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手壓泵浦鑽孔技術於減輕烏干達農村水資源短缺的社會經濟效益和永續發展目標的一致性：以穆科諾區姆彭格地區為例

Socio-Economic Effectiveness and Sustainable Development Goals Alignment of Hand Pump Borehole Technology in Mitigating Water Scarcity in Rural Uganda:

A Case Study of Mpunge Sub-County in Mukono District

卡烈

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本論文係卡烈(R11247015）在國立臺灣大學氣候變遷與永續發展國際學位學程完成之碩士學位論文，於民國 113 年 6 月 27 日承下列考試委員審查通過及口試及格，特此證明。

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Abstract

This research investigates the socio-economic effectiveness of hand pump borehole technology in addressing water scarcity in Mpunge Sub-County, Mukono District, Uganda, and its alignment with Sustainable Development Goals (SDGs). Utilizing quantitative methods, the study evaluates the functionality, reliability, and impact of boreholes on community development. The findings reveal that while hand pump boreholes significantly improve water accessibility and reduce the time spent fetching water, challenges such as sustainability issues and water quality concerns persist. The study highlights the alignment with multiple SDGs, including SDG 6 (Clean Water and Sanitation), SDG 1 (No Poverty), SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), and SDG 5 (Gender Equality). It demonstrates how access to clean water contributes to health improvements, educational opportunities, and economic growth. By ensuring clean water access, these boreholes support broader development goals that uplift communities and enhance quality of life. The Social Return on Investment (SROI) analysis over 25 years of borehole functionality reveals a significant socio-economic return. Communities experience enhanced livelihoods, reduced healthcare costs, and increased productivity. This long-term investment in borehole technology shows substantial benefits that justify continued support and development. This research provides critical insights for policymakers and stakeholders in rural water resource management. It advocates for strategies that enhance the sustainability and socio-economic impact of borehole technology. By addressing identified challenges and leveraging the opportunities presented, communities can achieve sustainable access to clean water, fostering socio-economic development and improving the quality of life for all residents.

Keywords: Hand pump boreholes, water accessibility, socio-economic impact, sustainable Development Goals (SDGs), community development.

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摘要

本研究探討了手動水井技術在解決烏干達穆科諾區(Mukono)，姆蓬格郡(Mpunge)，水資源短缺問題上的社會經濟效益及其與永續發展目標（SDGs）的契合度。研究採用定量分析法，評估了井的功能、可靠性及其對社區發展的影響。研究結果表明，儘管手動水井顯著提高了水的可獲得性，並減少了取水時間，但仍存在永續性問題和水質問題。研究結果計畫包含了多個永續發展的指標，包括SDG 6（清潔飲水和衛生設施）、SDG 1（消除貧窮）、SDG 3（良好健康與福祉）、SDG 4（優質教育）和SDG 5（性別平等）。研究顯示，獲得清潔水源有助於健康改善、教育機會和經濟增長。通過確保清潔水源的獲取，這些水井支持更廣泛的發展目標，提升社區並提高生活品質。對手動水井25年的社會投資回報（SROI）分析顯示出顯著的社會經濟回報。社區的生計得到改善，醫療成本減少，生產力增加。對水井的長期投資顯示出巨大的收益，證明了持續支持和發展的合理性。本研究為農村水資源管理的政策制定者和利益相關者提供了關鍵見解，宣導增強井技術的永續性和社會經濟影響的策略。通過解決現有的問題並利用提供的機會，農村社區可以實現永續的清潔水源，促進社會經濟發展並提高所有居民的生活品質。

關鍵字：手動水井，水的可及性，社會經濟影響，永續發展目標（SDGs），社區發展。

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List of Acronyms

HPBT	Hand Pump Borehole Technology
HPB	Hand Pump Borehole
HP	Hand Pump
MDLG	Mukono District Local Government
UN	United Nations
WHO	World Health Organization
NGOs	Non-Governmental Organizations
UBoS	Uganda Bureau of Statistics
UNDP	United Nations Development Programme
SSA	Sub-Saharan Africa
RBV	Resource Based View
URSB	Uganda Registration Service Bureau

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1. CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

It is approximated that half of the global population will be living in regions of high-water stress by 2030 (World Water Development Report, 2019). The global population is expanding by 80 million people annually, increasing the demand for freshwater by 64 million m³ a year. Nations around the world have been over-pumping their aquifers while most can be replenished (Bazaanah & Dakurah, 2021). As the earth's temperature continues to rise, we expect a significant impact on freshwater supplies with the potential for devastating effects on these resources. As temperatures increase, evaporation increases, resulting in droughts (Hasan & Muhammad, 2020). Historically, surface water sources such as open wells and rivers were common water sources; however, these often pose significant health risks due to contamination. Hand pump boreholes were introduced a few decades ago as a solution to provide safe and accessible water to communities (Mkandawire et al., 2020). The mechanism of drawing groundwater by pump and suction forces water to rise to the surface through the tubes connected to the pump. These pumps are essential during prolonged dry seasons in rural communities. Rainwater and groundwater resources like boreholes, wells, and springs help buffer short-term environmental variability and surface water evaporation (Bonsor et al., 2015). East Africa and the Horn of Africa see increased water demand during droughts, with only hand pump boreholes remaining operational of all the available water sources in these rural communities (MacDonald et al., 2022).

Rural areas are faced with the challenge of persistent water scarcity impacting the health, livelihoods, and overall well-being of millions of people (MacDonald et al., 2021). In such contexts, Hand Pump Borehole Technology (HPBT) has emerged as a widely utilized solution for addressing water scarcity challenges. According to a 1996 ground water study conducted by the government of Uganda which yielded vital information used to understand the reliability of Hand Pump Borehole Technology (Nsubuga et al., 2014). They used 3 catchment points namely, Ruizi, Wamala and Victoria which showed a decline in water resources. The latter of which affects the Mpunge area as the sub-county lies on the banks of Lake Victoria.

Despite global investments improving access to safe drinking water for 5.8 billion people by 2020 (UN World Water Development Report 2022), substantial inequalities persist, especially in rural

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Uganda. Rural communities often rely on untreated, unsafe surface water sources, exacerbating health risks and socio-economic disparities. Hand pump boreholes have emerged as sustainable solutions to these challenges, with 75% of Africa's population accessing water through boreholes, and 65% of Sub-Saharan Africa's population having access to basic water supply due to this technology (Danert et al., 2020). However, the effectiveness of hand pump boreholes in addressing water scarcity's socio-economic impacts is often overlooked. Factors such as poverty, education levels, and cultural practices influence the community's ability to maintain and utilize boreholes effectively (Etongo et al., 2018). Competing priorities and limited resources may lead to a focus on infrastructure development rather than long-term sustainability and impact assessment (Warinda et al., 2020).

Mukono District, located in central Uganda, has faced significant water scarcity challenges, similar to many other rural areas in the country (MDLG Report, 2020). Despite its proximity to the largest water body, the district, which comprises a mix of urban and rural communities, has historically struggled with water scarcity. Many residents rely on unprotected water sources such as streams, rivers, and open wells, which often pose health risks (Baguma et al., 2023). According to the MDLG Report (2020), Mpunge sub-county, one of the fastest-growing rural areas in the district, remains in danger due to a lack of safe water for domestic consumption. This scarcity has led to the highest waterborne disease-related deaths in the district, with up to 100 children and at least 30 adults dying in a single year. Due to insufficient resources, the government called upon NGOs to assist in providing safe water and water resource management solutions.

In response to these challenges, hand pump borehole technology was introduced by both the government and NGOs (Bonsor et al., 2015). Several initiatives in Mpunge sub-county have used hand pump boreholes as a primary source of potable water. However, the effectiveness of these boreholes in providing a safe and sustainable water supply remains a concern and warrants further investigation. This study aims to assess not only the impact on water quality and maintenance but also the broader implications for community well-being, encompassing health outcomes, economic productivity, and overall quality of life. Understanding these dynamics is vital for addressing the complex water challenges faced by communities in rural Uganda. The inclusion of these aspects in the study is crucial, as they directly affect the health, economic stability, and

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overall living standards of the communities, highlighting the importance of a holistic approach to water resource management and infrastructure development.

Examining the effectiveness of hand pump boreholes is crucial for ensuring that water infrastructure investments meet marginalized communities' needs and contribute to broader socio-economic development goals (Nyika & Dinka, 2023). Effective management and utilization of boreholes can help achieve Sustainable Development Goal 6 (Clean Water and Sanitation) and improve rural populations' quality of life. Community user management committees, composed of local members responsible for maintenance and equitable water distribution, are essential for the long-term functionality of these boreholes (Ngobi, 2017). Hand pump boreholes offer cost-effective solutions for potable water access, with significant positive impacts on local communities, such as reduced disease burdens and time savings for women and children tasked with water collection (Asaba et al., 2013). Despite Uganda's abundant water resources, many rural communities still struggle with access to safe drinking water due to contamination risks from open wells and rivers (Okot-Okumu & Otim, 2015; Baguma et al., 2023). Addressing these challenges is vital for ensuring clean and safe drinking water for rural populations.

This study was guided by the Water Scarcity and Development Theory, which highlights the critical relationship between water scarcity and socio-economic development, particularly in rural Uganda's Mpunge Sub-County in Mukono District. Access to clean water is essential for economic development, health improvement, and poverty alleviation in these areas (MacDonald et al., 2021). Hand pump borehole technology provides reliable access to clean water, directly contributing to better health outcomes, increased agricultural productivity, and enhanced livelihoods. The Resource-Based View (RBV) theory suggests that communities can achieve a sustainable competitive advantage by effectively managing their resources, including water infrastructure like hand pump boreholes (Davis & Simpson, 2017). In this context, hand pump boreholes are vital resources that significantly contribute to the socio-economic development of rural areas, offering valuable and often rare clean water.

1.2 Problem Statement

Water scarcity is a pervasive and pressing issue in rural areas where communities often lack reliable access to clean and safe drinking water sources. Access to safe and adequate quantities of

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water for drinking and domestic purposes is a vital component of poverty alleviation. Such access has been found to improve health and food security as well as increase the number of hours for economic opportunities and education, especially for women and girls. Given these benefits, access to safe and adequate quantities of water has featured prominently within international development efforts over the past forty years, for example, the UN Sustainable Development Goals (2016-2030) and others. Even though the introduction of hand pump borehole technology has been heralded as a solution to this problem, access to safe drinking water in rural areas remains a challenge. It often leads to a high prevalence of waterborne diseases among the affected people and negatively impacts their economic activities.

Questions have been raised as to the reliability and functionality of Hand Pump Borehole Technology. In the Mpunge sub-county, challenges related to maintenance and sustainability have been identified to affect the effectiveness, longevity, and usability of many hand pump boreholes (HPBs). For instance, in the Mpunge sub-county, residents face daily challenges in accessing potable water due to the limited availability of safe water sources (Tumwebaze et al., 2023). Carter (2021) notes that many residents rely on hand pump borehole technology, but issues related to maintenance and sustainability often compromise their effectiveness. Further, Harvey and Mukanga (2020) reveal that frequent breakdowns and the lack of trained personnel to repair these boreholes contribute to interruptions in water supply, exacerbating the community's water scarcity woes. Additionally, inadequate funding for borehole maintenance and the absence of community-led initiatives further hinders sustainable access to clean water (Dickson-Gomez et al., 2023). As these boreholes age, questions arise concerning the availability of resources and local community capacity for maintaining and repairing the infrastructure. Their effectiveness has been influenced by the governance, institutional, and policy frameworks in place to support its implementation and maintenance.

There is also little knowledge of HBP water quantity, quality, and acceptability standards. Studies in Uganda, for example, one conducted by Liddle. (2019), found that 42.3% of HPBs have poor color, sediments, and worms in the water. Likewise, despite the widespread use of hand pumps, evidence shows that only 57% of hand pumps are functional, 31% are sub-optimally functional, and 12% are not functioning at all. While hand pump boreholes provide a source of water that is generally safer than open surface water sources, the quality of the groundwater from boreholes

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requires to be consistently monitored to ensure it meets health and safety standards. The challenges related to contamination and pollution need to be evaluated. Even though hand pump borehole technology has shown promise in addressing water scarcity, a comprehensive assessment to determine its effectiveness in mitigating water scarcity in rural areas is required. The proposed assessment of hand pump borehole technology's effectiveness will address challenges and fill research gaps by evaluating its effectiveness on mitigating water scarcity in rural areas like the Mpunge sub-county. It will analyze water quality, reliability of supply, maintenance issues, and community satisfaction levels to identify areas for improvement.

Additionally, it will examine socio-economic and institutional factors influencing borehole performance, informing targeted interventions. This assessment will provide empirical evidence, contributing to evidence-based decision-making and the development of sustainable solutions to rural water scarcity.

1.3 Purpose of the Study

The purpose of the study is to comprehensively evaluate the socio-economic effectiveness and the Sustainable Development Goals (SDGs) alignment of the hand pump borehole technology in mitigating water scarcity in rural areas of Uganda. This involves assessing a range of key variables, including income generation, health outcomes, agricultural productivity, and access to education, to understand the broader impact of hand pump boreholes on rural communities. Specifically, the study will define and measure water scarcity mitigation by analyzing factors such as water availability, quality, reliability, and accessibility in rural areas. Examining these socio-economic factors and indicators alongside water scarcity metrics, the study aims to provide a comprehensive assessment of the effectiveness of hand pump borehole technology in addressing water scarcity challenges and improving the well-being of rural populations in Uganda.

1.3.1 Study Objectives

This study seeks to achieve the following objectives:

i. To evaluate the functionality and reliability of hand pump borehole technology in providing access to clean and safe water in the Mpunge sub-county(H_1).
ii. To assess the quality and safety of water provided by hand pump boreholes in the Mpunge sub-county.

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iii. To analyze the socio-economic effects of access to clean water by communities relying on hand pump boreholes in the Mpunge sub-county(H_2).

1.3.2 Research Questions

i. How functional and reliable are hand pump borehole technologies in providing access to clean and safe water in the Mpunge sub-county?

ii. What is the quality and safety of water provided by hand pump boreholes in Mpunge sub-county?

iii. What socio-economic effects come as a result of access to clean water by communities relying on hand pump boreholes in Mpunge sub-county?

1.3.2 Research Hypotheses

H_1: Hand pump borehole technology is functional and reliable in providing access to clean and safe water in the Mpunge sub-county.

H_2: Access to clean water through hand pump boreholes has positive socio-economic effects on communities in the Mpunge sub-county, including improved health outcomes, increased agricultural productivity, and enhanced educational opportunities.

1.4 Scope of the Study

The study was conducted in Mpunge sub-county which is found in Mukono district in the central region of Uganda. The study area was chosen because it has recently been ranked as one of the areas affected in terms of water shortage, accessibility, and reliability. These rankings stem from comprehensive assessments and reports conducted by governmental or non-governmental organizations, which highlight regions facing acute water challenges. Mpunge's designation in these rankings suggests that it faces notable difficulties in providing sufficient, accessible, and reliable water sources to its residents. These challenges might include factors such as insufficient infrastructure, population growth, environmental degradation, or inadequate water management practices. Mpunge as a sub-county alone is estimated to be slightly above average (57%). Also, many hand pump boreholes have faced challenges related to maintenance and sustainability. The study assessed the effectiveness of hand pump borehole technology in mitigating water scarcity in

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rural areas. The study considered, functional and reliability, the quality and safety of water, and socio-economic effects as a result of access.

In the study, water scarcity was assessed through a comprehensive evaluation of multiple variables including access, reliability, quality, and safety. Access to water was measured by analyzing the distance and ease of obtaining water sources, as well as the availability of water within a certain proximity to households. Reliability was determined by examining the consistency and predictability of water supply from hand pump boreholes over time. Water quality was assessed through laboratory testing of water samples collected from various boreholes, focusing on parameters such as microbial contamination, chemical pollutants, and physical characteristics. Safety encompassed factors such as the absence of contaminants harmful to human health and compliance with national water quality standards. To ensure clarity and consistency in the research methodology, specific measurement protocols and criteria were established for each variable. For example, access was quantified by calculating the average distance to the nearest borehole and conducting surveys to assess the convenience and reliability of accessing water sources. Reliability was assessed through monitoring of borehole functionality and water supply interruptions, recorded through field observations. Water quality analysis involved standardized testing procedures conducted in accredited laboratories, following international guidelines and standards.

However, it is essential to acknowledge the limitations and constraints that may have influenced the scope of the study. These could include factors such as limited time and resources available for data collection and analysis, as well as challenges in accessing accurate and up-to-date data on water scarcity indicators. Additionally, variations in environmental conditions and community behaviors may have impacted the study's findings, highlighting the need for cautious interpretation and generalization of results. Despite these limitations, the study provides valuable insights into the effectiveness of hand pump borehole technology in addressing water scarcity challenges in rural areas like Mpunge sub-county.

1.5 Motivation of the Study

Understanding the effectiveness of hand pump borehole technology in Uganda is a vital step towards addressing the water accessibility and quality challenges faced by communities in the Mpunge sub-county. This study contributes to the ongoing efforts to provide sustainable, reliable,

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and safe drinking water sources for all Ugandans as is in the Uganda Vision 2030, thereby improving the quality of life and fostering socio-economic growth and development in rural communities. Regardless of the significant freshwater resources in Uganda, the rapid population growth is believed to strain the water supply coupled with a lack of sufficient investments by the government, inappropriate water distribution infrastructures, and inefficient water resource management. This has caused challenges in most rural areas that experience wide inconsistencies in access to water supply. Likewise, Rubarenzya, (2008) indicates that other factors, such as urbanization, industrialization, water pollution, and climate change, have caused an enormous strain on the government's ability to distribute water equitably all over the country.

Specifically, Mpunge Parish is among the catchments impacted by water resource depletion endangering the water resource base. This has seen a reduction in agricultural output, scarcity of safe drinking water, loss of forest cover, disease prevalence, encroachment on wetland regions, and increased land degradation among others. The rise in population growth has exerted a strain on the available water and land resources increasing the demand for safe drinking water in the communities.

1.6 Justification

Groundwater which hand pump boreholes produce is currently in a state of increased strain due to an array of reasons including, unchecked growth in agricultural and industrial exploits. The strain is further compounded by the exponential growth in population causing high water demand. Katuva et al. (2020), in their coastal Kenya study, concluded groundwater plays a substantial role in the welfare of families and, consequently, communities. They further assert that the access and usability of these HPBs are cyclically linked to the welfare or socio-economic status of community members. Katuva and his associates thus highlighted the importance of conducting studies geared towards monitoring the efficacy of groundwater facilities like HPBs in improving the welfare of communities in which they are erected.

There is minimal information for a vast majority of countries, especially in Sub-Saharan Africa (SSA) concerning the use of groundwater sources further research on how they work is even more vital. According to a study by Danert et al (2009), only 33% of the 42 inspected countries in Sub-Saharan Africa had groundwater databases in the view of participants. The aim is to collect data

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on the state of boreholes and assess how effective they are within the communities in which they are situated. Researching the effectiveness of HPBs will emphasize state actors' role in increasing access to these resources to vulnerable communities.

The use of Hand Pump Technology has a pivotal role in the overall welfare of the communities they are intended to serve especially during natural disasters like drought (Schweitzer et al., 2021). Hand Pump Borehole Technology proved particularly useful in a study conducted by MacAllister et al. (2020); using Ethiopia as a guide, they found that 73% of residents used point water sources over any other sources, and HBPTs presented the overall highest average concerning overall functionality. Thus, ensuring the population has improved living conditions as a result of meeting the needs of the community through meeting Sustainable Development Goal 6–reduction in loss of lives.

The proposed study aims to contribute significantly to addressing critical research gaps and advancing knowledge in groundwater management and community welfare. Firstly, it seeks to fill the dearth of information, especially in Sub-Saharan Africa, regarding the use and efficacy of groundwater sources, particularly hand pump boreholes (HPBs). The study will provide valuable insights into the role of HPBs in improving community welfare by collecting data on the state of boreholes and assessing their effectiveness within communities. Moreover, the research will emphasize the crucial role of state actors in increasing access to these resources for vulnerable communities. For instance, findings from a study by MacAllister et al. (2020) in Ethiopia underscored the importance of HPBs, with 73% of residents relying on point water sources during natural disasters like drought. The study highlights their pivotal role in ensuring improved living conditions and contributing to achieving Sustainable Development Goal 6, reduction in loss of lives. Using specific examples and data, the research will illustrate how HPB technology can significantly enhance community welfare, especially during natural disasters like drought. By showcasing the effectiveness of HPBs in providing reliable access to clean water, the study will underscore the critical importance of investing in and maintaining such infrastructure to safeguard community well-being.

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1.7 Significance

This study contributes to understanding the viability of hand pump borehole technology as a solution to address water scarcity in rural areas. This will inform policymakers, NGOs, and local communities about the potential benefits and challenges of implementing this technology. These findings could offer practical insights into how institutions can enhance effective hand pump borehole technology in mitigating water scarcity in rural areas. The study findings might inform policymakers and institutional administrators about the effectiveness of the existing policies and suggest changes for improvement, leading to better governance and management of hand pump borehole technology to mitigate water scarcity. The study may help future researchers who may want to explore water scarcity in rural areas in other contexts with a guide and reference for further knowledge.

In addition to addressing immediate water scarcity challenges, this research holds broader significance in the context of global sustainability efforts outlined by the United Nations Sustainable Development Goals (SDGs). Specifically, the study aligns with SDG 6, which aims to ensure availability and sustainable management of water and sanitation for all. Evaluating the effectiveness of hand pump borehole technology in mitigating water scarcity, the research directly contributes to achieving SDG 6 targets related to clean water access in rural areas. Furthermore, the study's implications extend beyond SDG 6, touching upon various interconnected goals. SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 5 (Gender Equality), and possibly SDG 8 (Decent Work and Economic Growth) are all intertwined with access to clean water. Improved access to clean water positively impacts poverty reduction, food security, health outcomes, educational opportunities, gender equality, and economic development within rural communities.

