

**Factors Influencing Adoption of Rainwater Harvesting Technologies in
Habaswein - Wajir County**

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112778

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Management in Agribusiness at Strathmore University**

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DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the dissertation contains no material previously published or written by another person except where due reference is made in the dissertation itself.

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ABSTRACT

This study assesses the adoption and effectiveness of rainwater harvesting technologies (RWHT) for climate-resilient fodder production in Habaswein Sub-County in Wajir County, where chronic water scarcity continues to threaten fodder availability and the sustainability of pastoralist livelihoods. Grounded in the Sustainable Livelihoods Theory (SLT), the research examines how RWHT contributes to strengthening the five key livelihood assets that include: the natural, the physical, the human, the financial, and the social capital-within a highly vulnerable socio-ecological context. The purpose of the study is to provide information that helps pastoral communities living in the arid and semi-arid lands better feed their livestock in a fodder scarce environment. The research explores the overarching factors that condition the adoption of RWHT and thereby contribute to improving their livelihoods and resilience in a changing climate scenario. The specific objectives were to: (i) assess the extent and preference of RWHT adoption; (ii) analyze the socio-economic factors influencing adoption; (iii) evaluate ecological factors that condition the type of RWHT most suited to specific environments; and (iv) determine the impact of training and extension services on adoption and effectiveness of RWHT. A mixed-methods research design (both quantitative and qualitative) was used for data collection, involving a survey of 205 households, and key informant interviews, and focus group discussions representing the qualitative component. The participating households were obtained from beneficiaries of the World Food Programme's Food Assistance for Assets (FFA) initiative. The findings reveal significant variation in RWHT adoption across locations, technology types, and household profiles. Adoption was strongly associated with socio-economic factors such as education level, household income, land tenure, and livestock ownership, all of which directly relate to livelihood capital. Ecological conditions, especially soil type and rainfall distribution-were found to influence the appropriateness and performance of RWHT structures. While contour bunds had achieved widespread adoption across all sites, Zai pits and semi-circular bunds remained in the early or "pipeline" stages of adoption. Access to training and extension services was also a critical enabler, enhancing both the scale of RWHT adoption and the economic returns from fodder production. The study recommends tailored, context-specific RWHT approaches, increased technical and institutional support, and sustained investment in capacity building. However, the research faced limitations, including a sample that may not represent non-FFA beneficiaries, and insufficient secondary data for comprehensive trend analysis. It also identifies future research opportunities including longitudinal studies on sustainability, comparative analyses across ASAL regions, and deeper inquiry into gender dynamics and institutional frameworks affecting RWHT adoption.

KEYWORDS: Rainwater Harvesting Technologies (RWHT), fodder production, RWHT adoption, Arid and semi-arid lands, Food Assistance for Assets (FFA), sustainable livelihoods, Wajir County.

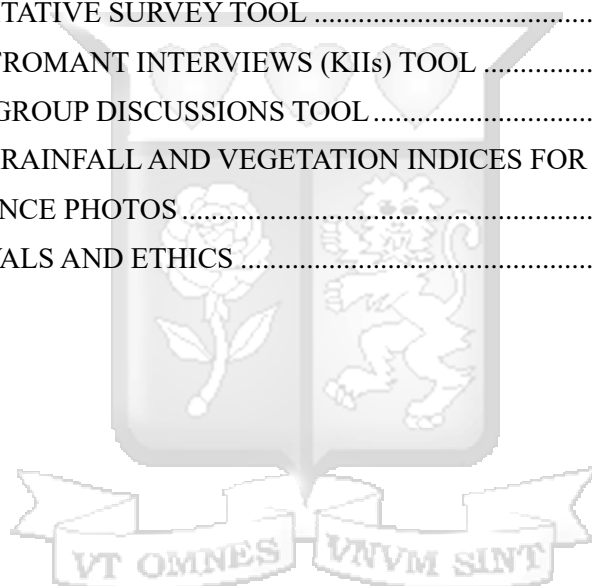
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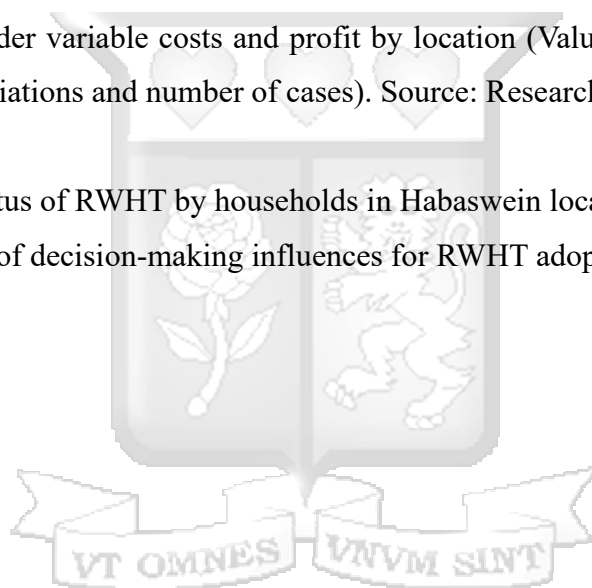
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DEFINITIONS

