential in addressing emerging water challenges and ensuring long-term resilience against climate change and population growth.

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APPENDICES

Appendix I: Questionnaire and Consent Form for Participation in Research Study

Consent Form for Participation in Research Study

Study Title: “Assessing Water Demands and Allocation Strategies in Kasese District, Western Uganda using GIS Technology”

Principal Investigator:

MUHINDO Morris

Master's Student, MSc in Water Policy

Pan African University Institute of Water and Energy Sciences (PAUWES)



Invitation to Participate in a Research Study

Dear Participant,

You are invited to contribute to a research study examining water demand, usage patterns, and allocation in Kasese District. This study aims to identify the main challenges faced by different water users and propose effective strategies for improving water management. Your input will play a crucial role in shaping sustainable water distribution methods.

Participation and Procedures

Voluntary Participation: Taking part in this study is entirely optional. You have the freedom to decide whether or not to participate, and your choice will not result in any penalties or the loss of any rights or benefits you would otherwise receive.

Procedures and Right to Withdraw: If you choose to participate, you will be required to fill out a questionnaire, which is expected to take around 20 to 30 minutes. You may choose to skip any question you do not feel comfortable answering. Additionally, you have the right to withdraw from the study at any point without giving a reason, and doing so will not have any negative consequences.

Confidentiality

Protection of Data: Any information you provide will be treated with strict confidentiality. Your responses will not be linked to your name unless you explicitly choose to disclose it. To ensure your privacy, all collected data will be anonymized before analysis.

Use, Storage, and Retention of Data: The information gathered will be used solely for academic research purposes. Findings may be presented at conferences or published in scholarly journals, but no personal identifiers will be included. Your responses will be securely stored, with digital data being password-protected. The data will be retained for five years for verification purposes and will be permanently deleted afterward

Section A: General Information

1. What is your gender?
 - a) Male
 - b) Female
2. What is your age group?
 - Below 20 years
 - 21–30 years
 - 31–40 years
 - 41–50 years
 - Above 50 years
3. What is your highest level of education?
 - No formal education
 - Primary education
 - Secondary education
 - Tertiary/University
4. What is your occupation?
 - Farmer
 - Businessperson
 - Civil servant

- Local leader
- Student

Section B: Household Water Access and Collection

5. What is your primary source of water? (Tick all that apply)

- ❖ Piped water
- ❖ Borehole
- ❖ Protected spring
- ❖ River/lake
- ❖ Rainwater harvesting
- ❖ Other (Specify) _____

6. How far is the nearest water source from your home?

- Less than 200 meters
- 200-500 meters
- 501–1 km
- 1.5-2km
- More than 2 km

7. How often do you experience water shortages?

- Daily
- Weekly
- Monthly
- Rarely

8. What are the main challenges you face in accessing clean water? (Tick all that apply)

- High cost of water
- Long distances to water sources

- Poor water quality
- Unreliable water supply
- Other (Specify) _____

9. Do you believe the water from your main source is safe for drinking?

- Yes
- No

10. If yes, please explain why?

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.....

11. Have there been any conflicts in your community over water use or access?

- Yes
- No

12. If yes, what was the cause?

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13. Have you or someone in your household ever felt unsafe while collecting water (e.g., exposure to violence, accidents, animal attacks)?

- Yes
- No

14. If yes, please explain.

.....

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.....

Section C: Water Demand and Usage

15. What is your average daily water consumption per household?

- ❖ Less than 20 liters
- ❖ 20–40 liters
- ❖ 41–80 liters
- ❖ 81-150 liters
- ❖ More than 150 liters

16. What do you primarily use water for? (Tick all that apply)

- Drinking
- Cooking
- Cleaning
- Irrigation
- Industrial use
- Other (Specify) _____

11. Have you noticed an increase in water demand in your community over the years? (Tick all that apply)

- ❖ Yes
- ❖ No
- ❖ Not sure

12. What do you think is the main cause of increased water demand? (Tick all that apply)

- Population growth
- Agricultural expansion
- Industrial activities
- Climate change
- Other (Specify) _____

Section D: Effects of Water Scarcity

13. How has water scarcity affected your household or livelihood? (Tick all that apply)

- Reduced agricultural yields
- Increased water costs
- Health issues (e.g., waterborne diseases)
- Time wasted fetching water
- Other (Specify) _____

14. How has water scarcity impacted businesses/industries in your area? (Tick all that apply)

- Reduced production
- Increased operational costs
- Loss of jobs
- No impact
- Other (Specify) _____

15. How has water scarcity affected farming activities in your area? (Tick all that apply)

- ❖ Reduced crop yields
- ❖ Livestock deaths
- ❖ Increased conflicts over water
- ❖ No impact

Section E: Water Governance and Solutions

17. Are you aware of any government programs or NGOs supporting water provision in your area?

- Yes No

18. Have you participated in any water management or community sensitization meetings?

- Yes No

19. In your opinion, what should be done to improve water access and management in your area?

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.....
.....
.....