The findings of this study hold significant implications for policymaking and community development efforts in addressing water scarcity in rural areas. Specifically, the study provides practical insights for policymakers, NGOs, and local communities on the benefits and challenges associated with implementing hand pump borehole technology. These insights can inform the development of targeted policies and strategies aimed at enhancing the effectiveness of this technology in mitigating water scarcity. One specific policy recommendation that may arise from the study findings is the need for increased investment in the maintenance and sustainability of

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hand pump boreholes. Another vital recommendation is to have water use committees as seen in Mpunge sub county whose role is to maintain and oversee good usage practices of the technology once implemented. By addressing challenges related to maintenance, such as training local technicians and ensuring adequate funding, policymakers can improve the reliability and longevity of borehole infrastructure, thereby enhancing access to clean water in rural communities.

Furthermore, the study findings may inform policymakers and institutional administrators about the effectiveness of existing policies and suggest changes for improvement. For example, recommendations may include strengthening community participation in borehole management, implementing monitoring and evaluation mechanisms, and improving coordination between government agencies and NGOs involved in water resource management. The study findings can serve as a valuable reference for researchers interested in exploring water scarcity in rural areas. Potential research questions could include investigating the socio-economic impacts of water scarcity interventions, evaluating the effectiveness of alternative water supply technologies, or assessing the long-term sustainability of water resource management initiatives. Methodologies could build upon the study's findings by incorporating participatory approaches, longitudinal studies, or comparative analyses across different geographical contexts. Overall, the study provides a foundation for advancing knowledge and informing policy and practice in addressing water scarcity in rural areas.

1.8 Structure of the Thesis

The thesis is presented systematically, commencing with the Introduction, which establishes the research topic, objectives, and importance. Key concepts, such as water scarcity and hand pump borehole technology, are introduced, along with the research questions and methodology. Next, the Literature Review thoroughly examines existing literature, identifying gaps and theoretical frameworks including resource-based view theory, diffusion of innovation theory, water scarcity and development theory which are crucial for framing the study. Additionally, we dive deep into written literature concerning functionality, and water quality of HPBT. Focus on socio-economic effects of access to clean water on factors like education, health, income, and agricultural productivity. This section also provides a peek into the relationships between selected research variables. Moving on to the Methodology chapter, the research design is comprehensively outlined, covering data collection methods, participant selection criteria, ethical considerations,

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and research limitations. The Results chapter then presents the empirical findings in an organized manner, addressing the research objectives and supplementing them with statistical analyses and visual aids for clarity.

In the Discussion chapter, the results are analyzed within the context of the research questions and theoretical framework. This section delves into the implications of the findings for theory, policy, and practice, as well as addressing the study's limitations and future research avenues. Lastly, the Conclusion chapter summarizes the primary findings, highlighting their significance, and reiterating the study's contribution to addressing water scarcity and achieving sustainable development goals. It concludes with recommendations for policymakers and NGOs and suggests further research directions.

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2. CHAPTER TWO: LITERATURE REVIEW

2.1 literature Search Strategy

The literature search strategy adopted a systematic approach to comprehensively explore scholarly publications, reports, and other relevant sources that explore hand pump borehole technology's functionality, water quality, and socio-economic effects in rural areas, focusing specifically on Mpunge sub-county, Uganda. Publications within the last decade were targeted to ensure currency and relevance. The literature search aimed to thoroughly explore scholarly publications, reports, and other relevant sources focusing on hand pump borehole technology's functionality, water quality, and socio-economic effects in rural areas, particularly in Mpunge sub-county, Uganda. The search was limited to studies published within the last decade to ensure relevance and currency. Through the careful selection of keywords and search terms pertinent to hand pump borehole technology, water quality, socio-economic effects, and rural areas, a search strategy was devised to capture a broad spectrum of relevant literature.

The inclusion criteria encompassed peer-reviewed journal articles, conference papers, and reports published in English, focusing on hand pump borehole technology in rural areas, particularly in Mpunge sub-county, Uganda. Studies addressing the functionality, water quality, and socio-economic effects of hand pump boreholes were considered. Publications published within the last ten years were included to ensure relevance and currency. Non-peer-reviewed sources such as opinion pieces, editorials, and non-academic blogs were excluded. Studies not relevant to hand pump borehole technology, water quality, or socio-economic effects in rural areas, as well as publications published before the specified timeframe of the last ten years, were also excluded. Non-English publications were not considered.

Employing Boolean operators, the search strategy combined keywords and search terms to effectively retrieve relevant literature addressing different facets of hand pump borehole technology, water quality, and socio-economic impacts. Following the screening of search results based on titles, abstracts, and full texts, duplicates were removed, and studies meeting the inclusion criteria were selected for further review. Only studies published in peer-reviewed journals, conference proceedings, or reputable reports were considered to uphold research quality and credibility. In addition to academic literature, grey literature, government reports, and

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organizational websites were consulted to supplement the findings and provide additional insights into hand pump borehole technology's socio-economic implications in rural areas.

2.2 Theoretical Framework

2.2.1 Resource-Based View (RBV)

The resource-based view (RBV) theory posits that sustained competitive advantage for organizations arises from their unique resources that are valuable, rare, inimitable, and non-substitutable (Barney & Arikan, 2005). These resources form the basis of a firm's strategy and determine its ability to outperform competitors. In the context of rural development, the RBV framework provides insights into how organizations or communities can leverage their resources effectively to achieve competitive advantage and socio-economic progress (Abaho et al., 2016). Hand pump borehole technology serves as a pertinent example within the RBV framework. In rural areas, access to clean water is often limited, posing significant challenges to socio-economic development. Providing reliable access to clean water, hand pump boreholes become valuable resources that contribute to enhancing the well-being of rural communities (Olive, 2019). The rarity of clean water sources in such areas further underscores the importance of hand pump boreholes as non-substitutable resources.

Moreover, the RBV theory emphasizes the role of effective resource management in achieving competitive advantage. Successful implementation and maintenance of hand pump boreholes require organizational and community efforts to manage water resources sustainably (Okot-Okumu & Otim, 2015). Community-led initiatives, such as water user committees, exemplify how local communities can manage and leverage hand pump boreholes to enhance their socio-economic conditions. Additionally, the RBV perspective illuminates the strategic implications of hand pump borehole technology. Focusing on internal resources, such as the availability and functionality of hand pump boreholes, organizations, and communities can develop strategies to address water scarcity and promote development in rural areas (Carter, 2021). This strategic approach aligns with the principles of RBV, as it emphasizes leveraging valuable resources to gain competitive advantage and drive socio-economic progress. The RBV framework elucidates the role of hand pump borehole technology in mitigating water scarcity and fostering socio-economic development in rural areas (Ali & Muathe, 2020). Recognizing hand pump boreholes as valuable, rare, and non-substitutable resources, organizations and communities can develop strategic

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initiatives that capitalize on these resources to achieve sustainable competitive advantage and improve livelihoods in rural contexts.

2.2.2 Diffusion of Innovation Theory

The diffusion of innovations theory explains how, why, and at what rate new ideas and technology spread. The theory was popularized by Everett Rogers in his book Diffusion of Innovations, first published in 1962 (Rogers, 2003). Rogers argues that diffusion is the process by which an innovation is communicated through certain channels over time among the participants in a social system. The origins of the diffusion of innovations theory are varied and span multiple disciplines. Rogers proposes that five main elements influence the spread of a new idea: the innovation itself, adopters, communication channels, time, and a social system. This process relies heavily on social capital. The innovation must be widely adopted to self-sustain. Within the rate of adoption, there is a point at which an innovation reaches critical mass.

Firstly, the innovation itself encompasses various attributes, such as its perceived advantages, complexity, and compatibility with existing practices. Innovations that are perceived as advantageous, easy to use, and compatible with current norms are more likely to be adopted by individuals and communities (Wynn, 2017). Secondly, adopters play a crucial role in the diffusion process. Vargo et al. (2020) provide that these are the individuals or groups who are the first to embrace innovation. Rogers categorized adopters into different groups based on their innovativeness, ranging from innovators (early adopters) to laggards (late adopters) (Rani & Kumar, 2021). Understanding the characteristics and motivations of adopters is essential for predicting and influencing the rate of adoption.

Communication channels serve as the conduits through which information about the innovation is disseminated. Melaku et al. (2024) note that these channels can be formal, such as mass media and educational programs, or informal, such as word of mouth and interpersonal networks. Hains and Hains (2020) suggest that the effectiveness of communication channels greatly influences the spread of innovation within a community. Time is another critical element of the diffusion process. Innovations typically undergo a lifecycle, starting from their introduction to eventual widespread adoption or abandonment (Markard, 2020). Zanello et al. (2016) add that the rate of adoption and the factors influencing it evolve, making it essential to consider temporal dynamics when studying

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diffusion. Lastly, the social system within which the innovation is introduced plays a significant role in its diffusion. This includes cultural norms, social networks, economic conditions, and institutional support. Wani and Ali (2015) posit that the social context shapes individuals' perceptions and behaviors regarding innovation, influencing its adoption and spread within the community.

This theory explores how new technologies, such as hand pump borehole technology, are adopted and diffused within communities. It posits that the adoption of innovations depends on factors such as perceived benefits, ease of use, compatibility with existing practices, and communication channels. In rural areas, the diffusion of hand pump borehole technology may be influenced by factors like the perceived benefits of improved water access, ease of use, compatibility with local customs, and the effectiveness of communication channels used to promote the technology. Furthermore, an introduction of a local committee of trained members whose role is to sensitize/ disseminate information on HPBT to their fellow neighbors on how to use this and maintain the innovative technology has been proven to engender a longer efficacy period of erected hand pump boreholes.

2.2.3 Water Scarcity and Development Theory

The Water Scarcity and Development Theory elucidates the intricate interplay between water scarcity and socio-economic development, positing that access to clean water is pivotal for fostering economic growth, improving health outcomes, and alleviating poverty. Firstly, it recognizes access to clean water as a fundamental human need essential for life and well-being (Jepson et al., 2017). According to Everard et al. (2018), it emphasizes the importance of holistic approaches to water management, considering social, economic, and environmental dimensions. Moreover, it aligns with the global agenda to achieve SDG 6 - Clean Water and Sanitation, and other relevant goals related to poverty eradication, health, education, and gender equality (Irannezhad et al., 2022; Libala et al., 2021). In relevance to HPB Technology, this theory underscores its role in facilitating access to clean water in rural areas where traditional sources may be limited or contaminated. Additionally, it highlights how access to clean water through hand pump boreholes reduces waterborne diseases, boosts agricultural productivity through irrigation, livestock watering, and crop cultivation, and empowers livelihoods by freeing up time spent collecting water, especially for women and girls. Overall, the theory emphasizes the critical

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importance of sustainable interventions like hand pump borehole technology in addressing water scarcity and driving socio-economic development in rural communities.

The contributions of key scholars, organizations, and publications have significantly influenced policy, practice, and research in the field of water scarcity and development. Scholars like Peter H. Gleick, through their extensive research and publications, have raised awareness about the complex challenges of water scarcity and its implications for society (Gleick & Cooley, 2021). Organizations such as the United Nations Development Programme (UNDP) and the World Bank have played crucial roles in shaping policies and implementing projects aimed at addressing water scarcity and promoting sustainable water management practices globally (Paquin & Cosgrove, 2016). Their reports and studies have informed policymakers, practitioners, and researchers about the multifaceted nature of water scarcity and the need for integrated approaches to water resource management. Additionally, influential publications like "The World's Water" series by Peter Gleick and reports by the UNDP and the World Bank have served as valuable resources for policymakers and researchers seeking evidence-based solutions to water scarcity-related issues. The contributions of these scholars, organizations, and publications have helped shape the discourse on water scarcity and development and have catalyzed actions to address this pressing global challenge.

2.3 Functionality of HPB Technology and Access to Clean and Safe Water

Research on the functionality of hand pump borehole technology and its impact on access to clean and safe drinking water is an important area of study in the field of water and sanitation (Bazaanah & Dakurah, 2021). Thomson (2021) provides that HPB technology is a simple and effective method for accessing clean and safe drinking water, especially in rural and remote areas where traditional water supply infrastructure may be lacking. This technology involves drilling a borehole (a narrow, deep hole) into the ground to tap into underground water sources. A hand pump is then installed to extract the water to the surface. According to Kilungo, Paterson and Young (2018), access to clean and safe drinking water is a fundamental human right, essential for maintaining health, eradicating poverty, and ensuring a sustainable environment. Unfortunately, millions of people around the world still lack reliable access to potable water (Martínez-Santos, 2017). Hand pump borehole technology plays a crucial role in addressing this global challenge, providing communities with a sustainable and efficient means of obtaining clean and safe drinking water.

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Likewise, Alom (2015), posits that hand pump borehole technology involves drilling a hole into the earth's surface to access underground aquifers, which store groundwater. A hand pump is then installed to draw water to the surface for consumption. Hasan and Muhammad (2020) indicate that hand pumps bring clean water sources closer to communities, reducing the distance people must travel to access water. Harvey (2019) observes that this, in turn, saves time and energy, particularly for women and children responsible for water collection. Moreover, Lapworth et al. (2020), offer that they are a sustainable water source, as they tap into groundwater, which is less susceptible to climate fluctuations. Local communities can manage and maintain hand pump boreholes, promoting ownership and sustainability. This empowers communities to take charge of their water supply (Hasan & Muhammad, 2020). Bonsor et al (2015) found that HPB technology is an effective means of providing access to clean and safe drinking water, particularly in regions with limited infrastructure. Martínez-Santos et al. (2020) note that its functionality, when coupled with proper maintenance and community involvement, can significantly improve public health, empower communities, and promote sustainable development. As global challenges related to water access persist, investment in hand pump borehole technology remains a critical solution in ensuring clean and safe drinking water for all (Bazaanah & Dakurah, 2021).

While other water source types and technologies do, and will increasingly, play an important role in increasing access to safe water, HPs, whether installed on boreholes or hand-dug wells, will continue to serve many millions of people in SSA for many years to come particularly in rural areas (Carter, 2021). Recent studies have shown that HPs installed on boreholes are essential for many rural communities during drought (MacAlister et al., 2020) and that groundwater is a resilient and safe source of water supply. However, poor performance of HPs, installed on boreholes or hand-dug wells, is a persistent problem in SSA. Foster et al. (2019) suggests that as many as one in four HPs may be non-functional at any one time. Recently there has been a concerted effort to better understand the factors that affect the functionality and performance of rural water supplies (Bjornlund et al., 2021; George-Williams et al., 2024). Most studies are based on large-scale water point monitoring datasets that enable a broad geographic assessment but are not designed to enable a detailed analysis of the underlying physical factors affecting HPB functionality (Steinbach et al., 2021).

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Despite their numerous benefits, hand pump boreholes face significant challenges that can hinder their effectiveness in providing access to clean and safe water (Foster et al., 2018). MacAllister et al. (2022) recommend regular maintenance to ensure the continued functionality of hand pump boreholes. The scholars caution that neglect or damage to pumps can lead to their malfunctioning, depriving communities of essential water access.

2.4 Quality and Safety of Water Provided by Hand Pump Boreholes

In many rural and peri-urban areas, hand pump boreholes are a vital source of drinking water. The quality and safety of water from these boreholes are of paramount importance to public health (Mkandawire et al., 2020). Casey, Nekesa & Etti (2016) found that the quality and safety of water provided by hand pump boreholes are critical factors for public health. Multiple factors influence water quality, including geological conditions, borehole construction, environmental pollution, and microbial contamination (Akhtar et al., 2021). Poor water quality poses risks to human health, causing waterborne diseases and exposure to harmful chemicals (Madhav et al., 2020; Lin et al., 2022). Liddle, (2019) indicated that access to safe and clean drinking water is a fundamental right, and it is imperative to ensure that hand pump boreholes meet these standards to promote the well-being of communities relying on them.

MacDonald et al. (2021) established that hand pump boreholes are essential for many rural communities during drought and that groundwater is a resilient and safe source of water supply. Much of the improvement in water supply coverage in recent decades has been achieved by the installation of hand pumps (MacAllister et al., 2022). However, after accounting for the rapid population increase in SSA, the total number of people without access to basic water supplies has increased from 350 million to 387 million (Ian et al., 2023). Recent research suggests that over 85% of Uganda's 40 million people depend on rural water supply systems such as hand pump boreholes (Huston et al., 2021). A more comprehensive description can be found in the reports by UBOS admin (2022) and UN-World Population Prospects (2022), where both reports indicate Uganda's population was growing at a rate of 3.1% by 2014, which trend has not changed, lately increasing to over 47 million at a rate of 3.04%. The literature about water scarcity in rural areas of Uganda strongly suggests that the management of natural water supply lacks the necessary institutions responsible for water service delivery to improve their capacity in availing a steady investment in water supply infrastructure. Additionally, Twinomucunguzi et al. (2020) note that

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proper siting and construction are essential to prevent groundwater contamination, as poorly constructed boreholes may introduce pollutants into the water source. Moreover, the requirement for skilled professionals to install and maintain hand pump boreholes can pose a barrier, particularly in remote or underserved areas (Leader & Wijnen, 2018; Nyika & Dinka, 2023). To address these challenges, collaboration between governments, NGOs, and local communities is crucial (Dos Santos et al., 2017; Hove et al., 2019). Developing effective policies and management strategies, implementing training programs for community members to maintain pumps and monitor water quality, and creating systems for financial sustainability are essential steps in ensuring the long-term functionality of hand pump boreholes (Nti et al., 2016; Bazaanah & Mothapo, 2023). These challenges directly relate to the research aim of assessing the functionality of hand pump borehole technology and its impact on access to clean and safe water, highlighting the importance of understanding and addressing these obstacles to achieve sustainable water provision in rural communities.

2.5 Socio-economic Effects of Access to Clean Water by Communities Relying on HPB

Communities reliant on Hand Pump Boreholes (HPBs) often face challenges related to water quality and accessibility. According to Carr (2021), improved access to clean water leads to better health outcomes. Waterborne diseases, such as cholera, dysentery, and typhoid, are significantly reduced when communities have access to clean water (Chan et al., 2021; Luby et al., 2020). Healthier individuals are more productive, reducing the burden on healthcare systems and improving overall well-being (Otim et al., 2020). Further, a report by UNICEF (Ian MacAuslan et al., 2023) reveals that access to clean water positively impacts education. When children have easy access to clean water, they are less likely to miss school due to waterborne illnesses (Yang et al., 2020; Nyika & Dinka, 2023). This contributes to better educational outcomes, reducing the cycle of poverty and improving the community's future socio-economic prospects. MacAllister et al. (2021) found that women and girls are often responsible for water collection in many communities reliant on HPBs. Access to clean water reduces the time and effort required for water collection, allowing women and girls to participate in education and income-generating activities. This empowerment contributes to greater gender equality.

According to Bazaanah and Dakurah (2021), clean water enhances economic productivity, being essential for agriculture, small-scale businesses, and industrial activities. Increased agricultural

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productivity leads to surplus food production, generating income and improving food security (Darko et al., 2020). MacAllister et al. (2021) affirm that sustained access to clean water is crucial for long-term socio-economic benefits. George-Williams et al. (2024) observe that communities reliant on HPBs face challenges such as equipment maintenance, infrastructure, and water resource management. Juju et al. (2020) emphasize that adequate funding and community involvement are essential to address these issues. MacAllister et al. (2022) found that access to clean water in communities reliant on HPBs has profound socioeconomic effects, improving health, education, gender equality, and economic productivity. However, sustaining this access presents challenges that require adequate resources and community engagement. Governments, NGOs, and local communities must work together to ensure that clean water is a fundamental right for all.

2.5.1 Education

Access to clean water significantly impacts educational outcomes in communities relying on Hand Pump Boreholes (HPBs), as evidenced by various studies. Research by Carr (2021) highlights the correlation between improved water access and reduced absenteeism due to waterborne illnesses, leading to better school attendance rates. Similarly, findings from a report by the World Health Organization (2019) underscore the importance of clean water in mitigating the spread of diseases, thereby promoting consistent school attendance among children. Furthermore, MacAllister et al. (2021) emphasize the role of clean water in enhancing cognitive function and concentration levels among students, positively influencing their academic performance. Buheji and Buheji (2024) suggest that access to clean water not only addresses immediate health concerns but also contributes to long-term educational development by ensuring uninterrupted access to learning opportunities. Thus, investing in clean water infrastructure emerges as a crucial strategy for promoting educational equity and breaking the cycle of poverty in rural communities reliant on HPBs.

2.5.2 Health

Access to clean water through Hand Pump Boreholes (HPBs) significantly improves health outcomes. Mutono et al. (2021) show that clean drinking water reduces diseases like cholera, dysentery, and typhoid. HPBs play a crucial role in reducing waterborne illnesses and enhancing overall well-being (Opio, 2021). Omona et al. (2020) highlight that clean water prevents diarrheal diseases, especially in children under five.

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Access to clean water also promotes proper hygiene practices, lowering water-related illness incidence (MacAllister et al., 2021). Musoke et al. (2021) argue that this improves both individual and public health. By addressing waterborne disease causes, HPBs support sustainable development goals related to health and well-being (Ibeneme et al., 2020). Ensuring access to clean water through HPBs is vital for improving health, quality of life, and socio-economic development in rural communities.

2.5.3 Income

Access to clean water through Hand Pump Boreholes (HPBs) significantly impacts household income and economic productivity in rural communities. Reliable access to clean water allows households to engage in income-generating activities more effectively, reducing the time spent fetching water and providing more opportunities, especially for women and girls, to participate in farming or small-scale businesses (Mutua & Juster, 2021; Jeil, 2020). This increased economic participation can lead to higher household incomes and improved livelihoods (Vhiga, 2019).

Clean water access also boosts agricultural productivity by supporting irrigation and livestock-rearing activities (Fetene & Kedir, 2024). Consistent water access enables year-round crop cultivation, increasing yields and surplus production for sale in local markets. This surplus improves food security and provides an additional income source for rural households (Yusuf et al., 2023; Pawlak & Kolodziejczak, 2020). HPBs contribute to poverty alleviation by empowering rural communities to engage in income-generating activities and enhancing agricultural productivity (Ayoo, 2022). Overall, HPBs play a crucial role in promoting sustainable development and socio-economic well-being in rural areas.