Rainwater: Precipitation in liquid form, typically from clouds, that falls to the earth's surface (Thomas TH and Martinson DB, 2007).

Rainwater harvesting: A technique aimed at inducing, collecting, storing, and conserving local surface runoff, primarily for agricultural use in ASAL regions (Boers and Ben Asher, 1982).

Rainwater harvesting technologies: Initiatives devised to gather water resources, with a specific focus in this study on runoff water harvesting as delineated by Boers and Ben Asher (1982).

Socio-economic factors: These encompass the social and economic circumstances influencing individuals, communities, and societies, including aspects such as income level, education, job prospects, and resource accessibility (UN-Habitat, 2022).

Household: Defined as either (a) a single-person household, where an individual provides for their own sustenance without combining resources with others, or (b) a multi-person household, consisting of two or more individuals cohabiting and pooling resources for shared living expenses. Members may be related or unrelated, and may maintain a common budget (United Nations, 2008).

Adoption: The decision to acquire and utilize a new invention or innovation (Baker & Laurence, 2001).

Innovators: Individuals or groups who introduce new concepts or actions, often pioneering new approaches (Nurulin et al., 2019).

Early adopters: Individuals who promptly begin utilizing a product or technology upon its availability (Everett M. Rogers, 2003).

Ecological Zones: Extensive areas characterized by relatively uniform vegetation types, such as tropical rainforest, tropical dry forest, boreal coniferous forest, etc. (Zhu, Z., 1997).

Late majority: Individuals who embrace new ideas or technologies after the average member of a system does so (Everett M. Rogers, 2003).

Laggards: They represent the final segment in a social system to embrace an innovation (Everett M. Rogers, 2003)

Value chain: A series of sequential steps involved in a production process, encompassing activities from the initial design of a product to its final consumption and eventual disposal. This process integrates all activities, including input sourcing, cultivation, transformation, marketing, and distribution, ensuring value addition at each stage. According to Kaplinsky and Morris (2001), the value chain encompasses the entire lifecycle of a product, highlighting the interconnectedness of its various components and their contribution to delivering value to the consumer.

Resilience: Capability of an entity to withstand, mainstream, manage, and recover from the impacts of hazards, while also adapting to long-term changes efficiently and in a timely manner, without compromising food security or well-being. (Pasteur, 2011).