Section F: Climate and Environmental Perceptions

20. Have you noticed changes in rainfall patterns in your area over the past 5–10 years?

Yes

No

21. If yes, explain how they have changed.

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.....

22. What is your main coping strategy during the dry season?

.....
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.....
.....

23. Have floods or droughts affected your water access?

.....
.....
.....
.....

Thank you for your time and valuable input!

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KASESE
UGANDA

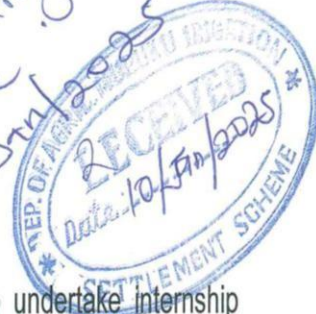
In any correspondence on this subject please quote..

Date: 7th January, 2025

TO WHOM IT MAY CONCERN:

✓ To OC Mubuku
Irrigation Scheme

Accepted to
conduct research
at Mubuku Irrigation
Scheme to 15/1/2025



RE: INTRODUCTORY LETTER FOR MR. MUHINDO MORRIS

Kasese District has offered an opportunity to Mr. Muhindo Morris to undertake internship training in the district. During his internship he will collect data focusing on "Optimization of Water supply, Demand and Allocation Strategies in Kasese District" from various institutions within the district. This data collection exercise will help him gain practical experience in water and natural resources management in the district, and also propose strategies to ensure sustainable water supply in the district. The exercise will be conducted during the period of January-March, 2025.

The purpose of this communication therefore, is twofold:

- (i) introduce to you the student, and
- (ii) request you to provide him with the necessary information and any other related support during that time.



**DISTRICT NATURAL
RESOURCES OFFICER**
KASESE LOCAL GOVERNMENT

Joseph Katswera (PhD)
DISTRICT NATURAL RESOURCES OFFICER

Copy: The Chief Administrative Officer- Kasese
Mr. Muhindo Morris



KASESE MUNICIPAL COUNCIL
Where Nature Meets

Office of the Town Clerk

P.O. Box 54, Kasese
Telephone: 0787 885 452 / 0742 209 493
E-mail: townclerk@kasesemc.go.ug

Date: 27th January, 2025

The Manager
National Water and Sewerage Corporation-Kasese
Plot 1 Rukidi Street
P.O. Box 356 Kasese, Uganda
Dear Sir/Madam,

Re: Introduction of MUHINDO MORRIS for Research Data Collection

I am writing to formally introduce Mr. Muhindo Morris, a student pursuing an MSc in Water Policy at Pan African University-Institute of Water & Energy Sciences (incl.) Climate Change (PAUWES) who is currently conducting research as part of his academic requirements. The research focuses on Assessing Water Demands and Allocation Strategies Using WEAP in Kasese District, Uganda. A case study of Nyamwamba Catchment aims to analyze water usage patterns, challenges, and solutions in the district.

As part of the study, Mr. Morris seeks to collect data and relevant information from the National Water and Sewerage Corporation (NWSC) – Kasese Area, given its vital role in water provision and management within the district. We kindly request your office to extend the necessary support and allow access to data or insights relevant to his research.

Mr. Muhindo Morris is currently undertaking a research internship with the Kasese District Local Government under the Natural Resources Office—Water Department and with the Kasese Municipality—Environment Department. His work has been commendable, and the findings from his study could contribute to water management strategies and policy development in the district.

We appreciate your cooperation and assistance in facilitating this academic endeavor. Please do not hesitate to contact me at +256 70188370 or +256 776880370, should you require further clarification or information regarding this request.

Thank you for your continued support in fostering research and knowledge development in our region.

Yours sincerely,




Mugume Evelyn

SENIOR ENVIRONMENT OFFICER

cc: The Town Clerk, Kasese Municipal Council

*AE & CO
Please help out with
data required in a
relevant manner.
30/1/25*

MUHINDO MORRIS

+256 779 683722
+213 69 9578113

APPENDIX II: Authorisation letters from the concerned authorities for data collection



Appendix III: Interviews held by the researcher with Key Stakeholders on Water Utilization & Management in Kasese District

(Source: Field Research, 2025)



Appendix IV: Researcher Evaluating Water Quality Monitoring Processes at the Kasese Water Treatment Plant Laboratory to Assess Municipal Supply Standards

(Source: Field Research, 2025).



Appendix V: The Researcher at Nyamwamba 1 Hydro Power Plant in Bulembia Division

(Source: Field Researcher, 2025).



Appendix VI: Researcher's GPS coordinates collected at Water Fetching Points and Monitoring Bamboo Growth for Nyamwamba Riverbank Restoration

(Source: Field Researcher, 2025).

Farmani

JU mc

~~MA~~

Supervisor: Prof. Raziyah
Farmani

Supervisor: Prof. Cherifa
Abdelbaki

Student: Muhindo Morris