2.5.4 Agricultural Productivity

Studies demonstrate the tangible impact of hand pump borehole (HPB) technology on improving livelihoods and socio-economic activities in rural areas. HPBs enhance agricultural productivity by providing reliable access to clean water for irrigation and livestock watering. Twongyirwe et al. (2019) note that a consistent water supply enhances agricultural productivity, supporting irrigation and livestock-rearing activities, and contributing to food security and economic stability.

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Balasundram et al. (2023) indicate that water from HPBs enables more efficient crop cultivation, increasing agricultural output and improving food security. Consistent water access allows farmers to implement irrigation systems, supplementing rainfall and mitigating drought effects (Dawit et al., 2020). Reuben et al. (2021) note that HPBs facilitate livestock farming by providing water for animals, ensuring their health and well-being. Access to clean water helps farmers maintain healthy herds and increase productivity (Eeswaran et al., 2021). HPBs contribute to the resilience of rural agricultural systems and help farmers adapt to changing environmental conditions. Increased agricultural productivity from access to clean water can lead to surplus food production, which can be sold in local markets, generating income for rural households (Jayne et al., 2021). This additional income contributes to poverty alleviation and economic development in rural communities.

2.5.5 Social Return on Investment

Social Return on Investment (SROI) is a comprehensive methodology used to measure and evaluate the social, health, environmental, and economic values generated by various projects beyond mere financial metrics. It is a participatory and beneficiary-led approach that assigns financial values to project outcomes, allowing for a ratio of costs to benefits to be calculated. SROI is crucial for non-profit Non-Governmental Organizations (NGOs) as it provides a comprehensive method for measuring the social, environmental, and economic value generated by their activities. This measurement framework helps NGOs demonstrate their impact to stakeholders and facilitates strategic planning and decision-making, ensuring that resources are allocated efficiently to maximize social value. It also fosters transparency and accountability, allowing NGOs to engage stakeholders in meaningful ways and improve their services based on feedback and measured outcomes ("Guide to Social Return on Investment 2012," 2023).

2.6 Gaps in Research

Hand pump borehole technology offers a promising solution for addressing water scarcity in rural areas, yet gaps remain in understanding its full socio-economic impacts and contribution to Sustainable Development Goals (SDGs). While studies highlight the positive effects of hand pump boreholes on water accessibility and health outcomes (Lapworth et al., 2020; Mkandawire et al., 2020), limited research explores their influence on education and agricultural productivity (Buheji

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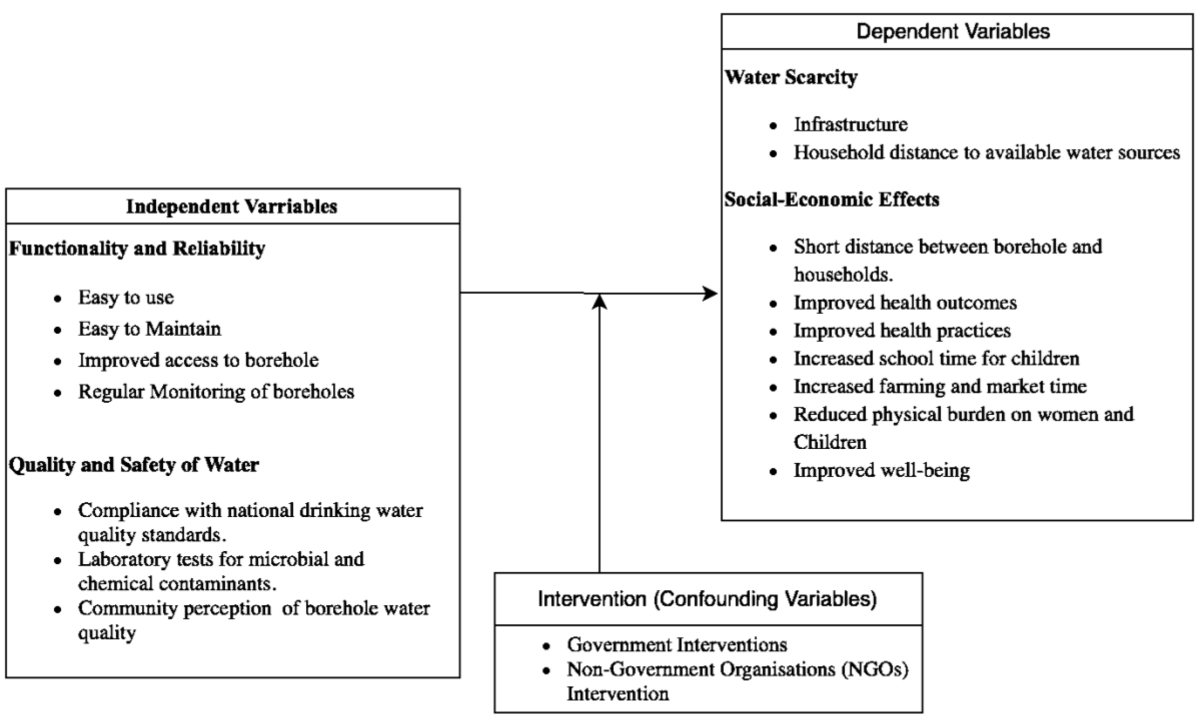
& Buheji, 2024). Investigating these areas is crucial for assessing the technology's overall effectiveness and alignment with SDGs, particularly SDG 6 (Clean Water and Sanitation).

Research is needed to understand how hand pump boreholes impact educational outcomes, including school attendance, academic performance, and educational attainment, which could contribute to SDG 4 (Quality Education). Additionally, examining their impact on market and garden productivity is essential for understanding their potential to support sustainable livelihoods and economic development (Hinton et al., 2021). By facilitating irrigation and livestock watering, hand pump boreholes may increase agricultural productivity and income generation, thereby supporting SDG 1 (No Poverty) and SDG 2 (Zero Hunger) (Ahmed et al., 2022).

Addressing these research gaps can inform policies and interventions to maximize the benefits of hand pump boreholes, advancing progress toward SDGs. Exploring the multifaceted effects of this technology can lead to comprehensive strategies for sustainable development and improved well-being in rural communities.

2.7 Conceptual Framework

Figure 1: Conceptual framework



Source: Adopted and modified from Orina, (2014)

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Independent Variables

Functionality and reliability

- Measure: Percentage of functioning boreholes over a specified period.
- Measure: Frequency of breakdowns and repairs required.
- Measure: Community satisfaction surveys on ease of use and reliability.

This variable assesses the operational status and consistency of hand pump boreholes (HPBTs) over time. Regular monitoring and maintenance contribute to their functionality and reliability. This is crucial as non-functional boreholes exacerbate water scarcity issues.

Quality and safety of water

- Measure: Compliance with national drinking water quality standards.
- Measure: Results of laboratory tests for microbial and chemical contaminants.
- Measure: Community perception surveys on water safety and taste.

Ensuring that water from HPBTs meets national drinking water quality standards is essential for community health. Regular testing for microbial and chemical contaminants ensures the safety of water for consumption, reducing the risk of waterborne diseases.

Dependent Variable

Water Scarcity

- Measure: Household distance to available water sources.
- Measure: Existence and condition of water infrastructure in rural areas.

These variable measures the level of water scarcity in rural areas, considering factors such as the distance households must travel to access water and the condition of water infrastructure. Increased distance and poor infrastructure indicate higher levels of water scarcity.

Socio-economic effects

- Measure: Average distance from households to boreholes.
- Measure: Health outcomes, such as incidence of waterborne diseases.
- Measure: Household surveys on changes in farming, market, and school attendance time.
- Measure: Women's and children's time spent collecting water.

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The socio-economic impacts of HPBTs include reducing the distance households need to travel to access water, improving health outcomes due to access to clean water, and freeing up time for productive activities like farming and attending school. Additionally, reducing the burden of water collection on women and children can lead to improved gender equality and well-being within communities.

Interventions (Confounding Variables)

Government intervention

- Role: Provision of funding, policies, and regulations related to water infrastructure.
- Role: Oversight and support for maintenance and sustainability efforts.

Government policies, funding, and regulations influence the availability and maintenance of water infrastructure. Effective government intervention can lead to improved access to clean water and reduced water scarcity.

NGOs

- Role: Implementation of water projects and community capacity-building initiatives.
- Role: Collaboration with local communities and government agencies to address water scarcity challenges.

NGOs play a significant role in implementing water projects and community capacity-building initiatives. Their activities complement government efforts and can have a direct impact on water scarcity by improving access to water sources and promoting sustainable water management practices within communities.

The conceptual framework illustrates how the functionality and reliability of hand pump borehole technology, quality and safety of water, socio-economic factors, and interventions by government and NGOs influence water scarcity in rural areas. For instance, improved functionality and reliability of HPBTs increase access to safe water, leading to better health outcomes and reduced burdens on women and children. Government intervention and NGO activities may act as confounding variables, influencing the relationship between independent and dependent variables by affecting the availability and maintenance of water infrastructure.

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2.8 Chapter Summary and Conclusion

The literature review examines hand pump borehole technology's role in addressing water scarcity and its socio-economic impacts in rural areas. Evidence shows that hand pump boreholes enhance water accessibility, improve health outcomes, and foster socio-economic development. However, gaps remain in understanding their influence on education, income, and agricultural productivity. The review emphasizes the need for further research to explore these areas and assess hand pump boreholes' contribution to achieving Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation), SDG 4 (Quality Education), SDG 1 (No Poverty), and SDG 2 (Zero Hunger). Addressing these gaps will help policymakers, NGOs, and communities develop effective strategies for sustainable water management and rural development. While hand pump borehole technology offers promising solutions to water scarcity, its full socio-economic potential remains to be realized. Continued research and targeted interventions are essential to maximize the benefits of hand pump boreholes, ensure equitable access to clean water, and advance progress toward achieving the SDGs, thereby improving the well-being of rural populations. This study aims to bridge the gap between existing information and real-world applications, assisting policymakers in understanding the socio-economic impacts of hand pump boreholes.

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3. CHAPTER THREE: METHODOLOGY

3.1 Geographical Coverage

The study was carried out in Mpunge sub-county located in Ntenjeru in Mukono District. The Uganda Bureau of Statistics (UBoS) estimates Mpunge sub-county to have a total population of 17,316 people, with a population density of over 406 people/km2. Based on the census results, it is one of the fastest-growing counties in terms of population (Uganda Bureau of Statistics (UBoS), 2024). Mpunge sub-county has 22 Villages, of these, 14 villages have received hand pump boreholes as clean water which still are not sufficient to meet the needs of the population in terms of socioeconomic activities. Mukono is one of the districts in the Central Region of Uganda. Mukono District is bordered by Kayunga District to the north, Jinja District to the east, Kalangala District to the south-west, Kira Town and Wakiso District to the west, and Luweero District to the north-west. The town of Mukono is about 21 kilometres (13 mi) by road, east of Kampala, the capital and largest city of Uganda. This is about 55 kilometres (34 miles) west of the town of Njeru, where the Nalubaale Power Station is situated, on the Kampala–Jinja Highway. Figure 3.1 below illustrates the location and study area of Mpunge sub-county.

National population and housing census 2024

Figure 2: Site Map showing the location and study area of Mpunge sub-county

The selection of Mpunge sub-county as the study area was based on several criteria, including its high population density, significant water scarcity challenges, and existing infrastructure. With a population density of over 406 people per square kilometer, Mpunge is one of the fastest-growing counties in Uganda (UBoS, 2024; Okurut et al., 2023), making it a representative setting for studying water scarcity issues in rapidly expanding rural areas. Moreover, Mpunge sub-county has

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been identified as experiencing persistent water scarcity despite the presence of hand pump boreholes, indicating the need for further investigation into the effectiveness of this technology (Okurut et al., 2023).

Additionally, the geographical location of Mpunge within Mukono District provides insights into rural water management practices within the broader context of central Uganda (Okurut et al., 2023). As a district bordered by various other regions, including Kayunga, Jinja, and Wakiso, Mukono represents a microcosm of the socio-economic and geographical diversity found in the central region (Okurut et al., 2023). Understanding the dynamics of water resource management in this area contributes to addressing broader challenges related to rural development and water security in Uganda.

3.1.1 Geographical Mapping of Boreholes

This section presents a detailed map of the hand pump boreholes (HPBs) in Mpunge sub-county. The map illustrates the locations of the boreholes in relation to key points such as villages, schools, and settlements. This spatial representation helps in understanding the accessibility and distribution of water resources within the community.

The specific location of each HPB is determined through a geo-hydro physical survey. For optimal accessibility, the water source is positioned within a maximum of 800 meters from the nearest target school and not more than 1.5 kilometers from the village's dense settlement.

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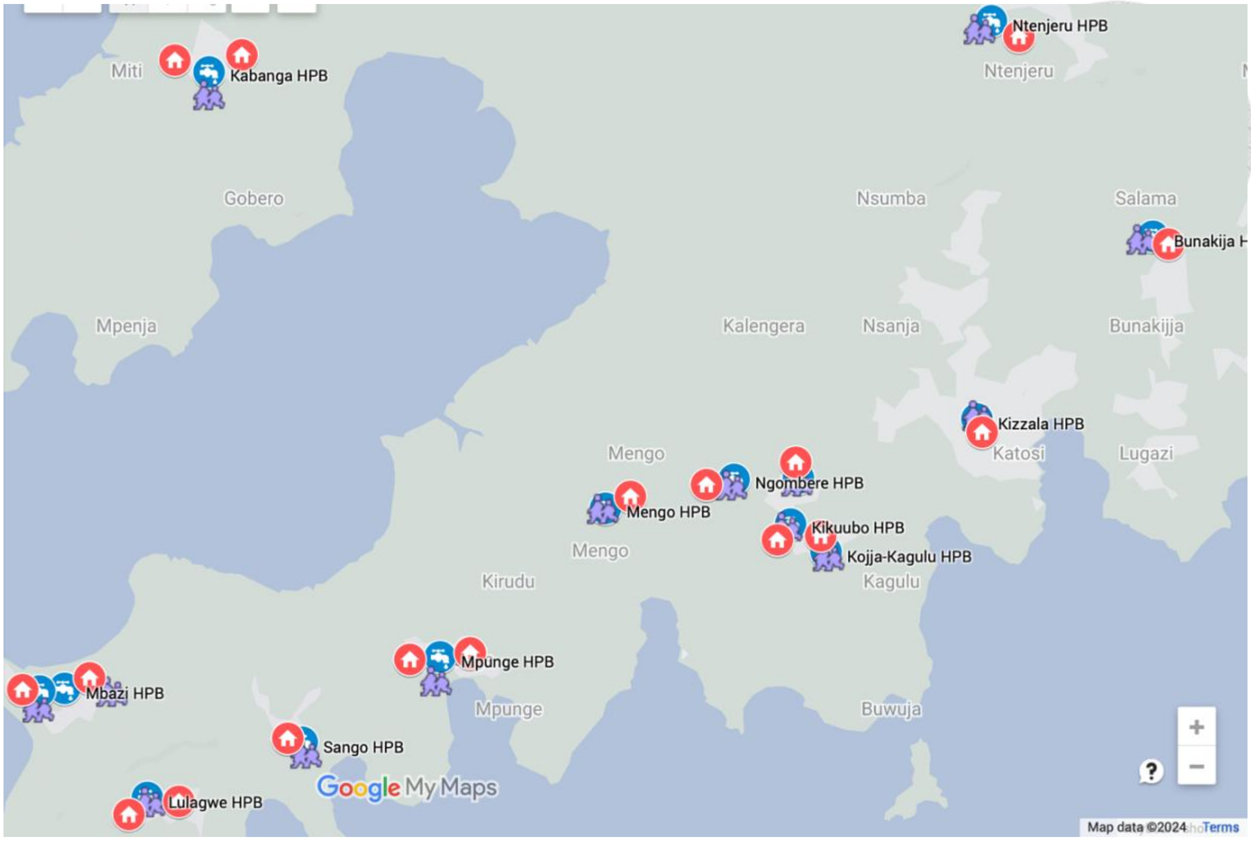

Figure 3: Geographical Mapping of Boreholes (google, 2024)

Key for map

	Hand Pump Borehole (HPB)
	Schools
	Village Settlements

3.2 Visual Documentation of Borehole Construction

To provide a comprehensive view of the hand pump borehole projects, this section includes images from various stages of the borehole construction process, as followed from the Love Binti International Standard Operating Procedure (SOP) for borehole drilling. The visual documentation covers initial site surveys, engineering and construction phases, and the final completed boreholes. Additionally, photographs of the nearby landscapes are included to contextualize the environment around the boreholes.

The borehole drilling process begins with administrative stages before the actual technical procedures. This is in line with the NGO Act (2016) and the Local Districts Governance Procedure for NGO operations. These administrative stages include needs identification through community

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fieldwork surveys and establishing community user committees responsible for supervising proper borehole usage and maintenance. These stages are conducted by both MDGL officials from water engineering, education, and community development offices, together with the NGO team, village local leaders, and the general community.

Below are some of the photos showing these stages of the borehole SOP:

Administrative Stages

1. **Needs Identification and Community Engagement**
    - Community meetings and surveys to identify the needs and establish user committees.

Figure 4: Community meeting for needs identification and engagement (Love Binti International, 2024).

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2. **Establishment of Community User Committees**

   - Formation and training of committees responsible for the supervision and maintenance of boreholes.

Figure 5:User committee being established and trained (Love Binti International, 2024).

3. **Looking at the existing water sources before installation of HPB**

Figure 6: Existing water sources before installation of HPB (Love Binti International, 2024).

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Technical Stages

3. **Site Survey and Selection**
   - Initial site surveys to determine the best locations for drilling boreholes.

Figure 7:Conducting site surveys for borehole placement (Love Binti International, 2024).

"Hydrological surveys, involving the mapping of drainage channels and watercourses, are essential for flood risk assessments, ecological planning, and the creation of wetland nature reserves. These surveys include flow data and water quality sampling, analysis, and interpretation. Specifically, geophysical surveys are used to map subsurface water flow, determining the optimal borehole location. This technical process is conducted by contracted experts using specialized machinery. After receiving the survey report, a meeting is held to discuss results and make drilling decisions," explained the Love Binti WaSH Project Manager.

4. **Drilling and Engineering**
   - The drilling process, including setting up equipment and engineering tasks.

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Figure 8: Drilling process and setting up equipment (Love Binti International, 2024)

5. **Construction and Installation**
    - Construction of the borehole structure and installation of the hand pump.

Figure 9:Construction and installation of the borehole (Love Binti International, 2024)

Final Stages

6. **Completed Boreholes and Surrounding Landscapes**

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- Finalized boreholes ready for use, with surrounding landscapes shown to contextualize the environment.

Figure 10:Finalized Hand Pump boreholes (Love binti International, 2024).

Figure 11: Borehole commissioning to user community (Love Binti International,2024).

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3.2 Research Design

3.2.1 Research Framework

The methodology description in this study was guided by the Saunders Research Onion model, which provides a structured framework for conducting research. The research onion consists of multiple layers, each representing different stages of the research process, including research philosophy, approach, strategy, data collection methods, and data analysis techniques. At the core of the onion is the research philosophy, which underpins the researcher's worldview and influences their approach to knowledge creation. Building upon this core, the subsequent layers of the onion encompass various methodological choices, such as the research philosophy (positivism, interpretivism, or pragmatism), research approach (inductive or deductive), methodological choices (qualitative, quantitative, or mixed methods), strategy (survey ethnography, experimental or case study) and specific data collection and analysis methods. Using the principles of the model, the study ensures a systematic and comprehensive approach to research methodology, enabling the investigation of the socio-economic impacts of hand pump boreholes in Mpunge sub-county

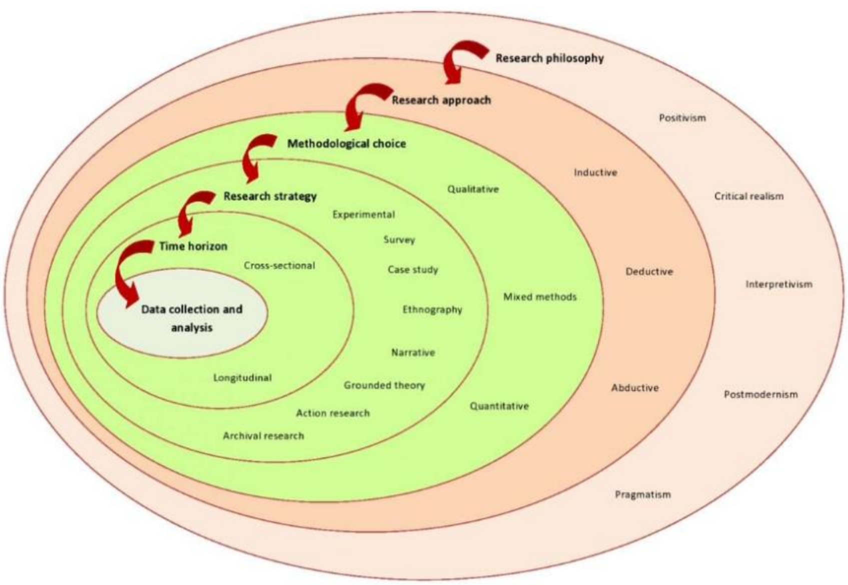

Figure 12: The Saunders research onion framework.

3.2.2 Research Philosophy

The research philosophy adopted for this study was positivism, chosen for its emphasis on objective, observable phenomena and the use of quantitative methods to generate empirical evidence. Positivism supports the systematic investigation of social phenomena through statistical analysis and hypothesis testing, aiming to produce reliable and generalizable findings. This

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philosophy aligns with the study's focus on quantitatively assessing the socio-economic impacts of hand pump borehole technology in Mpunge sub-county. Adhering to positivist principles, the research seeks to provide clear, data-driven insights into the effectiveness and challenges of hand pump boreholes in mitigating water scarcity and improving community well-being.

3.2.3 Research Approach

The research approach employed in this study was deductive. Deductive reasoning was used to develop hypotheses based on existing theories and literature related to hand pump borehole technology and its socio-economic impacts. These hypotheses were then empirically tested through the collection and analysis of quantitative data. This approach facilitated a systematic examination of the relationship between hand pump borehole technology and socio-economic development in Mpunge sub-county. Testing predefined hypotheses allowed the study to confirm or refute theoretical propositions, providing a structured and rigorous framework for investigating the research questions. The deductive approach ensured that the research remained focused on verifying established theories through empirical evidence, thereby contributing to a deeper understanding of the socio-economic effects of hand pump boreholes in rural communities.