LIST OF ABBREVIATIONS AND ACRONYMS

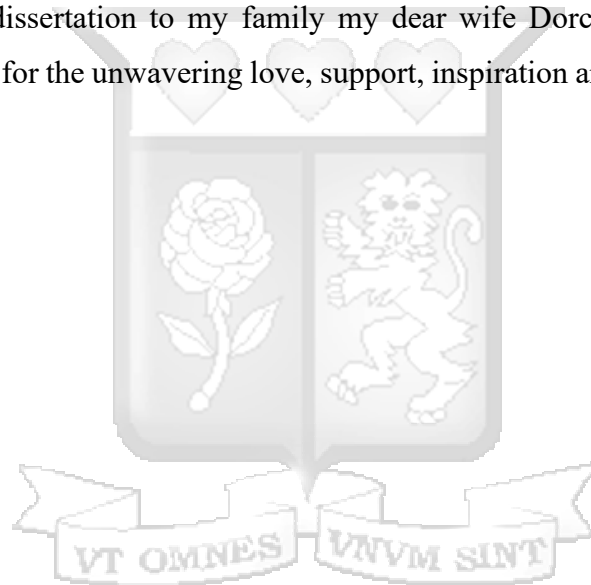
ASAL	Arid and Semi-arid Land
DFID	Department for International Development
DRC	Danish Refugee Council
UNFAO	United Nations Food and Agriculture Organization
FEWS NET	Famine Early Warning Systems Network
FFA	Food Assistance for Asset
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GoK	Government of Kenya
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KALRO	Kenya Agriculture and Livestock Research Organization
KIIs	Key Informant Interviews
NDMA	National Drought Management Authority
NGOs	Non-Governmental Organizations
RWHT	Rainwater Harvesting Technologies
SDG	Sustainable Development Goals
SLT	Sustainable Livelihood Theory
SPSS	Statistical Package for Social Sciences
UNCCD	United Nations Convention for Combating Desertification
UNEP	United Nations Environmental Program
UVR	Ultraviolet Radiation
WFP	World Food Programme

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DEDICATION

I wish to dedicate this dissertation to my family my dear wife Dorcas, and our children Joel, Raychellynn and Phoebe for the unwavering love, support, inspiration and motivation to soldier on and complete this work.



CHAPTER ONE:

INTRODUCTION TO THE STUDY

1.1 Overview

This chapter presents the background information associated with the factors that influence the adoption of rainwater harvesting technologies (RWHT) in arid and semi-arid lands (ASALs), with particular emphasis on their role in supporting fodder production systems. It outlines the contextual challenges faced by ASAL regions such as water scarcity, erratic rainfall, and recurrent droughts, which undermine agricultural productivity and livestock-based livelihoods. The chapter further highlights the potential of RWHT as a sustainable solution for enhancing water availability, promoting pasture regeneration, and improving household resilience to climate shocks.

The chapter begins with a detailed background information of the study importance, including global importance, regional applications, and national experiences with RWHT, and situates the research within the context of Wajir County an ASAL region where pastoral livelihoods are highly vulnerable to climatic stress. It proceeds to define the research problem and articulates the knowledge gaps that this study seeks to address, particularly the limited data (both empirical and observational) on RWHT effectiveness in fodder systems and its value chain in the Kenyan ASALs.

The chapter then outlines the overarching and specific objectives of the study, followed by the key research questions investigated. It also presents the scope of the study, including its theoretical grounding in the Sustainable Livelihoods Theory. Finally, the chapter explains the significance of the study by identifying the primary beneficiary's pastoralist households, policymakers, development agencies, and private sector actors and describing how they will benefit from the research findings.

1.1.1 Background Information

Rainwater harvesting (RWH) is increasingly recognized as a cost-effective and sustainable approach for addressing water scarcity, enhance agricultural productivity, and support livestock development, particularly in arid and semi-arid regions (FAO, 2021; Rockström, Falkenmark & Karlberg, 2018). Globally, countries such as India, Israel, and Australia have successfully implemented RWH systems to enhance groundwater recharge, to improve irrigation, and to support climate-resilient food systems (Agarwal & Narain, 1997; Boers & Ben-Asher, 1982; Coombes & Barry, 2008). In sub-Saharan Africa, techniques such as semi-circular bunds and Zai pits have proven effective in restoring degraded lands and increasing fodder yields (FAO, 2021; Reij, Tappan & Smale, 2009). Rainwater harvesting technologies (RWHT) are widely acknowledged as sustainable strategies for addressing water scarcity, enhancing fodder production, and building climate resilience in arid and semi-arid regions (Rockström et al., 2010; FAO, 2021). It has been shown globally, and in countries such as India, Israel, and Australia that RWHT including johads, check dams, and micro-catchment systems have significantly improved water availability for agriculture and livestock feed, and thereby reducing dependence on imported fodder (Sharma et al., 2016; Schwartz et al., 2017; Kumar et al., 2018).

Rainwater harvesting technologies (RWHT) including Zai pits, contour bunds, and semi-circular bunds have been promoted in Kenya through resilience-building programmes such as the World Food Programme's Food Assistance for Assets (FFA) initiative (WFP, 2021). However, empirical research on the adoption, ecological suitability, and long-term sustainability of RWHT for fodder production remains limited, especially in ASAL contexts (Ngigi, 2003; Mutunga, Onywere & Karanja, 2017).