3.2.4 Research Method

The research method employed in this study was a quantitative approach, focusing on the collection and analysis of numerical data. This method was chosen to provide a rigorous and objective assessment of the socio-economic effects of hand pump borehole technology in Mpunge sub-county. Quantitative components, such as surveys and statistical analysis, were utilized to gather data on variables like water quality, water accessibility, health outcomes, and economic indicators. These quantitative measures allowed for the assessment of relationships and patterns within the data, providing clear and generalizable findings. This method facilitated a systematic and detailed exploration of the research questions, enhancing the validity and reliability of the study findings.

3.2.5 Data Type (Primary vs. Secondary)

The data for this study primarily consists of primary sources gathered directly from the field through surveys conducted with community leaders and members in Mpunge sub-county. This approach allows for firsthand insights into local perspectives, experiences, and challenges related

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to hand pump borehole technology and water scarcity. Focusing on primary data ensures the collection of real-time and contextually relevant information that directly addresses the research objectives. This firsthand data is essential for conducting in-depth analyses and drawing meaningful conclusions about the socio-economic impacts of hand pump borehole technology in rural areas. Additionally, relying solely on primary data enhances the study's credibility and validity by minimizing potential biases or inaccuracies associated with secondary sources.

3.2.6 Research Instrumentation

The main instrument utilized in this study was the survey questionnaire. The survey questionnaire was designed to collect quantitative data on various aspects related to hand pump borehole technology and its socio-economic impacts in Mpunge sub-county. It included close-ended questions to gather demographic information, assess water accessibility, measure health outcomes, and evaluate economic indicators. The questionnaire was structured to ensure consistency and comparability of responses across participants.

3.3 Research Procedure

3.3.1 Study Location, Population, and Sample Size

The study targeted local community leaders and members in Mpunge sub-county, focusing on district and sub-county leadership to understand issues related to hand pump borehole technology and water scarcity. According to Kothari (2003), a sample is a proportion of the population whose results can be generalized to the entire population. The sample size of the study was 654 participants, drawn from a population of 17,316 individuals in the 22 villages of Mpunge sub-county (UBoS). This sample size was derived using Krejcie and Morgan's (1970) statistical formulas, which provide a widely used table for determining sample sizes in social science research. For a population of 17,316, their table recommends a sample size of approximately 377 to achieve a 95% confidence level with a 5% margin of error. However, this study utilized a sample size of 654, significantly higher than the recommended 377. A larger sample size enhances the statistical power of the study, reduces the margin of error, and increases the confidence level of the findings. It also improves the representativeness of the sample, ensuring it accurately reflects the diversity and characteristics of the total population. Thus, the sample size of 654 not only meets but exceeds standard recommendations, providing robust support for the reliability and validity of the research findings.

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Krejcie and Morgan's table illustrates that for a population of 17,316, a sample size of 377 is recommended. However, the actual sample size used in this study was 654, ensuring even greater accuracy and reliability in the research findings (Krejcie & Morgan, 1970).

Table 1: An excerpt from Krejcie and Morgan's table for determining sample size

Population Size	Sample Size
9500	375
10000	376
15000	375
20000	377
30000	379
40000	380
50000	381
75000	382

Note: The complete table can be found in Krejcie and Morgan (1970).

3.3.2 Sampling Technique

According to Sekaran (2003), sampling is the process of choosing the research units of the target population, which are to be included in the study. The study used a simple random sampling method which selects a sample without bias from the target/accessible population. The method was to select random samples from community members. This method is justifiable for the study because it ensures that all subjects of the subgroups are given an equal chance of being selected, minimizes bias, and simplifies the analysis of results. Further, a purposive sampling method was used. This method was used by the researcher to decide who to include in the sample based on their relevance. The purposive sampling technique is used to collect focused information from respondents which include district local leaders and those at the sub-county. The technique is used because the focus of the researcher is to get in-depth information and not simply generalize.

Obtaining the Population List:

To obtain the population list, the study first gathered comprehensive data from reliable sources such as government records, census data, and relevant databases from the Uganda Bureau of Statistics (UBoS) and Uganda Registration Service Bureau (URSB). This data was meticulously compiled into a single consolidated list that included all members of the target population in Mpunge sub-county. Ensuring the list's completeness and accuracy was essential to maintain the

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integrity of the sampling process. This involved cross-referencing multiple data sources to confirm the identity and eligibility of everyone.

Conducting Random Sampling Using Microsoft Excel:

To conduct random sampling, Microsoft Excel's random number generator was utilized to ensure an unbiased selection of participants. The process began by assigning a unique identifier to each member of the target population, totaling 17,316 individuals. In Excel, the RAND() function was used to generate random numbers for each identifier. These random numbers were then sorted in ascending order, and the first 654 entries were selected as the sample for the study. This method ensured that every individual in the population had an equal chance of being chosen, thereby maintaining the integrity and representativeness of the sample.

3.3.3 Data Collection Process

The data collection process was conducted both physically and virtually. Data was collected in two months from February 20th, 2024, through March 23rd, 2024, physical questionnaires were directly distributed to community members for random sampling and later we input the data on the google form. We printed the google form and distributed it physically since most people in the rural regions have limited access to electronic gadgets. Structured questionnaires were designed and distributed electronically to selected participants in the Mpunge sub-county. These questionnaires were tailored to gather quantitative data on various aspects related to hand pump borehole technology, water access, and socio-economic factors. Participants received the questionnaires via email or through online survey platforms, allowing them to respond at their convenience. All data collection activities were organized and systematic, with careful documentation of responses and observations. Following data collection, the researcher reviewed and organized the collected data, preparing it for analysis in line with the research objectives and questions. Data on the borehole drilling and community beneficiary and statistical information on Mpunge sub-county was obtained from MDLG water office data base for Non-Government Organization (NGO) drilled boreholes and the Love Binti International (LBI) the NGO which invested in and managed the drilling of boreholes in the 14 villages in our area of study and UBoS (2024) respectively.

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3.4 Data Quality Control

3.4.1 Validity

To control the quality of the data, the researcher attained a validity of coefficients of at least 0.70 or 70%. Kathuri & Pal (1993) assert that items with validity coefficients of at least 0.70 are accepted as valid and reliable in research. Upon performing the test if the results are 70% or 0.7 and above, the instrument will be considered reliable. To establish validity for quantitative data, the instruments were given to experts to evaluate the relevance of each item in the instrument to the objectives and rate each item on the scale of Strongly Disagree (5) Disagree (4), Not Sure (3), Agree (2), and Strongly Agree (1). According to Amin (2005), a content validity index of 0.7 qualifies the questionnaire as a valid instrument and can be adopted for use. (CVI = K/N Where, CVI Content Validity Index, K =Number of items considered relevant/suitable and N = Number of items considered in the instruments).

Three experts tested the face credibility and construct validity on the instruments. Basing on the two-point rating scale where 1 is relevant for items and 2 for irrelevant items, each reviewer provided their judgement on the items in the questionnaire during pretesting. Some of the items that were rated irrelevant were eliminated and replaced with relevant ones for example, some questions in the background section were removed and others rephrased for clarity. Content validity index (CVI) of the instrument was calculated by expressing the number of items declared relevant over the total number of the items issued out. The results of every reviewer are as follows in the proceeding table.

Table 2: Validity results for the inter-rater reviewers

Categories	**Reviewer 1**	**Reviewer 2**	**Reviewer 3**	**Mean**
Relevant	62	61	64	62
Irrelevant	10	11	8	10
Total	72	72	72	72
CVI	0.86	0.84	0.88	0.86

3.4.2 Reliability

For the quantitative data analysis, Cronbach's Alpha Coefficient tests were conducted to assess the internal consistency and reliability of the Likert-type scales. Cronbach's Alpha, a widely used

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statistic in psychometrics, measures the reliability of test scores for a sample of examinees (Sekaran, 2003). Typically, a reliability coefficient of 0.70 or higher is deemed acceptable for research instruments. In this study, the internal consistency of the instrument items was evaluated using Cronbach's Alpha, a method developed by Lee Cronbach in 1951. This coefficient indicates how well the items in an instrument are positively correlated with each other, ensuring quality control when the value is 0.70 or above. To verify the reliability, a pilot study was conducted using questionnaires in an area outside the Mpunge sub-county in Mukono district. Cronbach's Alpha Coefficient was calculated using the Statistical Package for Social Sciences (SPSS). According to Amin (2005), an alpha value closer to 1 signifies higher internal consistency.

The results, as shown in the table, indicate that the Cronbach Alpha coefficients for the constructs used to measure the variables ranged from 0.799 to 0.866. These values exceed the acceptable threshold of 0.70, confirming that the constructs are reliable and suitable for the study. A total of 42 samples were used to determine these reliability coefficients.

Table 3:Cronbach's Alpha Coefficients test results.

Construct	**Number of items**	**Cronbach's Alpha Coefficients**
Water Scarcity in Rural Areas	8	0.811
Functionality and reliability of HPBT	10	0.799
Quality and Safety of Water from Hand Pump Borehole Technology	10	0.866
Socio-Economic Effects of Access to Clean Water by Communities	12	0.808

3.5 Data Analysis

Quantitative data underwent descriptive and inferential analysis techniques, facilitated by Statistical Packages for Social Sciences (SPSS Version 21). Descriptive analysis provided an overview of the demographic characteristics and key variables related to hand pump borehole technology and water access, utilizing measures like frequencies, percentages, means, and standard deviations. These techniques revealed significant associations, trends, and patterns in the data, contributing to a deeper understanding of the research phenomenon. The results of the analysis were interpreted considering the research objectives, providing valuable insights into the effectiveness of hand pump borehole technology in addressing water scarcity in rural areas.

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Bivariate data analysis was conducted using the Pearson Correlation Coefficient to determine the linear relationship between the independent variables and the dependent variable. Additionally, multivariate data analysis involved simple regression analysis to predict the influence of each specific variable on the outcome. For the qualitative aspect of the study, responses from the Key Informant Interview (KIIs) were analyzed narratively. The narrative analysis facilitated a deeper understanding of the socio-economic effectiveness of hand pump borehole technology (HPBT) in mitigating water scarcity. The analysis also complemented and enhanced the understanding of the quantitative findings to make meaningful conclusions from the study.

3.6 Ethical Consideration

The study adhered to ethical guidelines to ensure the protection of participants' rights and confidentiality throughout the research process. Before data collection, ethical approval was obtained from the relevant institutional review board or ethics committee, ensuring compliance with ethical standards. Informed consent was obtained from all participants, detailing the purpose of the study, the voluntary nature of participation, and the confidentiality of their responses. Participants were assured of their anonymity and confidentiality, with data anonymized and stored securely to prevent unauthorized access.

Moreover, participants were informed of their right to withdraw from the study at any point without consequence. Respect for cultural norms and sensitivities was paramount, with efforts made to ensure that the research process was culturally appropriate and respectful of local customs and practices. Special care was taken to minimize any potential harm or discomfort to participants, particularly when discussing sensitive topics related to water scarcity and socio-economic challenges. To mitigate risks, participants were provided with support resources and referrals to relevant services if needed. Finally, the study ensured transparency in its methods, accurately reporting findings without bias or manipulation. Any conflicts of interest were disclosed, and the research process was conducted with integrity and professionalism, upholding the principles of academic rigor and ethical conduct.

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3.7 Chapter Summary and Conclusion

The methodology employed in this study was guided by the research onion model, facilitating a systematic and comprehensive approach to data collection and analysis. The pragmatic research philosophy was chosen for its flexibility and ability to address real-world problems effectively. Utilizing a mixed-methods approach allowed for a holistic understanding of the research topic by combining quantitative and qualitative data collection and analysis techniques. The research design involved a cross-sectional survey. Sampling techniques were carefully considered to ensure representative participant selection, with a sample size of 654 individuals determined using statistical methods.

Data analysis techniques included descriptive and inferential analyses for quantitative data using SPSS Version 21. Ethical considerations were paramount throughout the research process, with measures implemented to protect participants' rights, ensure confidentiality, and minimize harm or discomfort. Adhering to ethical guidelines and employing rigorous research methods, this study aimed to generate valuable insights into the socio-economic impacts of hand pump borehole technology on water-scarce rural communities. The methodology outlined in this chapter lays the foundation for producing credible and reliable research findings that contribute to addressing water scarcity challenges and advancing sustainable development goals.

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4. CHAPTER FOUR: RESULTS

4.1 Evidence of social-economic benefits from hand pump boreholes

This chapter presents the findings of the study on the socio-economic effectiveness of hand pump borehole technology (HPBT) in mitigating water scarcity in the Mpunge sub-county of Uganda. The data collection process was meticulously planned and executed to ensure high-quality, reliable results. The primary data was collected through structured survey questionnaires distributed to community leaders and members in the Mpunge sub-county. A quantitative research method was employed to provide a comprehensive understanding of the research topic. The survey achieved a high level of participation, with informed consent obtained from 100% of the respondents, ensuring ethical compliance and respect for participants' rights. Participants were fully briefed on the purpose of the study, the voluntary nature of their involvement, and the confidentiality of their responses. This transparency helped in building trust and encouraging honest and accurate responses.

A total of 700 questionnaires were distributed, out of which 654 were completed and found eligible for analysis. This results in a response rate of 93.4%, calculated as follows:

Response rate = $\left(\frac{654}{700}\right)$ x 100 = 93.4%

The response rate is calculated as the number if completed and eligible questionnaires against the total number of questionnaires distributed. This high response rate underscores the community's engagement and the relevance of the research topic to their daily lives. The data collected was subjected to rigorous analysis using Statistical Packages for Social Sciences (SPSS Version 21). Descriptive and inferential statistics were used to interpret the data, providing valuable insights into the effectiveness of hand pump borehole technology in addressing water scarcity and its socio-economic impacts in rural areas. The findings offer a detailed examination of the functionality, quality, safety, and socio-economic effects of HPBT in the Mpunge sub-county.

4.2 Demographic Characteristics of the Respondents

The demographic characteristics of the respondents provide valuable insights into the composition of the sample population and offer contextual understanding for interpreting the study findings. All respondents (100%) provided informed consent to participate in the study, indicating a high

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level of willingness and cooperation among the participants. This ensures ethical compliance and underscores the validity of the data collected. The survey examined the gender distribution across the study sample. The sample population consisted of 46.2% females, 52.1% males, and 1.7% other genders. The relatively balanced distribution between males and females suggests a representative sample that encompasses diverse perspectives and experiences related to hand pump borehole technology and water scarcity. The age assessment results reveal that the majority of respondents fell within the age range of 18-24 years (38.1%), followed by 25-34 years (22.6%), 35-44 years (15.7%), 45-54 years (12.1%), 55-64 years (7.6%), and those aged 65 years and over (3.8%). This concentration of younger individuals in the sample population reflects the demographic profile of Mpunge sub-county, where youth may be more actively engaged in community activities and development initiatives. Table 3 below illustrates the results for the demographic characteristics of the sample.

Table 4:Demographic characteristic of Respondents

Variable (n=654)	**Variable Category**	**Frequency**	**Proportion (%)**
Informed consent	Yes	654	100.0
	No	0	0.0
Gender	Female	302	46.2
	Male	341	52.1
	Other	11	1.7
Age	18-24 Years	249	38.1
	25-34 Years	148	22.6
	35-44 Years	103	15.7
	45-54 Years	79	12.1
	55-64 Years	50	7.6
	65 Years and over	25	3.8
Educational level	Bachelors	31	4.7
	Certificate/Diploma	116	17.7
	Secondary	294	45.0
	Primary	194	29.7

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	Other	19	2.9
Area of residence	Rural	478	73.1
	Urban	41	6.3
	Peri-Urban	135	20.6
Religion	Christian	528	80.7
	Muslim	102	15.6
	Other	24	3.7
Average monthly income	10,000 - 120,000 Ugx (2.57 - 30.94 USD)	259	39.6
	120,000 - 230,000 Ugx (30.94 - 59.30 USD)	297	45.4
	230,000 - 340,000 Ugx (59.30 - 87.67 USD)	47	7.2
	340,000 - 450,000 Ugx (87.67 - 116 USD)	30	4.6
	More than 450,000 Ugx (116 USD)	21	3.2
Duration of residence in the area	Less than one year	83	12.7
	1 - 3 years	98	15.0
	3 - 6 years	54	8.3
	6 - 9 years	127	19.4
	More than 9 Years	292	44.6
Occupation	Farmer	368	56.3
	Fisherman	43	6.6
	Market Vendor	61	9.3
	Teacher	105	16.1
	Other	77	11.8

Respondents had varying educational backgrounds, with the highest proportion holding secondary education (45.0%), followed by primary education (29.7%), certificate/diploma qualifications (17.7%), bachelor's degrees (4.7%), and other forms of education (2.9%). This diversity in

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educational attainment levels ensures a broad spectrum of perspectives and insights into the socio-economic impacts of hand pump borehole technology. The survey also sought to determine the participants' areas of residence within Mpunge County. Most respondents resided in rural areas (73.1%), followed by peri-urban areas (20.6%) and urban areas (6.3%). This distribution reflects the rural-centric nature of the Mpunge sub-county, where access to infrastructure and services may differ between rural and urban settings, potentially influencing perceptions and experiences related to water scarcity and access to clean water. Christianity was the predominant religion among respondents (80.7%), followed by Islam (15.6%) and other faiths (3.7%). The religious diversity within the sample population reflects the broader religious landscape of the Mpunge sub-county, highlighting the need for inclusive approaches in addressing water scarcity challenges.

Further, the results show that most respondents reported average monthly incomes ranging from 10,000 to 120,000 Ugandan Shillings (2.57 - 30.94 USD) (39.6%) and 120,000 to 230,000 Ugandan Shillings (30.94 - 59.30 USD) (45.4%), with smaller proportions falling into higher income brackets. This distribution underscores the economic diversity within the community and its implications for access to resources, including clean water. Also, respondents varied in the duration of their residence in the area, with a significant proportion (44.6%) residing for more than nine years. This long-term residency indicates a deep-rooted connection to the community and potentially greater awareness of local water scarcity issues and the effectiveness of HPBT in addressing them. Based on the results, the most common occupation among respondents was farming (56.3%), reflecting the predominant agricultural livelihoods in rural areas. Other occupations included teaching (16.1%), market vending (9.3%), fishing (6.6%), and various other professions (11.8%). The occupational diversity within the sample population highlights the multifaceted nature of community engagement and the potential interplay between livelihood activities and water resource management. The demographic characteristics of the respondents provide a comprehensive overview of the sample population, capturing key socio-economic factors that may influence perceptions, behaviors, and outcomes related to hand pump borehole technology and water scarcity mitigation efforts in the Mpunge sub-county.

4.3. Community Water Access and Impact Assessment

Additionally, the survey examined water accessibility within the community and assessed the impacts of hand pump borehole technology (HPBT) on water availability, quality, and overall

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community well-being. This comprehensive assessment covered various aspects, including water sources, distance to water points, time spent collecting water, perceptions of water quality, and the broader socio-economic impacts of improved water access.

Firstly, the survey evaluated the presence of HPBs within residences. Among the 654 respondents, 326, or half of the respondents, reported the availability of hand pump boreholes in their communities, indicating widespread access to this water source technology. An equal proportion, 320 respondents, reported the absence of hand pump boreholes, highlighting disparities in water infrastructure across the surveyed areas. This disparity was intentionally investigated to compare the socio-economic differences between communities with boreholes and those without. A small percentage, only 8 respondents, expressed uncertainty about the availability of hand pump boreholes.

Respondents reported a diverse range of water sources. Wells was the most prevalent, with 350 respondents, or approximately 53.5% indicating their use. Rainwater harvesting followed, with 110 respondents, or 16.8% reporting its usage. Hand pump boreholes accounted for 101 respondents or 15.4%. Piped schemes and other sources accounted for smaller proportions, with 42 respondents (6.4%) and 51 respondents (7.8%), respectively, reflecting varied water access infrastructure within surveyed communities. Regarding hand pump borehole (HPB) usage, 349 respondents, or approximately 53.4%, reported using hand pump boreholes, indicating widespread reliance on this technology for water access. Regarding the duration of usage, respondents reported varied experiences. Approximately 21.6% of respondents (141 individuals) reported using hand pump boreholes for less than one year, while 31% (203 individuals) reported usage for 1-3 years. About 19% (124 individuals) reported usage for 4-6 years, and 28.4% (186 individuals) reported using hand pump boreholes for more than 6 years. One-third of respondents, 220 individuals or approximately 33.6%, reported changes in income since the installation of hand pump boreholes, suggesting potential economic impacts associated with improved water access. Table 4 below illustrates the above-discussed findings.

Table 5: Community Water Access and Impact

Variable (n=654)	**Variable Category**	**Frequency**	**Proportion (%)**
Hand Pump Borehole availability	Yes	326	49.8

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	No	320	48.9
	Maybe	8	1.2
Community-led maintenance system	Yes	298	45.6
	No	327	50.0
	Maybe	29	4.4
Water sources	Hand pump boreholes	101	15.4
	Wells	350	53.5
	Piped Schemes	42	6.4
	Rainwater Harvesting	110	16.8
	Other	51	7.8
Have you used HPBs	Yes	349	53.4
	No	305	46.6
Duration of HPB use	Less than one year	141	21.6
	1 - 3 years	203	31.0
	4 - 6 years	124	19.0
	More than 6 years	186	28.4
Income changes since the installation of HPBs	Yes	220	33.6
	No	355	54.7
	Maybe	76	11.6

4.3.1 Analysis of Community-Led Maintenance Systems for Water Sources.

The figure below illustrates the respondents' views on the presence of a community-led maintenance system for available water sources. Opinions varied, with a slight majority of respondents, 298 individuals (45.6%), indicating the existence of such a system for hand pump boreholes. Notably, 282 (94%) of these respondents were from communities with boreholes, highlighting community involvement in maintaining and ensuring the functionality and sustainability of these water sources. However, a significant portion, 327 respondents (50%), reported the absence of a community-led maintenance system. Among these, 299 individuals (91%) were from communities without boreholes, suggesting a potential reliance on external support for maintenance in these areas. Additionally, only 29 individuals, approximately 4.4%, were uncertain about the existence of a community-led maintenance system.

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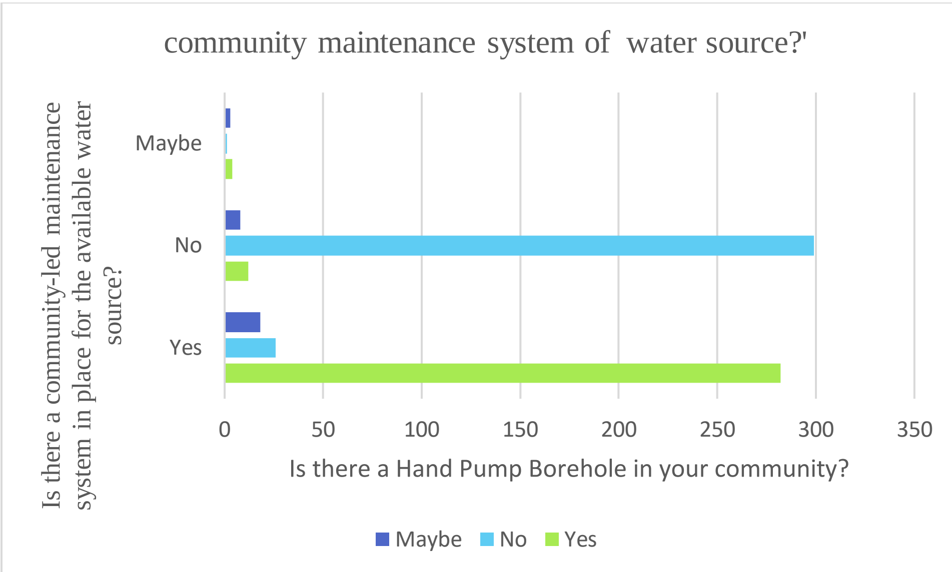

Figure 13: community-led HPB Maintenance System.

4.3.2 Waterborne Disease Prevalence and Hand Pump Borehole Availability

The figure below illustrates respondents' perceptions on waterborne disease prevalence in relation to the presence of hand pump boreholes in their communities. Opinions varied regarding the impact of hand pump boreholes on waterborne diseases. Among the respondents, 268 individuals, or approximately 41%, reported a decrease in waterborne diseases since the installation of hand pump boreholes. Notably, 220 (82%) of these respondents were from communities with hand pump boreholes, indicating that the installation of these boreholes has had a positive impact on reducing the incidence of waterborne diseases in these areas.

Conversely, a similar percentage, 275 respondents or 42%, reported no change in waterborne disease prevalence. Importantly, 222 (81%) of these respondents were from communities without hand pump boreholes, highlighting the ongoing challenges these communities face in managing waterborne diseases without the aid of this technology. It is also important to note that a significant number of respondents (45) from communities with hand pump boreholes reported no decrease in waterborne diseases. This suggests that while hand pump boreholes are beneficial, they may not be sufficient on their own to address all factors contributing to waterborne diseases. Additionally, a considerable fraction of respondents, 107 individuals or 17%, remained uncertain about the impact of hand pump boreholes on waterborne diseases. This uncertainty indicates the need for further investigation and community education regarding the effectiveness of water interventions.

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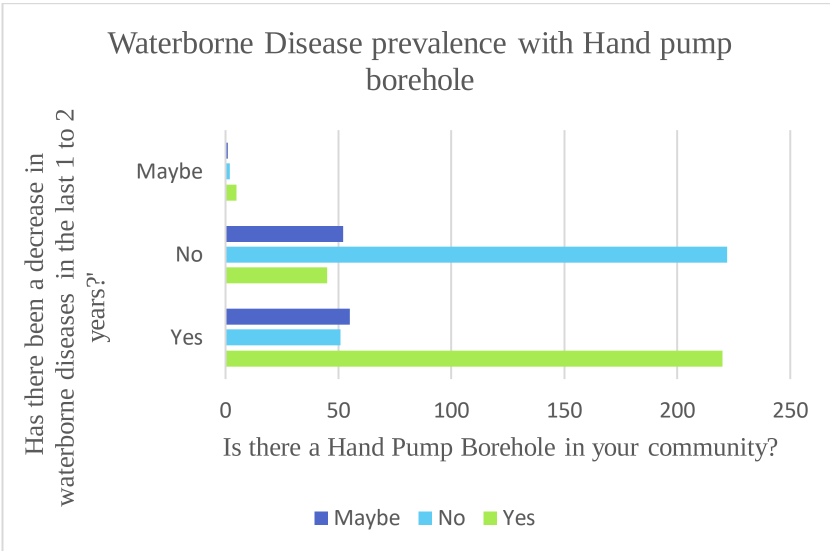

Figure 14: Waterborne diseases prevalence.

4.3.3 Status of Nearest Hand Pump Boreholes

The figure below illustrates the status of the nearest hand pump boreholes as reported by respondents from communities with boreholes. The survey asked respondents to classify their nearest hand pump borehole as either functional, broken, non-functional, or abandoned.

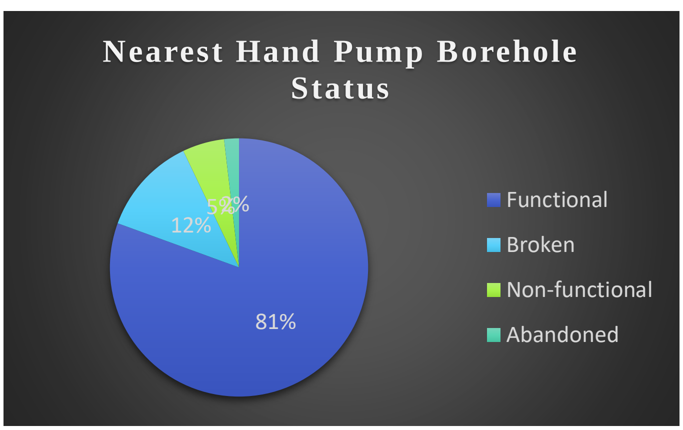

Figure 15: Nearest Borehole/Water Source Status

Functional: The majority of respondents, 81%, reported that their nearest hand pump borehole is functional. This indicates that most communities with boreholes have reliable access to operational water sources. **Broken**: 12% of respondents indicated that their nearest hand pump borehole is broken. This status suggests that these boreholes are currently inoperable due to mechanical issues or damage but may be repairable. **Non-functional**: 5% of respondents reported their nearest

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borehole as non-functional, indicating that these boreholes are not providing water and may require significant repair or replacement to restore functionality. **Abandoned**: A small portion, 2%, of respondents indicated that their nearest hand pump borehole is abandoned. This status implies that these boreholes are no longer maintained or used, potentially due to severe damage or depletion of the water source. This assessment highlights that while the majority of hand pump boreholes are functional, a notable proportion requires maintenance or repair to ensure continued access to clean water.

4.3.4 Borehole Users Per Day

Figure 2 below shows the result for the number of borehole users per day in the county. The data on borehole users per day, collected from respondents within communities with hand pump boreholes, provides a clear picture of the usage intensity and demand placed on these water sources. The distribution of users across different boreholes highlights several key points about community water access and the pressures on the existing infrastructure.

A significant proportion of respondents, 122 individuals (37%), reported that their boreholes serve more than 200 people daily. This high usage level indicates that these boreholes are crucial water sources for large segments of the community. High user numbers can lead to rapid wear and tear, necessitating frequent maintenance and potential upgrades to sustain service quality and reliability. It also suggests a high dependency on these boreholes, emphasizing their importance in daily life and the potential impact of any service disruption. The second-largest group, with 97 respondents (30%), indicated borehole usage by 50-100 people per day. This moderate level of usage suggests that these boreholes are less pressured but still vital for the local population. Proper maintenance and management are necessary to ensure these boreholes remain functional and can continue to serve their users effectively.

Boreholes serving 100-150 and 151-200 people per day, reported by 57 and 50 respondents respectively, are also under significant use. These usage levels point to considerable demand, indicating the need for efficient management practices to ensure sustainable operation. The boreholes in these categories must be monitored regularly to prevent overuse and to maintain water quality and availability.

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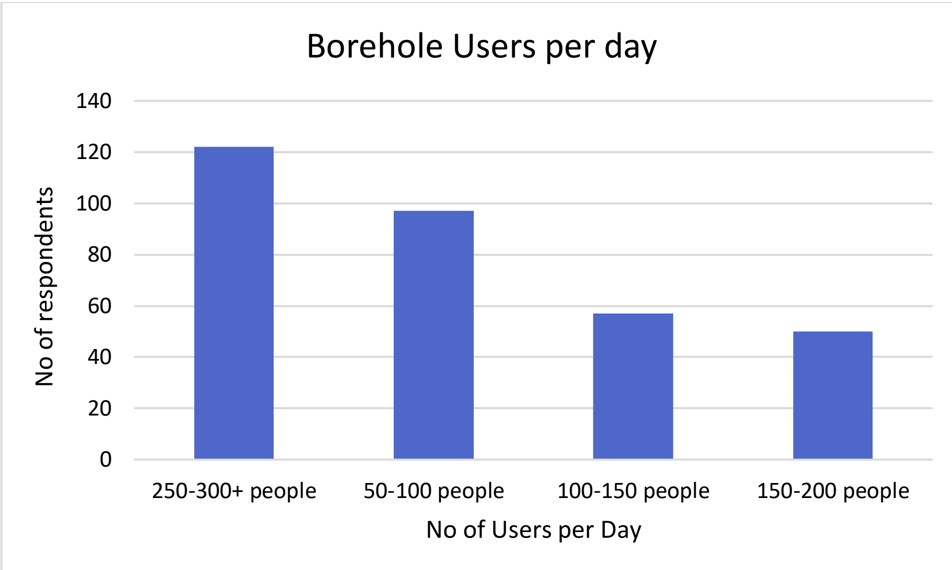

Figure 16: Borehole users per day

4.3.3 Daily Water Usage

The research also examined the daily rate of water usage among the respondents. The results provide insights into household water consumption patterns in Mpunge sub-county. Understanding these patterns is crucial for assessing the adequacy of water supply and planning for sustainable water resource management. Most respondents, 322, reported using between 41 and 80 liters of water daily. This indicates a moderate level of water usage, likely sufficient for basic household needs such as drinking, cooking, and minimal washing. This range of usage is reflective of the living standards and possibly the availability of water-saving practices or technologies in these households. The second-largest group, with 195 respondents, consumes between 81 and 160 liters per day. This higher consumption level may be indicative of larger household sizes, increased agricultural activities, or higher standards of living where water usage extends beyond basic needs to include activities like laundry and personal hygiene. This category suggests a greater reliance on water sources and the need for consistent and reliable access.

A smaller number of respondents, 65, reported daily water usage between 161 and 320 liters. This significant amount of water usage could point to even larger families, extensive agricultural activities, or small-scale commercial enterprises operating within these households. Such high levels of water consumption highlight the need for robust water supply systems to support these

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demands. Interestingly, 61 respondents reported using more than 321 liters of water daily. This substantial consumption level suggests households involved in extensive farming, livestock rearing, or other water-intensive activities. This group represents a critical segment of the population whose water needs are far above average, indicating the importance of ensuring high-capacity water sources and possibly tailored water management solutions to prevent over-extraction and resource depletion. On the lower end, only 11 respondents use less than 40 liters of water per day. This minimal usage could be due to limited access to water, smaller household sizes, or stringent water conservation practices. This group may represent the most vulnerable households with restricted water access, underscoring the need for targeted interventions to improve their water supply and quality. Figure 3 below illustrates the findings for this category.

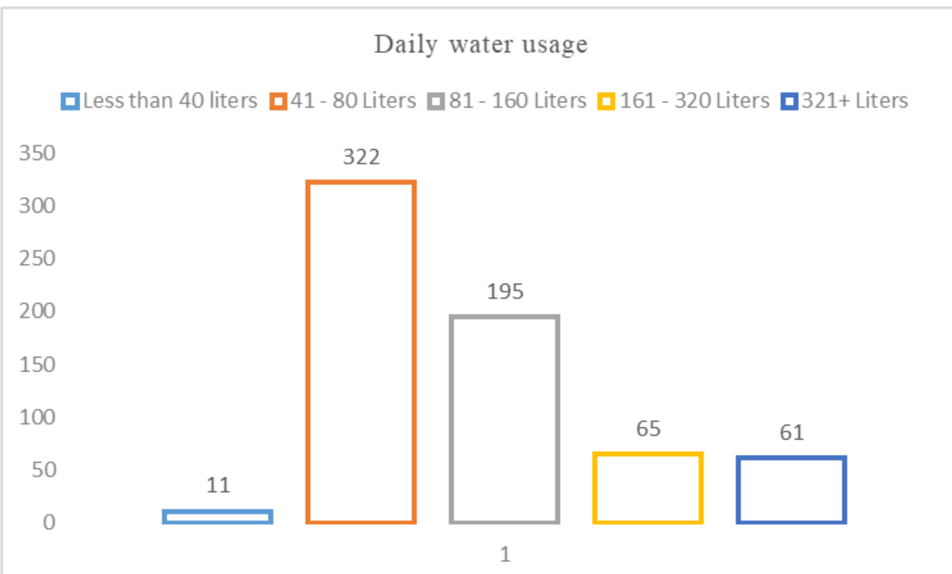

Figure 17: Daily water usage

4.3.4 Duration to Nearest Water Source

The figure below illustrates the relationship between the presence of hand pump boreholes in communities and the duration it takes to reach the nearest water source. A significant majority of respondents from communities with hand pump boreholes (157) reported that it takes less than 30 minutes to reach the nearest water source, highlighting the positive impact of having a borehole in the community. Short travel times reduce the physical burden and time spent fetching water, allowing more time for other productive activities. In contrast, communities without boreholes had noticeably fewer respondents (50) reporting such short travel times.

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Both groups showed a substantial number of respondents needing 30 to 60 minutes to reach water sources, with around 95 respondents from communities with boreholes and about 89 from those without. Notably, a higher number of respondents from communities without boreholes indicated needing 60 to 90 minutes (95 respondents), 90 to 120 minutes (29 respondents), and more than 120 minutes (51 respondents) to fetch water. This illustrates the considerable travel times faced by these communities, increasing the physical burden and limiting the amount of water that can be transported, potentially leading to insufficient water supply for household needs. Excessive travel time can also adversely affect health, education, and economic activities, as a substantial portion of the day is spent fetching water.

It is important to note, however, that a significant number of respondents from communities with boreholes also report needing 60 to 90 minutes (24 respondents), 90 to 120 minutes (19 respondents), and more than 120 minutes (11 respondents) to fetch water. This suggests the need for further investigation to understand why people in these communities still require more than one hour to access water.

Overall, this data clearly indicates that communities with hand pump boreholes enjoy significantly better access to water, as evidenced by the shorter durations reported. The presence of these boreholes appears to dramatically reduce the time spent fetching water, underscoring the socio-economic benefits of such infrastructure. The differences in travel times between communities with and without boreholes highlight the crucial role of these boreholes in improving water accessibility and enhancing the overall quality of life.

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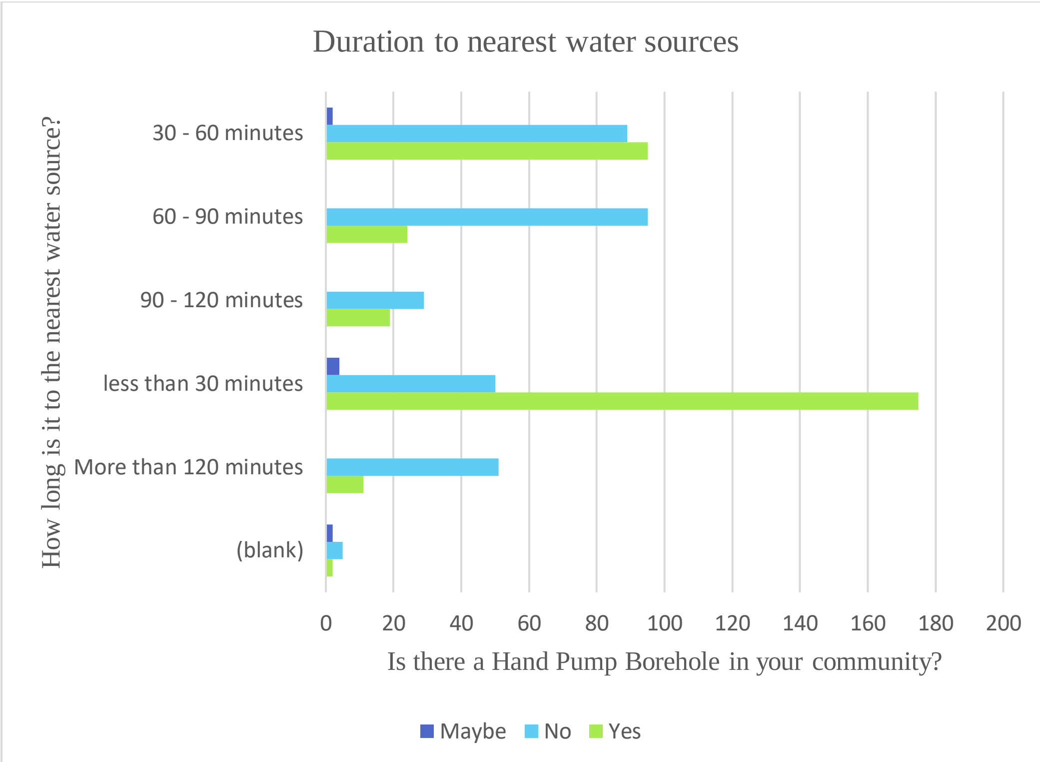

Figure 18:Duration to the nearest water source.

4.3.5 Water Fetching Trips Per Day

The figure below illustrates the number of waters fetching trips per day in communities with and without hand pump boreholes. A significant number of respondents from communities with hand pump boreholes (248) reported making 1 to 5 trips per day to fetch water. Similarly, 209 respondents from communities without boreholes also reported making 1 to 5 trips per day, indicating a comparable ease of access for this range. This suggests that these households either meet their daily water needs with a few trips or have sufficiently close water sources, making the water collection routine relatively manageable. This range implies that these households spend limited time and effort on water-fetching activities.

However, the 6 to 10 trips per day category shows a higher number of respondents (74) in communities without boreholes, compared to 48 respondents from communities with boreholes. This increased frequency of trips could be due to higher water needs, smaller container sizes, or greater distances to water sources, necessitating multiple trips. While this frequency is still within a moderate range, it suggests a higher burden on these households, potentially impacting other daily activities. In the higher trip categories, the differences become more pronounced. About 24 respondents from communities without boreholes reported making 11 to 15 trips per day, whereas

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significantly fewer respondents from communities with boreholes (9) fell into this category. Very few respondents from both types of communities reported making 16 or more trips per day (9 and 14 respondents), with slightly more in communities with boreholes. Additionally, 14 respondents chose not to disclose how many trips they make per day, with the majority (7) from communities with hand pump boreholes.

The presence of hand pump boreholes appears to reduce the number of trips required for water fetching, particularly for those making more frequent trips. This highlights the infrastructure's role in easing the daily burden of water collection, emphasizing the importance of boreholes in improving access to water and reducing the physical effort required by community members.

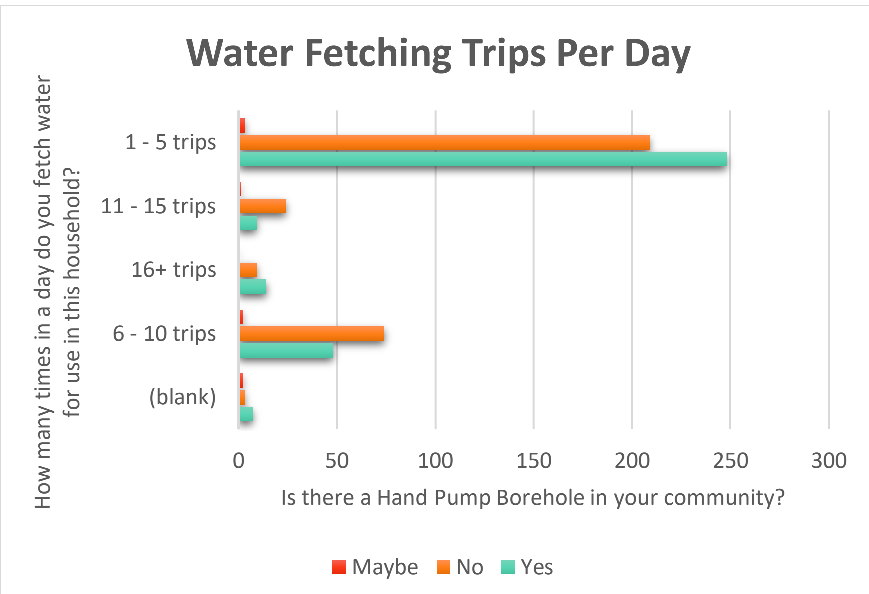

Figure 19: Water fetching trips per day

4.3.6 HPBT Experience Ratings

The figure below illustrates the experience ratings provided by respondents who answered "Yes" to having personally used a hand pump borehole for water access. This data offers valuable insights into the overall satisfaction and effectiveness of HPBT in meeting the community's water needs, focusing on ease of use, maintenance issues, and water yield.

Out of 326 respondents, a significant portion (127) rated their experience with HPBT as 5, indicating a high level of satisfaction. This suggests that many community members find HPBT effective in providing reliable access to water with minimal hassle. Additionally, 59 respondents

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rated their experience as 4, reflecting a generally positive perception of HPBT, though with some minor issues. These respondents likely perceive HPBT as reliable and convenient for meeting their water needs, with occasional minor issues that do not significantly detract from its overall effectiveness. In contrast, fewer respondents rated their experience as 1 (34 respondents), 2 (30 respondents), or 3 (59 respondents). These ratings suggest varying degrees of dissatisfaction or challenges with HPBT. Respondents who rated their experience as 1 or 2 likely encounter significant issues with the technology, such as frequent breakdowns, low water yield, or difficulty in operation, leading to frustration and inconvenience. Those who rated their experience as 3 may perceive HPBT as adequate but not exceptional, with occasional maintenance issues or limitations in water availability.