This study addresses these knowledge gaps by investigating how RWHT adoption influences fodder production and pastoral resilience in Habaswein. Specifically, it examines socio-economic drivers (e.g., education, land tenure, income), ecological factors (e.g., soil type, rainfall), and the role of training and extension services in enhancing RWHT effectiveness (Mohamed & Wasonga, 2019; Fatondji et al., 2016; Akroush et al., 2017). By focusing on these variables, the research aims at contributing knowledge and insights that contribute to improving fodder water access, boosting fodder availability, and strengthening climate resilience among pastoralist communities in northern Kenya.

1.1.2. Rainwater Harvesting Technologies (RWHT) and Fodder Production

Techniques like Zai pits, demi-lunes, and runoff harvesting have improved pasture regeneration and reduced drought-related livestock losses in Niger, Ethiopia, and Jordan (Rockström et al., 2018; Gebregziabher, Namara & Holden, 2016; Al-Adamat, 2012). However, the large-scale adoption of RWHT for fodder in developing countries is constrained by high costs, limited technical capacity, insecure land tenure, and weak policy support (Mohamed & Wasonga, 2019; Mutunga, Onywere & Karanja, 2020). Despite these barriers, global evidence shows that RWHT adoption can be scaled through targeted investments, institutional support, and community-based initiatives (Schwartz, Weisbrod & Yakirevich, 2017). These lessons are highly relevant to Kenya's ASALs, including Wajir County, where integrating RWHT into the fodder value chain can help mitigate climate risks, enhance food security, and generate income for pastoralist households (Munyasia, Kariuki & Wekesa, 2022). This study builds on international best practices to examine the adoption, challenges, and socio-economic outcomes of RWHT for fodder production in Habaswein, contributing to policy recommendations aimed at promoting sustainable and resilient pastoral systems.

2.2.2 Rainwater Harvesting Technologies (RWHT) in Sub-Saharan Africa

Rainwater harvesting technologies (RWHT) are increasingly recognized across Sub-Saharan Africa as vital tools for addressing climate change impacts, improving water security, and supporting agricultural and pastoral productivity in arid and semi-arid regions (Rockström et al., 2018). Countries such as Ethiopia, Niger, and Burkina Faso have successfully implemented RWHT ranging from micro-dams and percolation pits to Zai-pits and demi-lunes leading to improved pasture regeneration, increased fodder production, and enhanced drought resilience (Gebregziabher, Namara & Holden, 2016; Fatondji et al., 2016; Sawadogo et al., 2017). Despite these gains, adoption in Kenya's ASALs remains limited due to socio-economic and institutional barriers, including high installation costs, limited technical capacity, insecure land tenure, and inadequate extension services (Mutunga et al., 2020; Mekonnen, Kassa & Zeleke, 2019). Ecological constraints such as poor soils, steep topography, and high evaporation rates further affect RWHT performance, necessitating location-specific designs and support systems.

While initiatives like the WFP's Food Assistance for Assets (FFA) programme have promoted RWHT to stabilize fodder supply, widespread adoption requires stronger policy frameworks,

community involvement, and increased investment in training and research (WFP, 2021; Haregeweyn et al., 2015). Lessons from countries with successful RWHT integration offer valuable insights for Kenya, particularly in Wajir County, an arid and semi-arid county.