Overall, while a majority of respondents express satisfaction with HPBT, a notable portion indicates room for improvement or addresses specific challenges that need attention. Understanding the factors driving these ratings, such as operational reliability, maintenance responsiveness, and water availability, is essential for optimizing HPBT's effectiveness in providing sustainable water access to rural communities. Addressing any identified issues can contribute to enhancing community satisfaction, ensuring the long-term sustainability of HPBT, and improving water security in the area. Figure 6 below illustrates the respondents' HPBT experience ratings.

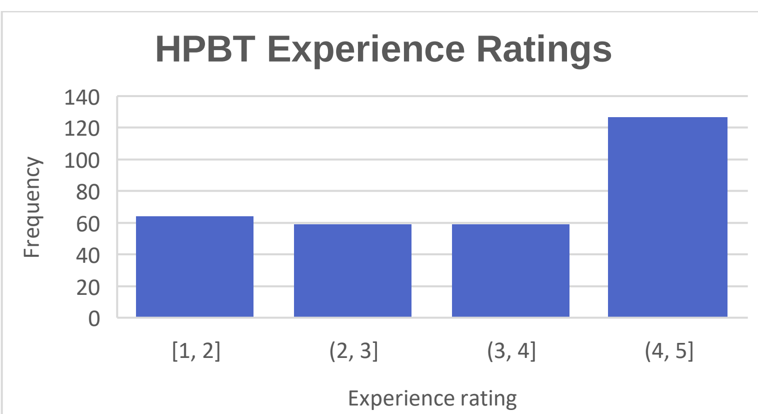

Figure 20:Experience ratings

4.4 Analysis of Borehole Data in Various Mpunge County Villages

Table 3 below provides detailed information on borehole drilling projects in various villages, focusing on metrics such as the number of households, standard beneficiaries, village population,

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drilling duration, borehole depth, yield, and cost. The number of households varies significantly, from a minimum of 110 in Lulagwe to a maximum of 350 in Mbazi Village. Correspondingly, village populations range from 480 in Mpunge Village to 1832 in Bunakija, reflecting the varied sizes and needs of these communities. The drilling duration ranges from as short as 8 hours in Buleebi Village and Mengo Village to as long as 4 days in Mpunge Village. This variation might be influenced by the geological conditions and the depth required to reach the water table. Borehole depths range from 41 meters in Buleebi Village to 130 meters in Lulagwe. Deeper boreholes, such as in Lulagwe, may indicate more challenging geological conditions or the necessity to reach deeper aquifers. The yield of the boreholes shows significant variation, from a low of 500 liters per hour in multiple villages to a high of 3060 liters per hour in Buleebi Village. High-yielding boreholes are crucial for meeting the water needs of larger populations and for agricultural productivity. The cost of drilling and equipping each borehole is uniformly 12,000 USD across all villages. This consistency suggests standardized pricing, possibly reflecting a uniform approach in the drilling process and equipment used.

Table 6:Borehole Data in Various Mpunge County Villages

Village/Community	**No. of Household**	**Avg Number of Children per household**	**Village Population**	**Drilling Duration**	**Borehole Depth (Meters)**	**Yield (liters/hr)**	**Cost (USD)**
Ngombere Village	180	2	720	3 days	55.1	500	12,000
Mpunge Village	120	3	480	4 days	55	2780	12,000
Mbazi Village	350	4	1400	2 days	49	1090	12,000
Buleebi Village	200	2	800	8 hours	41	3060	12,000
Kikubo Village	200	3	800	1 day	55	500	12,000
Kojja-Kagulu Village	220	3	880	2 days	59	500	12,000
KalengelaB Village	250	3	1000	3 days	64	500	12,000
Mengo Village	320	3	1280	8 hours	45.7	2350	12,000
Sango Village	250	3	1000	2 days	45.9	2180	12,000
Kizala Buganda	280	5	1750	1 Day	61	800	12,000

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Ntenjeru	210	6	1600	1 Day	51	3000	12,000
Bunakija	160	8	1832	3 Days	51	2000	12,000
Kabanga	190	6	1300	2 days	66	1000	12,000
Lulagwe	110	5	900	1 day	130	2000	12,000

Source: Data from MDGL Water office archive for NGO drilled HPB & UBos (2024) & LBI WaSH data 2023

4.4.1 Borehole Depth vs. Yield

The illustration in the figure below depicts the relationship between borehole depth and water yield. It shows a wide range of depths from 41 to 130 meters and yields from 500 to 3060 liters per hour. Interestingly, the highest yield of 3060 liters per hour is from a relatively shallow borehole of 41 meters, whereas the deepest borehole at 130 meters yields 2000 liters per hour, indicating that deeper boreholes do not always guarantee higher yields. Some depths, such as 51 meters, consistently show high yields of up to 3000 liters per hour, while others, like 55 meters, exhibit significant variability in yield. This variability suggests that factors beyond depth, such as geological formations and water table levels, critically impact the yield. The figure underscores the importance of site-specific assessments in drilling projects, as water availability can significantly vary even at similar depths.

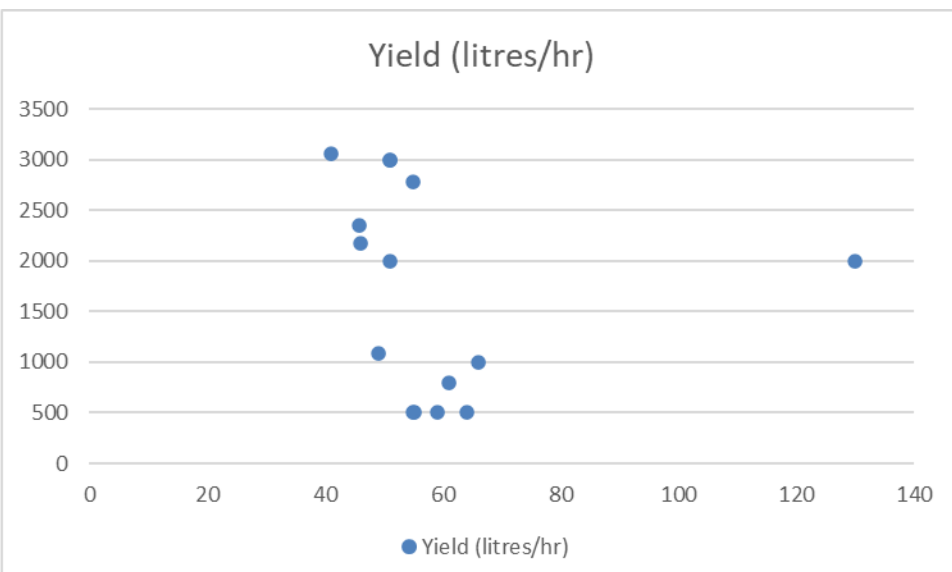

Figure 21: Borehole depth vs. yield

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4.5 Social Return on Investment (SROI) for Mpunge County

The Social Return on Investment (SROI) considers two fundamental components; the social impact value (SIV) and total investment. The Social Return on Investment (SROI) analysis for Mpunge County involves evaluating the social impact value (SIV) relative to the total investment made in drilling boreholes. This calculation incorporates both economic and social benefits derived from providing clean water access through boreholes.

Where, Total Social Impact Value (SIV) for the County:

Total SIV = ∑ Number of Households × Benefit per Household)

Total Investment for the County:

Total Investment = Cost per Borehole ×Number of Villages

Firstly, calculate the total SIV:

Total SIV= ∑ (Number of Households × Benefit per Household)

Quantifying Benefit per Household

To quantify the benefits per household, we considered measurable social and economic impacts within a short-term framework, given the study's non-longitudinal nature. The benefits include:

1. **Health Benefits:** Reduction in waterborne diseases translates to savings on medical bills. In the survey we found out that the Average monthly medical expense for waterborne diseases per household is Uganda Shillings 50,000 (USD 13.51). Respondents from health centers and general communities reported to attend to this healthy situation on average four months in the whole year. Therefore, the Annual medical expense without safe water in this community is monthly medical expenses on related diseases times average number of months it strikes in a year 13.51×4(months) = 54.04 USD. This implies if clean water is provided and the community doesn’t have to spend this money on medical bills, the Annual savings per household due to clean water provided by HPBs will be 54.04 USD per year.
2. **Agricultural Productivity:** Time saved from fetching water is redirected to farming activities. Time saved per day with boreholes 4 hours per day. From the survey we conducted about the wages for hiring people to farm in the garden, we found out that a person is paid Uganda Shillings 2,000 (USD 0.54) per hour. Therefore, the value of farming time per hour: USD 0.54. Farming days per year: 50 days, 5 hours per day, this information is survey based tailored to responses from Mpunge subcounty and MDLG.

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Total farming hours per year: 50×5=250 hours. Implying with HPBs provided near homesteads and people save time on water fetching and this time is redirected into farming, it will increase the community members yearly income by USD 135 from agriculture making HPBs contribute to the annual agricultural productivity increase per household by (250×0.54) = 135 USD.

3. **Marketplace Income Generation**: Time saved from fetching water is redirected to market activities. According to marketplace survey we found out that the profit from small businesses per day: USD 0.49. Working days per year: 250 days. Annual market income increases per household: 0.49×250=122.50 USD.
4. **Education Benefits:**

Step 1: we calculate Additional Education Time per Year

Daily Saved Time**:** 4 hours per day due to boreholes existence

School Year Duration**:** 260 days.

Total Additional Hours per Year = 4 hours/day × 260 days/year = 1040 hours/year.

Step 2: we convert Additional Hours to School Year

According to the Uganda school academic calendar, the standard school day is 7.5hours: Additional School Years due to boreholes construction and time saved = $\left(\frac{1040 \text{ hours/year}}{7.5 \text{ hours } x \text{ } 260 \text{ } days}\right) = \left(\frac{1040}{1950}\right)$ = 0.533 year

Step 3: we calculate Increase in Lifetime Earnings

Given that each additional year of schooling increases lifetime earnings by 11.9% "UNICEF-Uganda-Genesis-Analytics Cost-Benefit Analysis 2023,"(Ian MacAuslan et al., 2023):

Additional Earnings for 0.533 Years:

Earnings Increase for 0.533 Years = 11.9% × 0.533 = 6.3427%

Additional Income per Child (assuming a base lifetime earnings value):

Additional Income per Child = 6.3427% × Base Lifetime Earnings.

According to UNICEF-Uganda-Genesis-Analytics Cost-Benefit Analysis 2023, one additional year in school equates to roughly 1,465 USD in increased lifetime earnings (Ian MacAuslan et al., 2023). Thus, 0.533 years equates to:

Additional Income per Child = 0.533 × 1 ,465 USD = 780.845 USD

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Step 4: we calculate Annual Increase

Given an average working lifetime of 40 years, we distribute the additional income over this period:

Annual Additional Income per Child in UGX:

Annual Additional Income per Child = $\left(\frac{780.845}{40}\right)$ = 19.52

Step 5: Calculate Total Annual Increase for a Household

For a household with an average of 4 children from the MDLG borehole drilling table above the total average number of children per household is 56 out of 14 villages.

Average number of children in the county = $\left(\frac{\text{Total average number of children/household}}{\text{Total number of villages}}\right)$

= $\left(\frac{56}{14}\right)$ = 4

Total Annual Additional Income in USD**:**

Total Annual Additional Income from education = 19.52 USD/child/year × 4 children = 78.08 USD/year.

For a household with an average of 4 children, the total additional annual earnings due to the borehole saving 4 hours of class time per day over a school year of 260 days are approximately **78.08 USD/year**

Total Benefit per Household = 54.04(Health)+135(Agriculture)+122.50(Market Income) + 78.08(education) = 389.62 USD (rounded to 390 USD)

Table 7:Total Social Impact Value (SIV) calculation

Village	Number of Households	Benefit per Household (USD)	Total Benefit (USD)
1	180	390	70,200
2	120	390	46,800
3	350	390	136,500
4	200	390	78,000
5	200	390	78,000
6	220	390	85,800

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7	250	390	97,500
8	320	390	124,800
9	250	390	97,500
10	280	390	109,200
11	210	390	81,900
12	160	390	62,400
13	190	390	74,100
14	110	390	42,900
Total	**3040**		**1,185,600**

Total Investment=12,000 USD (cost per borehole) ×14 (number of villages)

Total Investment=12,000×14=$168,000.

The following formula is used for the calculation of the SROI

$$\text{SROI} = \left(\frac{\text{Total SIV}}{\text{Total Investment}}\right) - 1$$

$$\text{SROI} = \left(\frac{1185600}{168{,}000}\right) - 1$$

SROI = 7.06 – 1

SROI = 6.06.

Therefore, the SROI for Mpunge County is 6.06 USD per year, indicating a significant return on investment in terms of social and economic benefits derived from the borehole projects.

Significant maintenance expenses are anticipated after approximately ten years of hand pump use, as slow-moving parts and corroded components will need replacement. If these maintenance tasks are performed every ten years, the hand pump could potentially last up to 25 years ("Hardware Elements of Handpump Technology Field experiences and views on the future," 1996). The lifetime of a hand pump borehole which is well maintained is therefore 25 years. To calculate the Social Return on Investment (SROI) for the entire lifetime of a borehole assuming a 25-year range, we will used the values provided in the one-year SROI Calculation above in the following steps:

Step 1: we calculate the Total Social Impact Value (SIV) 25 Years

The SIV is calculated as: Total SIV=∑ (Number of Households x Benefit per Household).

SIV for 25 Years = 1,185,600 USD/year × 25years = 29,640,000 USD

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Step 2: we calculate the Total Investment

The total investment for drilling boreholes in 14 villages is $168,000.

Step 3: we calculate the SROI.

The formula for SROI is:

$$\text{SROI} = \left(\frac{\text{Total SIV}}{\text{Total Investment}}\right) - 1$$

$$\text{SROI} = \left(\frac{29{,}640{,}000}{168{,}000}\right) - 1$$

SROI = 176.43– 1

SROI = 175.43 USD

For every dollar invested in the boreholes, the social return is approximately $175.43 for a 25-year period. Therefore, the SROI for Mpunge County is $175.43, indicating a significant return on investment in terms of social and economic benefits derived from the borehole projects per 1$.

4.6 Descriptive and Regression Analysis

4.6.1 Functionality and Reliability of Hand Pump Borehole Technology (HPBT)

4.6.1.a Descriptive Analysis of hand pump borehole functionality

The table below illustrates the mean values recorded for the functionality and reliability of hand pump borehole technology. The HPBT reveals generally positive perceptions among the 326 respondents from communities utilizing HPBT, with the highest mean score of 4.0920 for "Is effective and reliable," reflecting strong confidence in the technology's effectiveness. Following closely, "It is easy to use" achieved a mean score of 3.9571, suggesting that respondents find HPBT user-friendly for accessing safe water. The mean score of 3.9202 for "It is adequate" implies that the respondents view HPBT as a satisfactory solution for their water needs. The perception that HPBT "Functions well even during peak usage times" garnered a mean score of 3.8804, indicating adequate performance during high demand periods. "It rarely experiences breakdowns or failures" had a mean score of 3.8313, suggesting reliability with few breakdowns, while "Demonstrated long-term reliability" scored 3.8129, showing a reliable level of confidence in the technology's sustained performance.

The mean scores indicate positive attitudes towards HPBT, but the high standard deviations (above 3.5) reveal significant variability in opinions. For instance, a mean score of 4.0920 for "Is effective and reliable" with a standard deviation of 3.7678 shows that while many respondents rated the

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technology highly, others rated it much lower, leading to a wide range of responses. This variability suggests differing personal experiences or contextual factors. Therefore, while the overall perception is positive, the diverse responses suggest that certain areas may require targeted improvements to ensure consistent performance and satisfaction across all user groups.

Table 8:Functionality and reliability of hand pump borehole technology (HPBT)

	N	Min	Max	Mean	Std. Deviation
Is effective and reliable	326	1.0	5.0	4.092	3.768
It is easy to use	326	1.0	5.0	3.957	3.647
It is adequate	326	1.0	5.0	3.920	3.640
Functions well even during peak usage times.	326	1.0	5.0	3.880	3.611
It rarely experiences breakdowns or failures.	326	1.0	5.0	3.831	3.604
Demonstrated long-term reliability	326	1.0	5.0	3.813	3.54
Valid N (listwise)	326				

4.6.1.b Inferential statistics (Chi-Square test) on Borehole Functionality and reliability

The Chi-square test conducted to assess the functionality and reliability of hand pump borehole technology (HPBT) in Mpunge sub-county yielded a p-value of 0.04789522. This p-value indicates that the observed data significantly differ from what was expected by chance. Since the p-value (0.04789522) is less than the alpha level of 0.05, we rejected the null hypothesis, which posited no significant difference in community perceptions of HPBT's functionality and reliability. This result supports the alternative hypothesis (H1) that HPBT is indeed functional and reliable in providing access to clean and safe water. The significant difference between observed and expected frequencies shows that the positive perceptions of the community are genuine and not due to random variation.

Table 9: Chi-Square test results

The Observed Values				
	Agree	**Disagree**	**Neutral**	**Totals**
Is effective and reliable	253	42	31	326
It is easy to use	250	54	22	326

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It is adequate	250	56	20	326
Functions well even during peak usage times.	237	61	28	326
It rarely experiences breakdowns or failures.	227	72	27	326
Demonstrated long-term reliability	227	62	37	326
Totals	1444	347	165	1956
The Expected Values	(Total row*Total Columns/Grand Toal)			
	Agree	**Disagree**	**Neutral**	**Total**
Is effective and reliable	240.7	57.8	27.5	326.0
It is easy to use	240.7	57.8	27.5	326.0
It is adequate	240.7	57.8	27.5	326.0
Functions well even during peak usage times.	240.7	57.8	27.5	326.0
It rarely experiences breakdowns or failures.	240.7	57.8	27.5	326.0
Demonstrated long-term reliability	240.7	57.8	27.5	326.0
Total	1444.0	347.0	165.0	1956.0
The Chi-Square Test (P-Value)	CHISQTEST, (actual range, expected range)			
P-Value	0.04789522			

4.6.2 Quality and Safety of Water Sources of Hand Pump Borehole Technology.

4.6.2.a Descriptive Analysis Quality and Safety of Water of HPB Water

The survey also assessed the quality and safety of water sources, the table below illustrates the findings for the assessment of the quality and safety of water sources. The mean values offer valuable insights into respondents' perceptions regarding the quality, safety, and sustainability of the water from the borehole source. "The water is safe for drinking" received the highest mean score of 3.5917, indicating a general belief among respondents that the water from the borehole source is safe for consumption. Similarly, " The water source contributes to the overall well-being of the community." and " Improved the safety of water access in our community" both received mean scores above 3.5, reflecting positive perceptions about the impact of the water source on community well-being and safety. Regarding water quality, "Water has no odor and no bad taste" and " Water is clear & no visible crystals " both scored above 3.4, suggesting that respondents generally perceive the water from the borehole source as free from obvious signs of contamination. " Water is regularly tested for contaminants." received a mean score of 3.5505, indicating a moderate level of confidence among respondents in the regular testing of water for contaminants.

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On sustainability and maintenance, " The water source is a sustainable solution for our water needs" and " Authority Promptly address the maintenance of the hand pump " both received mean scores above 3.5, suggesting confidence in the sustainability and maintenance practices associated with the borehole water source. Overall, respondents generally perceive the borehole water source positively in terms of safety, quality, community well-being, and sustainability, with some confidence in the regular testing and maintenance practices associated with the water source. However, there may still be room for improvement in certain areas, such as raising awareness about waterborne diseases and further enhancing maintenance practices to ensure continued community satisfaction and confidence in the water source.

Table 10:: Quality and Safety of Water Sources

	N	Minimum	Maximum	Mean	Std. Deviation
Water is clear & no crystals	654	1.00	5.00	3.4755	1.24558
Water has no odor and no bad taste.	654	1.00	5.00	3.4862	1.22966
The water is safe for drinking	654	1.00	5.00	3.5917	1.21501
I am aware of waterborne diseases	654	1.00	5.00	3.3761	1.38437
Water is regularly tested for contaminants.	654	1.00	5.00	3.5505	1.20986
Safety measures in place to protect the water from contamination.	654	1.00	5.00	3.4572	1.26218
The water source contributes to the overall well-being of the community.	654	1.00	5.00	3.6254	1.22582
Improved the safety of water access in our community.	654	1.00	5.00	3.5856	1.19513
The water source is a sustainable solution for our water needs.	654	1.00	5.00	3.5841	1.19908
Authority Promptly address the maintenance of the hand pump.	654	1.00	5.00	3.5841	1.19396
Valid N (listwise)	654				

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4.6.2.b Laboratory Water Quality Test of HPB

Figure below illustrates the lab results for water quality tests. Laboratory water quality test results provided valuable insights into the overall quality of water from various boreholes in the study area. The turbidity level of 7.6 NTU suggests moderate clarity, indicating the presence of suspended particles and sediment in the water, which could affect its quality. The apparent colour measurement of 79 PtCo indicates noticeable colouration in the water, possibly due to organic or inorganic contaminants. On a positive note, the pH level falls within the acceptable range of 5.5 to 9.5, suggesting neutral acidity, which is essential for the water's suitability for consumption and other uses. However, the electrical conductivity of 218 µS/cm suggests the presence of dissolved minerals or salts, which could impact the water's taste and safety. Additionally, the total dissolved solids (TDS) level of 153 mg/l indicates the presence of dissolved substances, which may affect the water's overall quality. Other parameters such as total hardness, calcium hardness, magnesium hardness, sodium, potassium, alkalinity, bicarbonates, fluoride, sulfates, chlorides, nitrates, nitrites, ammonium, phosphates, and total iron were also assessed, providing comprehensive insights into the water's chemical composition and potential contaminants. Overall, these findings highlight the need for continued monitoring and management of water quality to ensure safe and clean water access for the community

Figure 22:. Figure below illustrates the lab results for water quality tests.