2.2.3 Rainwater Harvesting Technologies (RWHT) and Fodder Production in Habaswein

Habaswein, in Wajir County, Kenya, faces significant water scarcity, erratic rainfall, and recurrent droughts, severely affecting fodder production and pastoral livelihoods (NDMA, 2017). With livestock being the primary source of income and food security, sustainable water management solutions like rainwater harvesting technologies (RWHT) are crucial (KNBS, 2023). Rainfall in the region is unpredictable and insufficient, leading to pasture depletion, high livestock mortality, and forced migration in search of water and fodder (GoK, 2020; Wario, 2021). RWHT, including rooftop rainwater collection, water pans, sand dams, and subsurface dams, have been introduced to enhance water storage and availability (Mutunga et al., 2020). However, adoption remains low due to socio-economic barriers, lack of awareness, and inadequate technical support (Mohamed & Wasonga, 2019). Fodder production is further constrained by land degradation and overgrazing, increasing dependency on costly commercial feeds (FAO, 2021). Integrating RWHT with fodder cultivation has improved pasture productivity in similar arid areas like Garissa County (Munyasias et al., 2022; Kariuki et al., 2018). Fodder species such as *Cenchrus ciliaris* and *Chloris gayana* have demonstrated success in ASAL regions with RWHT implementation (Wekesa et al., 2019). Additionally, fodder banks created through RWHT have enhanced household incomes by reducing reliance on food aid and promoting local fodder markets (ILRI, 2023). Despite these benefits, barriers such as high installation costs, financial constraints, land tenure insecurity, high evaporation rates, and soil degradation hinder RWHT adoption in Habaswein (Mohamed & Wasonga, 2019; Wario, 2021). Limited technical support and capacity-building initiatives further slow adoption (Mutunga et al., 2020). While interventions like the World Food Programme's (WFP) Food Assistance for Assets (FFA) program have promoted RWHT, there is a need for further research on the long-term sustainability of these efforts (WFP, 2021). This study examines the effectiveness of RWHT in stabilizing fodder production, identifies adoption barriers, and provides policy recommendations for scaling up RWHT in Habaswein. Addressing these challenges is critical to enhancing food security, economic resilience, and sustainable pastoral livelihoods in Wajir County.

1.2 Problem Statement

Water scarcity remains a major challenge in Kenya's ASALs, particularly in Habaswein Sub-County of Wajir County, where climate change, erratic rainfall, and extreme weather events have disrupted pastoral livelihoods and food security (UNEP, 2002; NDMA, 2017). Increasingly unreliable rainfall has led to diminished pasture and water availability, causing livestock deaths and reduced household incomes (FAO, 2021). Livestock remains the main economic asset in the region, yet frequent droughts have resulted in financial losses due to reduced productivity and market value (World Bank, 2022). Unlike other ASAL counties with boreholes and irrigation support, Wajir still depends on traditional water sources like pans and shallow wells, which often fail during prolonged droughts (Malesu, Oduor & Odhiambo, 2007).

Furthermore, rainfall in arid and semi-arid lands (ASALs) is both limited and erratic, often resulting in flash floods that do not support consistent pasture growth, and thereby constraining fodder production that leads to overgrazing, land degradation, and livestock-related economic losses (Malesu et al., 2007; ILRI, 2015). This situation forces pastoralists to sell their livestock at low prices during droughts while struggling to meet their basic needs (Barron & Okwach, 2005). Since livestock is the primary source of income and livelihoods support, declining animal health and numbers directly affect household income and food security (Little et al., 2008). Rainwater harvesting (RWH) has emerged as a promising solution for addressing water scarcity and for improving fodder production, with successful applications shown in countries like India, Ethiopia, and across the Sahel (Ngigi, 2003; Rockström, Barron & Fox, 2002). For instance, India's community-led RWH initiatives have enhanced pasture regeneration and livestock health (Agarwal & Narain, 1999), while Ethiopia's sand dams and subsurface reservoirs have enabled year-round fodder cultivation (Kay & Fipps, 2004). In Kenya, where over 80% of the land is classified as ASAL, regions like Wajir County face acute water shortages, degraded ecosystems, and dwindling livestock productivity due to climate change and erratic rainfall (UNEP, 2002; NDMA, 2017). Habaswein Sub-County, in particular, remains reliant on unreliable traditional water sources, resulting in high vulnerability among pastoralist households (Malesu, Oduor & Odhiambo, 2007; FAO, 2021).

Habaswein presents a valuable case for assessing the role of rainwater harvesting (RWH) in enhancing fodder production and pastoral resilience (Barron & Okwach, 2005; GoK, 2020).

Scalable RWH techniques can support pasture regeneration, reduce livestock mortality, and stabilize household incomes (Barron & Okwach, 2005). Moreover, integrating small-scale irrigation for commercial fodder production may diversify income sources and reduce reliance on distress livestock sales during droughts (Nori & Davies, 2007). Examples from Sudan and Niger show that community-led RWH initiatives can transform fodder production into profitable ventures, and thereby improving food and economic security (Malesu et al., 2007).

Many existing empirical studies have focused primarily on the role of RWH in crop irrigation and general water conservation (Ngigi, 2003; Rockström et al., 2002), with minimal investigation into their applicability for livestock-based economies. Studies by Malesu et al. (2007) and Mutunga et al., (2017) discuss RWH implementation but do not examine its effectiveness in fodder production or its influence on pastoral household resilience. Furthermore, while RWH techniques such as Zai pits and semi-circular bunds have been introduced, little evidence exists on their ecological suitability, economic returns, or impact on livestock productivity in ASALs (Mutunga, Onywere & Karanja, 2017; Liniger et al., 2011; Mati et al., 2006). There is a lack of research on the socio-economic and institutional factors influencing RWH adoption including the role of land tenure systems, extension services, and training (Mati et al., 2006; Mutunga, Onywere & Karanja, 2017; Mohamed & Wasonga, 2019). Moreover, the long-term sustainability and integration of RWH in fodder production have not been adequately explored, particularly in drought-prone regions like Habaswein (Mati et al., 2006; Mutunga, Onywere & Karanja, 2017; Liniger et al., 2011). This study is therefore purposed to addresses these gaps by assessing the extent of use and adoption of RWH technologies in fodder production, identifying adoption determinants, and assessing their contribution to livelihood resilience in pastoralist communities of Habawein.

1.3 Overarching Research Objective

To assess the adoption of rainwater harvesting technologies on the fodder production and sustainable livelihoods in the arid and semi-arid lands of Habaswein Sub County in Wajir County.

1.3.1 Specific Objectives

The following were the stated objectives of the study.

- i. Assess the extent and preference of RWHT adoption;
- ii. Analyze the socio-economic factors influencing adoption;
- iii. Evaluate ecological factors that condition the type of RWHT most suited to specific environments; and
- iv. Determine the impact of training and extension services on adoption and effectiveness of RWHT.

1.3.2 Research Questions

- i. Are there relationships between RWHT and their adoption in the study area?
- ii. Which socio-economic factors drive the adoption of RWHT in the study area?
- iii. Which ecological factors determine the adoption of RWHT and subsequently the expansion of the fodder value chain for the pastoral and agro-pastoral communities in Habaswein?
- iv. Does training determine the extent to which RWHT are adopted in the study area?
- v. Is fodder production profitable to households in the study areas?

1.4 Scope of Study

This study was conducted in Habaswein Sub-County of Wajir County, located within Kenya's arid and semi-arid lands (ASALs), a region that faces chronic water scarcity, erratic rainfall, and recurrent droughts. The research focused on evaluating factors that influence the adoption of rainwater harvesting technologies (RWHT) for climate-resilient fodder production. Habaswein was purposively selected due to its acute vulnerability to climatic shocks and its inclusion in the World Food Programme's (WFP) Food Assistance for Assets (FFA) initiative, which supports community-based water and land resource management in ASAL regions (WFP, 2021). The sub-county frequently experiences prolonged dry spells and episodic flash floods that undermine pasture availability and livestock productivity, resulting in widespread food insecurity (FAO, 2021; World Bank, 2022). The study covered the period between 2021 and 2023, during which the region experienced heightened climatic variability. This timeframe provided a critical context to examine the real-time performance of RWHT interventions in supporting fodder systems and mitigating drought-induced feed shortages (NDMA, 2023). The research is theoretically grounded in the Sustainable Livelihoods Theory (SLT), which emphasizes the importance of five livelihood capitals—natural, physical, financial, human, and social—in shaping adaptive capacity and

resilience (Chambers & Conway, 1992; Scoones, 1998). In this context, RWHT interventions contribute to natural and physical capital by enhancing water availability and pasture regeneration. These, in turn, strengthen financial capital through improved livestock productivity and income diversification. The study also integrates resilience theory, which highlights the ability of socio-ecological systems to absorb shocks and adapt to climate risks (Folke et al., 2010), and vulnerability frameworks, which examine how external stressors such as climate change and weak institutions increase livelihood risk (Ellis, 2000).

Methodologically, the study adopted a mixed-methods design, combining quantitative and qualitative approaches to ensure a comprehensive and contextualized analysis. Quantitative data were collected through structured household surveys involving 205 respondents, while qualitative data were obtained through key informant interviews (KIIs) and focus group discussions (FGDs). This methodological approach enabled triangulation and enriched the understanding of the socio-economic, ecological, and technical factors influencing RWHT adoption.