TEST RESULTS Ref No: PM7.8 R-01 E00 NWQRL24-0601

Source Name			Buleebi 2 Primary School Borehole, DWD 75216	Potable water standards (EAS12:2018 Maximum permissible for Natural potable Water)
Village			Buleebi 2	
Parish			Mbazi	
Sub county			Mpunge	
District			Mukono	
Lab Identifier code			E24/02900	
Parameter	**Method Code**	**Units**	Results	
Turbidity	TM/C-03/01	NTU	7.6	25
Colour (Apparent)	TM/C-04/01	PtCo	79	50
pH	TM/C-01/01	pH units	7	5.5-9.5
Electrical Conductivity	TM/C-02/01	µS/cm	218	2500
Total disolved solids	TM/C-02/02	mg/l	153	1500
Total Hardness as CaCO3	TM/C-06/01	mg/l	80	600
Calcium hardness as CaCO3	TM/C-06/01	mg/l	50	600
Magnesium hardness as CaCO3	TM/C-06/01	mg/l	30	600
Calcium	TM/C-06/01	mg/l	20	150
Magnesium	TM/C-06/01	mg/l	7	100
Sodium	TM/IO-03/01	mg/l	11	200
Potassium	TM/IO-03/01	mg/l	4.6	50
Total Alkalinity	TM/C-05/01	mg/l	104	–
Bicarbonates	TM/C-05/01	mg/l	127	–
Fluoride	TM/IO-01/01	mg/l	0.57	1.5
Sulphates	TM/IO-01/01	mg/l	11.4	400
Chlorides	TM/IO-01/01	mg/l	3.1	250
Nitrates as N	TM/IO-01/01	mg/l	0.3	10
Nitrites as N	TM/IO-01/01	mg/l	<0.001	0.9
Ammonium as N	TM/IO-01/01	mg/l	0.049	0.5
Phosphates as P	TM/IO-01/01	mg/l	0.349	0.7
Total Iron	TM/C-08/01	mg/l	1.26	0.3
E.Coli	TM/IO-02/01	CFU/100ml	<1	<1

Note: 1. *This certificate shall not be reproduced except in full without approval of the NWQR laboratory*
2. ** Test method is accredited*
3. *Analysis site is the National Water Quality Reference Laboratory-Entebbe*
4. *The NWQR Laboratory LQMS conforms to ISO/IEC 17025: 2017 laboratory quality management system.*

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4.6.3 Socio-Economic Effects of Hand Pump Borehole Technology (HPBT)

4.6.3.a Descriptive Analysis on Socio-Economic Effects of hand pump borehole

The study investigated the socio-economic effects of HPBT through descriptive analysis. The mean values of various socio-economic indicators provide insights into the community's perception of HPBT's impact. "Creation of employment opportunities" received the highest mean score of 3.5933, indicating a strong positive effect on job creation within the community due to the availability of boreholes. This suggests that HPBT has significantly contributed to local economic development by generating employment opportunities.

Additionally, indicators related to healthcare expenses, such as "There has been a decrease in medical expenses related to waterborne diseases in the last 1 to 2 years" and "Your expenditure on health services has lowered?" both received mean scores above 3.5. This implies that the implementation of HPBT has led to reduced healthcare expenses, likely due to a decrease in waterborne diseases and associated medical costs.

Income levels and employment status also showed improvement, with the mean score for "Has your income level, and current employment status improved in the last 1 to 2 years?" at 3.5642. This indicates perceived improvement in income levels and employment status among respondents over the specified period, suggesting that HPBT may have contributed to socio-economic empowerment.

Other factors, such as improved access to clean and safe water, reduction in waterborne diseases, and increased time spent by children in classrooms with improved quality of education, also received mean scores above 3.3. This indicates positive socio-economic effects attributed to HPBT implementation. These findings suggest that HPBT has had various positive socio-economic effects on the community, including job creation, reduced healthcare expenses, improved income levels, and enhanced access to education, highlighting its significance in promoting community development and well-being.

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Table 11: Socio-Economic Effects of HPBT from Likert scale for descriptive analysis

Variables	N	Min	Max	Mean	Std. Deviation
Improved access to safe & clean water	654	1.00	5.00	3.3547	1.28705
Improved healthcare practices	654	1.00	5.00	3.2202	1.30395
A reduction in waterborne diseases	654	1.00	5.00	3.3945	1.30274
Increased Income generating activities	654	1.00	5.00	3.2278	1.35394
Reduced waterborne diseases medical expenses	654	1.00	5.00	3.5505	1.20986
Increase in Agricultural productivity	654	1.00	5.00	3.4419	1.26157
Creation of employment opportunities	654	1.00	5.00	3.5933	1.22619
There has been a sense of community cooperation	654	1.00	5.00	3.3731	1.35502
Improved classroom time & quality of education	654	1.00	5.00	3.5428	1.21772
Lower Health service expenditure	654	1.00	5.00	3.5275	1.19788
Increased school attendance in your households	654	1.00	5.00	3.2936	1.30826
improved employment status & Income level.	654	1.00	5.00	3.5642	1.19647
Hygiene practices like wash hands more frequently	654	1.00	5.00	3.5275	1.32880
Valid N (listwise)	654				

4.6.3.b Regression Analysis on Socio-Economic Effects of hand pump borehole

The regression analysis was conducted to evaluate the hypothesis that access to clean water through hand pump boreholes has positive socio-economic effects on communities in Mpunge sub-county. The analysis included various independent variables to assess their impact on socio-economic outcomes.

Table 12: Regression Analysis Summary output

Variable	Coefficient	Standard Error	t-Stat	P-value	95% Confidence Interval (Lower)	95% Confidence Interval (Upper)

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Intercept	-0.253	0.055	-4.607	4.959E-06	-0.361	-0.145
Improved access to safe & clean water	0.057	0.016	3.523	0.000457	0.025	0.088
Improved healthcare practices	0.096	0.016	5.954	4.380E-09	0.064	0.128
A reduction in waterborne diseases	0.048	0.014	3.550	0.000414	0.022	0.075
Increased Income generating activities	-0.002	0.014	-0.158	0.875	-0.029	0.025
Reduced Medical expenses	0.037	0.015	2.525	0.011812	0.008	0.065
Increase in Agricultural productivity	-0.043	0.013	-3.188	0.001504	-0.069	-0.016
Creation of employment opportunities	-0.017	0.014	-1.262	0.208	-0.044	0.010
Improved quality of education	0.037	0.012	3.002	0.002791	0.013	0.061
Lower Health service spending	0.026	0.013	2.054	0.040407	0.001	0.052
Increased school attendance and Class time	0.020	0.013	1.463	0.143869	-0.007	0.046
improved employment status & Income level.	-0.000	0.011	-0.017	0.986469	-0.022	0.021
Hygiene practices like wash hands more frequently	-0.023	0.013	-1.745	0.081528	-0.049	0.003

The regression analysis revealed several significant predictors of socio-economic effects due to access to clean water through hand pump boreholes. Improved access to safe and clean water had

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a significant positive impact on socio-economic well-being ($\beta = 0.057$, $p < 0.001$), underscoring the importance of clean water in reducing the time and effort spent on water collection and allowing community members to engage in more productive activities. Access to clean water significantly improved healthcare practices ($\beta = 0.096$, $p < 0.001$), crucial for maintaining hygiene and preventing waterborne diseases, thus contributing to better health outcomes.

There was a significant reduction in waterborne diseases with improved access to clean water ($\beta = 0.048$, $p < 0.001$), lessening the burden on healthcare systems and enhancing overall community health. Reduced medical expenses were also significant ($\beta = 0.037$, $p < 0.05$), attributed to fewer water-related illnesses and a consequent reduction in the need for medical treatment.

Interestingly, the analysis indicated a negative relationship between access to clean water and agricultural productivity ($\beta = -0.043$, $p < 0.01$). This unexpected result suggests the presence of other confounding factors, such as land quality or agricultural practices, that need further investigation. The quality of education was significantly improved by access to clean water ($\beta = 0.037$, $p < 0.01$), enhancing school attendance and students' ability to concentrate, thereby improving academic performance. Communities with better access to clean water had lower health service spending ($\beta = 0.026$, $p < 0.05$), likely due to fewer health complications and reduced need for healthcare services.

While some variables, such as increased income-generating activities and improved employment status, were not statistically significant, the overall model demonstrated that access to clean water had substantial positive impacts on the socio-economic conditions of the communities in Mpunge sub-county. The findings from this analysis support the hypothesis that access to clean water through hand pump boreholes has positive socio-economic effects. Significant improvements in health outcomes, reduced medical expenses, and enhanced educational opportunities highlight the critical role of clean water in community development.

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5. CHAPTER FIVE: DISCUSSION OF RESULTS

5.1 Discussion of the Study Findings

5.1.1 Functionality and Reliability of Hand Pump Borehole Technology

Comparing Functionality and Reliability in Communities with/without Access

The functionality and reliability of hand pump boreholes are critical in determining water accessibility and reducing water scarcity in rural communities. The findings of this study reveal a significant disparity between communities with and without access to boreholes. Communities equipped with boreholes report markedly improved water accessibility and reduced instances of water scarcity compared to those without such infrastructure. This is evident from the data showing variations in borehole depth, yield, and drilling duration across different villages. For example, the data indicate significant differences in drilling duration, with some villages experiencing longer periods due to geological conditions or the depth required to reach the water table. Similarly, variations in borehole depth and yield suggest diverse challenges and opportunities associated with implementing hand pump borehole technology in different contexts.

Challenges persist in areas such as maintenance, sustainability, and equitable resource distribution. Despite uniform drilling costs across villages, disparities in borehole depths and yields necessitate tailored maintenance and management strategies to ensure the infrastructure's longevity and effectiveness. Furthermore, socio-economic differences between communities with and without boreholes highlight the importance of equitable resource distribution and community empowerment in achieving sustainable development goals. Prior research underscores the positive impact of boreholes on water accessibility; however, discrepancies may arise regarding the extent of these benefits and the effectiveness of intervention strategies (Nyika & Dinka, 2023). The varied socio-economic dynamics of communities with differing access to boreholes warrant a deeper examination of these differences. While some studies emphasize the role of boreholes in enhancing agricultural productivity and economic development (Magunda, 2020), others highlight potential drawbacks such as increased competition for water resources and environmental degradation (Okot-Okumu & Otim, 2015). Contextual factors such as geographic location, climatic conditions, and governance structures also influence the outcomes of borehole interventions (Baguma et al.,

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2023). Therefore, understanding these complexities is crucial for devising tailored interventions that address each community's specific needs and challenges.

Effectiveness of Hand Pump Boreholes

The current research underscores the effectiveness of hand pump boreholes in mitigating water scarcity and improving water accessibility within rural communities. The data on borehole depth, yield, and drilling duration across various villages indicate a significant reduction in water scarcity instances and an improvement in water accessibility among communities with access to boreholes. Survey findings show that villages with hand-pump boreholes experience shorter distances and less time spent fetching water, with fewer trips per day than communities without boreholes. This indicates more efficient access to water resources, suggesting that hand pump boreholes serve as reliable and sustainable water sources, leading to positive socio-economic outcomes for community members. Additionally, the data highlight the role of hand pump boreholes in empowering communities and fostering self-reliance by providing greater control over their water supply.

These observations are consistent with prior research, which highlights the positive impact of boreholes on water accessibility (Dickson-Gomez et al., 2023). Similarly, Harvey and Mukanga (2020) demonstrated the crucial role of hand pump boreholes in addressing water scarcity challenges and improving water accessibility in rural areas. This research contributes to the existing body of literature on the socio-economic implications of hand pump borehole technology, offering valuable insights for policymakers and practitioners aiming to enhance water access in rural communities. The findings emphasize the need for continued investment in and maintenance of hand pump borehole infrastructure to ensure sustainable water access for rural populations.

Challenges and Considerations

Despite their benefits, the sustainability of hand pump borehole technology faces significant challenges, including maintenance issues and groundwater depletion. Ensuring the continuous functionality of boreholes requires regular maintenance and repair, which may be hindered by limited resources and technical expertise in rural communities. Additionally, over-extraction of groundwater for domestic and agricultural purposes contributes to aquifer depletion, jeopardizing the long-term viability of borehole systems. Concerns about water quality also persist, with variations in water composition affecting its suitability for consumption and other domestic uses.

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High levels of turbidity, dissolved solids, and contaminants can compromise the reliability of water supplied by boreholes, posing health risks to communities (Raimi et al., 2021). Furthermore, equity considerations must be addressed to ensure that all community members have equitable access to clean and safe water (Kohlitz et al., 2020). Abrams et al. (2021) found that socio-economic disparities may influence access to borehole services, exacerbating inequalities in water accessibility. Comprehensive strategies that integrate sustainable water management practices, regular monitoring of water quality, and equitable distribution mechanisms are essential to overcome these challenges.

5.1.2 Quality and safety of water provided by hand pump boreholes

Ensuring the quality and safety of water from hand pump boreholes is crucial for safeguarding public health and promoting sustainable development in rural communities. This section discusses the comparative analysis of water quality, detailed findings from laboratory tests, and the broader implications of these results on public health, agriculture, and community well-being.

Comparative Analysis

The investigation revealed notable differences in the quality and safety of water from hand pump boreholes compared to other water sources in communities. Borehole water generally exhibits lower levels of turbidity and microbial contamination than surface water sources such as rivers and ponds, indicating its potential as a reliable source of clean water. The laboratory water quality test results further support these findings, highlighting parameters such as turbidity, pH, and total dissolved solids (TDS). However, challenges such as chemical contamination from agricultural runoff or industrial pollution may still affect borehole water quality, as indicated by the data on electrical conductivity and TDS. These findings underscore the need for ongoing monitoring and treatment to ensure the safety of borehole water for consumption. Accessibility and convenience also play significant roles in determining the preference for borehole water over other sources, particularly in rural areas where alternative options may be limited.

Past studies corroborate these findings, consistently highlighting the positive impact of boreholes on water accessibility and quality. For instance, Lapworth et al. (2017) found that communities with access to boreholes experienced fewer incidences of waterborne diseases compared to those reliant on surface water sources. Similarly, Twongyirwe et al. (2019) reported lower levels of

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microbial contamination in borehole water samples compared to river water samples in a similar context. These studies underscore the importance of boreholes in improving access to clean water and reducing health risks associated with contaminated water sources. Additionally, they emphasize the need for continued research and investment in water infrastructure to ensure sustainable access to safe drinking water for all communities.

Analysis of Laboratory Water Quality Test Results

Several key parameters were assessed to determine the overall quality and safety of the water from hand pump boreholes. The findings indicate relatively low levels of turbidity, suggesting clear water with minimal suspended particles. Additionally, the pH levels fell within the acceptable range, signifying neutral acidity suitable for consumption. However, elevated levels of electrical conductivity and TDS were observed, indicating potential contamination from dissolved minerals or salts. Furthermore, the presence of contaminants such as nitrates, sulfates, and chlorides raise concerns about water quality and safety.

These new findings complement the existing discussion, providing additional insights into specific parameters affecting water quality. They underscore the importance of regular monitoring and treatment to ensure that borehole water meets safety standards and remains suitable for consumption and other domestic uses. Bakyayita et al. (2019) emphasize the importance of monitoring and maintaining water quality in boreholes to prevent contamination and ensure safe drinking water. Lukubye and Andama (2017) found that elevated levels of dissolved solids and contaminants were associated with increased health risks in communities reliant on borehole water. Similarly, Tumwebaze et al. (2023) highlighted the importance of implementing water treatment measures to mitigate the impact of chemical contaminants on public health. These studies underscore the need for ongoing efforts to address water quality challenges and ensure the long-term sustainability of hand pump borehole technology as a reliable source of clean water for communities.

Parameters and Implications

Concerning the parameters and implications of water quality from hand pump boreholes, the analysis revealed important insights into the characteristics of the water and their potential impacts on public health, agriculture, and community well-being. Specifically, parameters such as

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turbidity, color, pH, electrical conductivity, and TDS were assessed to evaluate water quality. The findings indicate generally acceptable levels of turbidity and pH, suggesting clear and neutral water suitable for consumption. However, elevated levels of electrical conductivity and TDS raise concerns about potential contamination and the need for further treatment. These parameters are crucial indicators of water quality and can influence the suitability of borehole water for various uses, including drinking, irrigation, and livestock watering.

The implications of water quality on public health, agriculture, and community well-being are significant. Poor water quality can lead to health problems such as gastrointestinal illnesses and waterborne diseases, impacting the overall well-being of community members. Additionally, contaminated water may adversely affect agricultural productivity and livestock health, further exacerbating socio-economic challenges in rural communities. Past research by Bjornlund et al. (2020) highlighted the importance of monitoring and maintaining water quality in boreholes to safeguard public health and promote sustainable development. Etongo et al. (2018) demonstrated the link between poor water quality from boreholes and increased incidences of waterborne diseases in rural communities. Similarly, Bonsor et al. (2015) emphasized the role of water quality management practices in enhancing agricultural productivity and improving livelihoods in water-stressed areas. Existing evidence underscores the need for comprehensive approaches to water quality management that address both chemical and microbial contaminants to ensure the long-term sustainability of hand pump borehole technology.

5.1.3 Socio-Economic Effects of Access to Clean Water in Communities

The socio-economic impacts of access to clean water through hand pump boreholes in rural communities are profound and multifaceted. This section explores the comparative analysis of communities with and without access to clean water, the specific impacts of hand pump boreholes, their alignment with Sustainable Development Goals (SDGs), and strategies for addressing socio-economic gaps and challenges.

Comparative Analysis

The analysis of socio-economic outcomes between communities with and without access to clean water through hand pump boreholes reveals significant disparities. Communities with access to clean water demonstrate higher levels of education, better health outcomes, increased income

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generation opportunities, and enhanced community development compared to those without such access. Clean water access is directly linked to improved sanitation practices, reduced incidences of waterborne diseases, and better overall health, contributing to increased school attendance rates and academic performance (Dawit et al., 2020).

Additionally, access to clean water facilitates agricultural productivity, fosters economic growth through income-generating activities such as farming and entrepreneurship, and promotes community cohesion and resilience (Irannezhad et al., 2022). In contrast, communities without access to clean water face numerous challenges, including limited educational opportunities, higher healthcare costs due to waterborne illnesses, reduced economic prospects, and constrained community development (Jayne et al., 2021). These disparities underscore the critical importance of addressing water access inequalities to promote socio-economic development and improve the overall well-being of rural communities. Collaborative efforts involving government agencies, non-governmental organizations, and local communities are essential to implement targeted interventions that ensure equitable access to clean water resources and foster inclusive socio-economic development.

Discussion on the Impact of Hand Pump Boreholes

The impact of hand pump boreholes on education, health, income generation, and community development are profound and multifaceted. Access to clean water through hand pump boreholes positively influences education outcomes by reducing absenteeism rates among students, particularly girls who are traditionally tasked with water collection responsibilities (Sharma, 2023). The regression analysis supports this, showing that improved access to clean water significantly boosts educational outcomes ($\beta = 0.037$, $p < 0.01$). This improvement in education is crucial for the long-term socio-economic development of these communities, as better-educated individuals are more likely to secure employment and contribute positively to their local economy.

Improved water access enhances health outcomes by reducing the prevalence of waterborne diseases and improving overall hygiene practices within communities. The regression results confirm this, indicating a significant reduction in waterborne diseases with improved access to clean water ($\beta = 0.048$, $p < 0.001$), which lowers healthcare costs ($\beta = 0.037$, $p < 0.05$) and allows

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community members to allocate resources towards other essential needs, such as education and economic activities (Ayoo, 2022).

Hand pump boreholes also contribute to income generation by facilitating agricultural activities, promoting entrepreneurship through small-scale businesses related to water supply, and creating employment opportunities within the community (Lapworth et al., 2020). However, the regression analysis revealed a complex relationship between clean water access and agricultural productivity ($\beta = -0.043$, $p < 0.01$), suggesting the presence of other factors, such as land quality or agricultural practices, that require further investigation. Despite this, the positive impacts on health, education, and reduced medical expenses underscore the vital role of hand pump boreholes in fostering sustainable community development.

The presence of hand pump boreholes fosters community development by promoting social cohesion, empowering residents to take ownership of water resource management, and supporting initiatives for infrastructure development and environmental conservation. With reliable access to clean water, communities can establish sustainable practices for water usage, sanitation, and hygiene, leading to improved living standards and enhanced resilience to environmental challenges. The presence of boreholes enables communities to diversify their economic activities, explore new livelihood opportunities, and build stronger social networks, contributing to long-term socio-economic stability and growth.

Overall, hand pump boreholes play a crucial role in enhancing socio-economic well-being and fostering sustainable development in rural communities. By addressing water access challenges and promoting community empowerment, borehole projects contribute to achieving the United Nations Sustainable Development Goals (SDGs) related to clean water and sanitation, health, education, and poverty alleviation. To maximize their impact, it is essential to adopt holistic approaches that consider local contexts, engage community members in decision-making processes, and prioritize long-term sustainability in water resource management initiatives.

Alignment with Sustainable Development Goals (SDGs)

Hand pump boreholes are a vital source of clean water in impoverished rural communities, significantly contributing to sustainable development. They support nine Sustainable Development

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Goals (SDGs) and achieve 22 specific indicators. For example, they help achieve SDG 6 (Ensure availability and sustainable management of water and sanitation for all) by increasing access to safe drinking water (indicator 6.1.1), promoting sanitation and hygiene (indicator 6.2.1), and supporting community water management (indicator 6.b.1).

Beyond SDG 6, boreholes contribute to other SDGs as well. Socio-economic benefits such as poverty alleviation and economic growth are realized through increased productivity, income generation opportunities, and community development initiatives facilitated by access to clean water. With boreholes located near homesteads and schools, the time spent fetching water is significantly reduced. This allows women to devote more time to gardening and market activities, improving their production and income, thereby decreasing the proportion of the population living below the international poverty line. Additionally, students can spend more time in school, enhancing their educational outcomes and future job prospects, further aiding in poverty reduction.

Water is essential for life, and when hand pump borehole water meets quality standards, it provides one of the basic services outlined in SDG 1 (No Poverty). This means that hand pump boreholes not only contribute to achieving indicators 1.1.1 and 1.2.1 but also help eradicate poverty by ensuring access to basic services, as measured by indicator 1.4.1.

Hand pump boreholes save an average of at least four working hours per day, which can be redirected towards farming, increasing production volume per labor unit. This boosts small-scale income through increased garden production and higher yields, contributing to SDG 2 (Zero Hunger) indicators 2.3.1, 2.3.2, and 2.4.1.

Access to clean water enhances health outcomes by reducing mortality rates, improving overall well-being, and supporting disease prevention efforts, contributing to SDG 3 (Good Health and Well-being). Communities with these boreholes report significant reductions in waterborne disease infections, directly contributing to targets 3.3 and indicator 3.9.2.

By building hand pump boreholes in rural communities, the intervention supports SDG 4 (Quality Education) by improving health, reducing time spent on water collection, enhancing hygiene and sanitation, and promoting gender sensitivity. This contributes to creating an inclusive and effective learning environment, directly impacting indicator 4.a.1.

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Hand pump boreholes also support SDG 5 (Gender Equality) by alleviating the time burden on women and girls for water collection, enhancing their health, and increasing educational opportunities for girls. This intervention allows women to participate more actively in economic activities and community decision-making, promoting their leadership roles, contributing to indicators 5.5.1 and 5.5.2.

Additionally, hand pump boreholes in rural communities significantly contribute to achieving SDG 8 (Decent Work and Economic Growth) by reducing the time burden of water collection, particularly for women and girls, allowing them to engage in education, vocational training, and income-generating activities. This leads to improved health, higher productivity, and greater employability, thus reducing the unemployment rate (indicator 8.5.2). Improved participation in the workforce also helps achieve equal pay for equal work (indicator 8.5.1).

Hand pump boreholes enhance climate resilience and promote sustainable water management, supporting SDG 13 (Climate Action). They provide reliable access to groundwater, reducing the impact of droughts and water scarcity and reducing greenhouse gas emissions by eliminating the need for electricity or fuel. This supports indicator 13.1.2 and aligns with national strategies to enhance disaster risk reduction and water security. Additionally, by reducing reliance on surface water sources, hand pump boreholes help conserve freshwater ecosystems and promote biodiversity conservation, aligning with SDG 15 (Life on Land). This supports indicators 15.1.2, 15.3.1, and 15.5.1 by promoting the sustainable use of ecosystems, managing forests sustainably, and halting biodiversity loss.

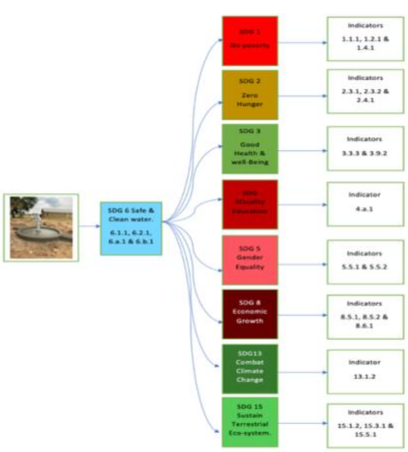

Figure 23:Alignment of borehole with SDG6 and other SDG Goals and indicators

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Addressing Socio-economic Gaps and Challenges

Communities without access to clean water face significant socio-economic challenges that hinder their development and well-being. These challenges include limited educational opportunities, higher healthcare costs, reduced economic prospects, and constrained community development. Addressing these gaps requires comprehensive strategies that prioritize equitable access to clean water resources, infrastructure development, and capacity-building initiatives. Collaborative efforts involving government agencies, non-governmental organizations, and local communities are essential for implementing sustainable solutions that address the root causes of water access disparities (Leader & Wijnen, 2018).

Investing in water infrastructure, such as hand pump boreholes, is a fundamental step in bridging socio-economic gaps and improving the overall livelihoods of communities without access to clean water (Huston et al., 2021). By providing reliable and safe drinking water, hand pump boreholes mitigate the adverse effects of water scarcity, reducing healthcare costs associated with waterborne diseases and allowing communities to allocate resources towards education and economic activities. Moreover, promoting community-based water management practices empowers local residents to take ownership of water resources, fostering self-reliance and community resilience in the face of water-related challenges.

Education and training on water conservation, hygiene practices, and sustainable water management are crucial components of addressing socio-economic challenges in communities without access to clean water (Huston et al., 2021). By promoting awareness and behavioral change, these initiatives help improve health outcomes, enhance environmental sustainability, and build community capacity to address water-related issues effectively. Furthermore, addressing broader systemic issues such as poverty, inequality, and environmental degradation is essential for achieving sustainable socio-economic development (Leader & Wijnen, 2018). Integrating water resource management into broader development agendas can help create synergies between water access, poverty reduction, and environmental conservation efforts, leading to more holistic and effective solutions for addressing socio-economic challenges in marginalized communities.

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5.3 Implications of the Study

5.3.1 Theoretical Implications

The theoretical implications of this study reverberate across interdisciplinary fields, particularly in rural development, environmental sustainability, and public health. The research enriches existing theoretical frameworks concerning water resource management and community empowerment by exploring the socio-economic effects of hand pump borehole technology. It contributes to a deeper understanding of the intricate interplay between water accessibility, socio-economic status, and community resilience, shedding light on the multifaceted nature of rural development challenges. Therefore, publication of this study ensures emphasis on RBV and provides much needed data on the situation on ground.

Moreover, the study augments theoretical discussions surrounding the Sustainable Development Goals (SDGs), elucidating the pivotal role of clean water access in achieving broader development objectives such as poverty eradication, health promotion, and gender equality. The emphasis on hand pump boreholes in addressing water scarcity and improving socio-economic well-being underscores the interconnectedness of clean water access with various dimensions of sustainable development (Ibeneme et al., 2020). Additionally, the findings offer theoretical insights into the mechanisms through which investments in water infrastructure can stimulate socio-economic progress and enhance community well-being in resource-constrained settings. Through the examination of the socio-economic impacts of hand pump boreholes, the study provides empirical evidence to support theoretical propositions regarding the transformative potential of water access on poverty alleviation, health promotion, and community development. This research provides relevance to the Zimbabwean Bush Pump shown to work in the early 2000s which favored use of natural locally sourced materials to curb water scarcity (de Laet & Mol, 2000).

Furthermore, the study underscores the importance of integrating socio-economic considerations into water management strategies and policy frameworks to address disparities effectively and foster sustainable development pathways. Recognition of the socio-economic implications of hand pump borehole technology enables policymakers and practitioners to design more targeted interventions that prioritize the needs of marginalized communities and promote inclusive development outcomes. Moreover, highlighting the significance of adopting participatory approaches and community-centered interventions ensures the equitable distribution of water

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resources and empowers marginalized populations in rural areas. Involving local communities in decision-making processes and capacity-building initiatives enhances the sustainability and effectiveness of water management interventions while promoting social equity and community resilience.

5.3.2 Practical Implications

The practical implications of this study extend to policymakers, practitioners, and community stakeholders involved in water resource management and development initiatives. Firstly, the findings emphasize the need for targeted interventions aimed at improving water accessibility in underserved communities through the implementation of hand pump borehole technology. Policymakers can use these insights to allocate resources more effectively and prioritize investments in water infrastructure projects that address the specific needs of rural populations.

Highlighting the importance of community engagement and participation in the planning, implementation, and maintenance of water supply systems to ensure their long-term sustainability, the study suggests practical recommendations such as capacity-building programs, community-driven initiatives, and multi-stakeholder partnerships. Involving communities in decision-making processes and empowering them with the necessary skills and knowledge can enhance the resilience of water supply systems and promote community-led development initiatives.

Furthermore, the study underscores the significance of holistic approaches that integrate water, sanitation, hygiene, and socio-economic development interventions to achieve sustainable outcomes and improve the overall quality of life in rural communities. Adopting integrated approaches that address the interconnected challenges of water access, sanitation, and socio-economic development can maximize the impact of interventions and create lasting improvements in community well-being. This emphasizes the importance of adopting a comprehensive and interdisciplinary approach to water resource management that considers the complex interactions between water, health, livelihoods, and environmental sustainability.

5.4 Limitations of the Study

Identifying the study's limitations is essential for delineating its scope. Firstly, the sample size might not fully represent all communities reliant on hand pump boreholes. Secondly, the self-reporting nature of the survey and its online format could have introduced response bias,

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particularly among those unfamiliar with technology or with limited internet access. Thirdly, the cross-sectional design restricts causal inference, warranting longitudinal studies for robust conclusions. Fourthly, external factors such as governmental policies or economic changes may have influenced the study outcomes. Fifthly, potential confounders, like cultural practices or community dynamics, might not have been adequately captured. Lastly, resource constraints limited the depth of exploration. Recognizing these limitations provides a varied understanding of the study's outcomes, guiding future research directions and ensuring judicious interpretation of findings.

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6. CHAPTER SIX: CONCLUSION

6.1 Summary of the Study Findings

The research examines the economic effectiveness and SDGs alignment of hand pump borehole technology in mitigating water scarcity in rural areas in Uganda. Firstly, it assesses the socio-economic impact of hand pump borehole technology in rural communities. Secondly, it evaluates the quality and safety of water provided by hand pump boreholes and thirdly it assesses the social-economic effects of the hand pump borehole and how they contribute to achieving specific SDGs indicators. The study explored the phenomenon using a comprehensive methodology of quantitative analyses. The investigation of functionality and reliability produced varied results. While hand pump boreholes showcased effectiveness in mitigating water scarcity and improving water accessibility, challenges such as sustainability concerns and water quality issues were identified. Socio-economic disparities between communities with and without boreholes underscored the importance of equitable access to clean water resources. Further, the analysis of laboratory water quality test results elucidates the overall water quality from hand pump boreholes, with parameters such as turbidity, color, pH, and electrical conductivity playing crucial roles. Implications of water quality on public health, agriculture, and community well-being were discerned, emphasizing the need for rigorous monitoring and maintenance efforts.

Examining socio-economic effects, the study highlighted the transformative potential of hand pump boreholes, particularly in education, health, income generation, and community development. Access to clean water through hand pump boreholes was found to contribute significantly to achieving specific indicators of Sustainable Development Goals (SDGs), including those related to poverty alleviation, health improvement, and economic growth. It also addressed socio-economic gaps and overcame challenges faced by communities without access to clean water. Further, the theoretical implications of the study extend to the broader understanding of water accessibility in rural contexts, emphasizing the multifaceted nature of socio-economic interventions. Practical implications underscore the importance of targeted policy interventions and community-based initiatives to enhance the effectiveness and sustainability of hand pump borehole technology. Despite offering valuable insights, the analysis has various limitations. The sample size and cross-sectional design constrain the generalizability of findings, while potential biases and external influences warrant cautious interpretation. Despite these limitations, the

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research contributes to advancing knowledge in the field, informing policy decisions, and guiding future research endeavors.

6.2 Recommendations for the Study

The following recommendations have been developed to address the specific challenges identified within each research objective while promoting holistic approaches to improving water accessibility and socio-economic outcomes in rural communities.

Objective One: Functionality and Reliability of Hand Pump Boreholes

Table 13: Recommendations for Objective 1

Recommendation	Action Step
Strengthen community-based maintenance systems	1. Allocate GoU funds to finance community-monitoring systems to bolster maintenance. 2. Provide training on basic maintenance procedures, such as pump repair and parts replacement. 3. To improve the sustainability of hand-pump drilling, a community maintenance fund is recommended
Provide training and capacity building	4. Offer workshops and training sessions to local stakeholders on borehole maintenance techniques, including troubleshooting and minor repairs.
Foster partnerships	5. Collaborate with local organizations, government agencies, and NGOs to facilitate sustainable management practices and resource allocation for borehole maintenance.

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Objective Two: Quality and Safety of Water Provided by Hand Pump Boreholes.

Table 14: Recommendations for Objective 2

Recommendation	Action Step
Enhance water quality monitoring	1. Implement routine testing and monitoring programs to assess water quality parameters, such as turbidity, pH, and microbial contamination.
Invest in treatment infrastructure	2. Install filtration or treatment systems to address specific water quality concerns, such as sedimentation or microbial contamination, ensuring safe and reliable water supply.
Promote community engagement	3. Engage local communities in water quality management initiatives, encouraging participation in monitoring activities and promoting awareness of safe water practices.

Objective Three: Socio-economic Effects of Access to Clean Water in Communities

Table 15:Recommendations for Objective 3

Recommendation	Action Step
Promote health and hygiene education	1. Develop educational campaigns focused on hygiene practices, sanitation, and waterborne disease prevention to improve public health outcomes.
Support income-generating activities	2. Provide resources and training for community-led initiatives, such as small-scale agriculture or water-related businesses, to enhance economic opportunities and livelihoods.
Foster intersectoral collaboration	3. Facilitate partnerships between government agencies, NGOs, and community organizations to address broader socio-economic challenges and promote sustainable development.

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Appendix 2: Survey Questionnaire

Socio-Economic Effectiveness of Hand Pump Borehole Technology Survey Questionnaire

Dear Sir/Madam,

My name is **Kafeero Swalle Excel** pursuing a master's degree in **Climate Change and Sustainable Development** of National Taiwan University. I am conducting a study to *"Assess the Effectiveness of Hand Pump Borehole Technology in Mitigating Water Scarcity in Rural Areas in Uganda"* as part of the partial requirement for the degree award. You have been selected in your category as a respondent to provide us with your views on this study based on your experiences as a worker in this district. Your views will be kept and treated confidential and at no moment will it be used against you.

* Indicates required question

Participants conceit.

The interview will take about 30 minutes.

Please fully understand the question before you write down the answers. The whole data will be confidential (feel free to write answers that matches your real experience)

1. Do you agree to be interviewed? *

   Mark only one oval.

   ◯ Yes

   ◯ No

Section A: Demographic information

This section profiles the demographic characteristics. The information is fundamental for segmenting ar understanding the composition of the study population.

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2. What is your Gender?

Mark only one oval.

- ⬭ Male
- ⬭ Female
- ⬭ Other

3. What is your age? *

Mark only one oval.

- ⬭ 18-24 Years
- ⬭ 25-34 Years
- ⬭ 35-44 Years
- ⬭ 45-54 Years
- ⬭ 55-64 Years
- ⬭ 65 Years and over

4. What is your highest education level?

Mark only one oval.

- ⬭ Primary
- ⬭ Secondary
- ⬭ Certificate/Diploma
- ⬭ Bachelors
- ⬭ Other: ______________________

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5. What is your place of residence?

Mark only one oval.

- Rural
- Pre-Urban
- Urban
- Other: ______________________

6. What is your religion/faith ?

Mark only one oval.

- Christian
- Muslim
- Other: ______________________

7. What is your monthly average income?

Mark only one oval.

- 10,000 - 120,000 Ugx (2.57 - 30.94 USD)
- 120,000 - 230,000 Ugx (30.94 - 59.30 USD)
- 230,000 - 340,000 Ugx (59.30 - 87.67 USD)
- 340,000 - 450,000 Ugx (87.67 - 116 USD)
- 450,000 - 560,000 Ugx (116 - 144.40 USD)
- More than 560,000 Ugx (> 114.40 USD)

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8. How long have you been residing in this community?

Mark only one oval.

- ◯ Less than one year
- ◯ 1 - 3 years
- ◯ 3 - 6 years
- ◯ 6 - 9 years
- ◯ 9 - 12 years
- ◯ More than 12 Years

9. What is your occupation? (pick at **most 2** relevant answers) *

Tick all that apply.

- ☐ Farmer
- ☐ Fisherman
- ☐ Market Vendor
- ☐ Other: ____________________

Section B: Social economic status in regards to availability of safe and clean water.

Understanding the availability of water sources and challenges related to water scarcity as experienced by the community members.

10. Is there a Hand Pump Borehole in your community?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

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11. Has there been a decrease in waterborne diseases like diarrhoea, cholera, dysentery and others in the community since the implementation of hand pump borehole technology or the last 1 to 2 years?

Mark only one oval.

- Yes
- No
- Maybe

12. Is there a community-led maintenance system in place for the hand pump boreholes or th available water source?

Mark only one oval.

- Yes
- No
- Maybe

13. What is the status of the nearest borehole or water sources in your community?

Mark only one oval.

- Functional
- Non-functional
- Broken
- Abandoned
- None

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14. Estimate the number of people who use this borehole or the water sources per day in your area?

Mark only one oval.

- ⬭ 50-100 people
- ⬭ 100-150 people
- ⬭ 150-200 people
- ⬭ 250-300+ people

15. What are the available water sources in your community (Pick at most 2)?

Tick all that apply.

- ☐ Piped Schemes
- ☐ Wells
- ☐ Hand pump boreholes
- ☐ Rainwater Harvesting
- ☐ Other: ________________

16. Which water source(s) is easily accessible in your community? (pick only 2 **most** relevant answers)

Tick all that apply.

- ☐ Piped Schemes
- ☐ Wells
- ☐ Hand pump boreholes
- ☐ Rain water Harvesting

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17. How much water do you use daily?

Mark only one oval.

- 40 -80 Liters
- 80 - 160 Liters
- 160 - 320 Liters
- 320 - 640+ Liters

18. How long is it to the nearest water source?

Mark only one oval.

- less than 30 minutes
- 30 - 60 minutes
- 60 - 90 minutes
- 90 - 120 minutes
- More than 120 minutes

19. How many times in a day do you fetch water for use in this household?

Mark only one oval.

- 1 - 5 trips
- 6 - 10 trips
- 11 - 15 trips
- 16+ trips

20. Have you personally used a hand pump borehole for water access?

Mark only one oval.

- Yes
- No

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21. If your answer to the previous question is **Yes** please scale your overall experience with th hand pump borehole technology. (e.g., ease of use, maintenance issues, water yield)

Mark only one oval.

	1	2	3	4	5	
Poo	◯	◯	◯	◯	◯	Excellent

22. How long have you used a hand pump borehole or the water source in your community?

Mark only one oval.

- ◯ Less than one year
- ◯ 1 - 3 years
- ◯ 4 - 6 years
- ◯ More than 6 years

23. Have you obtained a higher income since the borehole was built or in the last 1 to 2 years?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

Section C: Functionality and reliability of Hand Pump Borehole Technology (HPBT)
Please rate your level of agreement with the following statements regarding the functionality and reliability hand pump borehole technology. Use the scale below to express your opinion:

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24. Functionality and reliability of the hand pump borehole technology

Mark only one oval per row.

	1 Strongly Agree	2 Agree	3 Neutral	4. Disagree	5 Strongly Disagree
Is effective and reliable	⬭	⬭	⬭	⬭	⬭
It is easy to use	⬭	⬭	⬭	⬭	⬭
It is adequate	⬭	⬭	⬭	⬭	⬭
Functions well even during peak usage times.	⬭	⬭	⬭	⬭	⬭
It rarely experiences breakdowns or failures.	⬭	⬭	⬭	⬭	⬭
Demonstrated long-term reliability	⬭	⬭	⬭	⬭	⬭
Community confident in reliability of HPBT	⬭	⬭	⬭	⬭	⬭
Community receives timely support	⬭	⬭	⬭	⬭	⬭

Section C: Quality and Safety of Water from Hand Pump Borehole Technology or available wate source in your community.

Please rate your level of agreement with the following statements regarding the quality and safety of water from hand pump borehole technology. Use the scale below to express your opinion:

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25. **Section C: Quality and Safety of Water from Hand Pump Borehole Technology or other water sources**

Mark only one oval per row.

	1 Strongly Agree	2 Agree	3 Neutral	4 Disagree	5 Strongly Disagree
The water is clear and free of visible contaminants	⬭	⬭	⬭	⬭	⬭
The water has no odour and no bad taste.	⬭	⬭	⬭	⬭	⬭
The water is safe for drinking	⬭	⬭	⬭	⬭	⬭
I am aware of waterborne diseases associated with the borehole water.	⬭	⬭	⬭	⬭	⬭
I believe that the water is regularly tested for contaminants.	⬭	⬭	⬭	⬭	⬭
I am satisfied with the safety measures in place to protect the water from contamination.	⬭	⬭	⬭	⬭	⬭
The water source contributes positively to the overall well-being of our community.	⬭	⬭	⬭	⬭	⬭
The water source has improved the safety of water access in our community.	⬭	⬭	⬭	⬭	⬭
The water source has proven to be a sustainable solution for our water needs.	⬭	⬭	⬭	⬭	⬭
The maintenance of the hand pump is promptly addressed by responsible authorities.	⬭	⬭	⬭	⬭	⬭

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SECTION D: Socio-Economic effects of HPBT

Please rate your level of agreement with the following statements regarding the socio-economic effects of access to hand pump borehole technology (HPBT). Use the scale below to express your opinion:

26. **Socio-economic effects of access to clean water by communities relying on Hand Pump Boreholes or in the last 1 or 2 years.**

Mark only one oval per row.

	1 Strongly Agree	2 Agree	3 Neutral	4 Disagree	5 Strongly Disagree
Improved access to clean and safe water	⬭	⬭	⬭	⬭	⬭
Has improved your healthcare and hygiene practices	⬭	⬭	⬭	⬭	⬭
A reduction in waterborne diseases in our community.	⬭	⬭	⬭	⬭	⬭
The availability of the boreholes(other water sources) has increased opportunities for income-generating activities in our community.	⬭	⬭	⬭	⬭	⬭
There has been a decrease in medical expenses related to waterborne diseases in the last 1 to 2 years.	⬭	⬭	⬭	⬭	⬭
There has been a positive effect in agricultural productivity in our community.	⬭	⬭	⬭	⬭	⬭
There has been creation of local employment opportunities in the last 1 to 2 years.	⬭	⬭	⬭	⬭	⬭
There has been a sense of community cooperation and responsibility in the last 1 to 2 years.	⬭	⬭	⬭	⬭	⬭
In the last 1 to 2 years there has					

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been an increase in time spent by children in classrooms and improved the quality of education for the children in schools	○	○	○	○	○
Your expenditure on health services has lowered?	○	○	○	○	○
Children in your household are attending school more than before	○	○	○	○	○
Has your income level, current employment status improved in the last 1 to 2 years?	○	○	○	○	○
Do you wash your hands more frequently now?	○	○	○	○	○

END

****Thank you for your cooperation and participation****

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