1.5 Significance and Benefits of the Study

This study is significant in its contribution to pastoralist communities, development practitioners, county and national policymakers, research institutions, and private sector actors operating within Kenya's arid and semi-arid lands (ASALs). The study generates actionable knowledge that strengthens the evidence necessary for improving water and fodder security in ASALs. It supports multi-stakeholder decision-making aimed at enhancing pastoral resilience, promoting sustainable livelihoods, and reducing climate-related vulnerability in drought-prone regions like Habaswein. These climate-induced disasters have significantly affected 82,756 residents in areas such as Eldas, Bute, Buna Arbajahani, Habaswein, Laqboqol, and Khorof/Harar, in Wajir County causing long-term population displacement and destruction of property. Women and children are particularly vulnerable, facing increased risks of malnutrition, with 27.5% of children under five at risk, and higher exposure to gender-based violence due to the stresses of climate-induced displacement and resource scarcity.

1.5.1 Pastoralist and agro-pastoralist households in Habaswein Sub-County.

Climate change has severely impacted Wajir County, Kenya, where over 80% of the population relies on pastoralism for their livelihood. The county has experienced prolonged droughts, floods, and locust invasions, leading to the loss of livestock, food insecurity, and displacement of communities (Maarifa Centre 2023). The pastoral community stand to benefit directly from the study's findings on the effectiveness and extent of the adoption of rainwater harvesting technologies (RWHT) for fodder production. By identifying socio-economic, ecological, and technical factors that influence RWHT adoption, the study offers practical guidance on improving access to water for fodder cultivation, ultimately supporting livestock health, reducing drought-related livestock mortality, and stabilizing household incomes (FAO, 2021; NDMA, 2023). The study also examines the economic viability of fodder production, equipping local communities with evidence to pursue income diversification through commercial fodder ventures.

1.5.2 Development partners and NGOs,

World Food Programme (WFP), FAO, and other humanitarian actors engaged in resilience-building programs, will benefit from empirical and qualitative data and analysis including evidence that contributes to enhancing the targeting, design, and scaling of RWHT initiatives. The findings provide a deeper understanding of community-level adoption dynamics, which can improve the sustainability and impact of interventions funded under food assistance or climate adaptation programs (WFP, 2021; Rockström et al., 2018).

1.5.3 County governments and national policymakers

Both levels of governments (County and National) will gain valuable insights into the institutional and policy barriers affecting RWHT adoption. The study highlights the importance of land tenure security, extension services, and capacity-building efforts, enabling policymakers to design evidence-based strategies, update county development plans, and align investments with national goals such as Kenya's Vision 2030, the ASAL Climate Adaptation Plans, and the Sustainable Development Goals (SDGs) (Mati et al., 2006; GoK, 2020).

1.5.4 Academic and research institutions

The academia and research will benefit from the study's contribution to literature on climate-resilient water management in ASAL contexts. The research fills a knowledge gap on RWHT's

role in the fodder value chain, offering a foundation for further studies on technology adoption, livelihoods, and dryland agriculture (Mutunga, Onywere & Karanja, 2020).

1.5.5 Private sector actors

Private sector players including agricultural input suppliers, fodder traders, and microfinance institutions, may use the findings to explore investment opportunities in fodder production and small-scale irrigation markets. The study identifies market entry points and highlights enabling conditions that could stimulate agribusiness development and rural employment in ASAL counties (Nori & Davies, 2007; Kihara et al., 2011).



CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter presents a critical review of existing literature relevant to the adoption and effectiveness of rainwater harvesting technologies (RWHT) in Habaswein with a specific focus on their integration into fodder production systems. The review is organized to provide a theoretical and empirical foundation for the study by examining global, regional, and local perspectives on RWHT, their role in climate-resilient agriculture, and their potential for enhancing pastoral livelihoods. The chapter begins by discussing the theoretical frameworks underpinning the study, notably the Sustainable Livelihoods Theory, which explains how RWHT can strengthen livelihood assets and adaptive capacity. It then explores empirical evidence on the application of RWHT in different contexts, highlighting best practices, adoption drivers, ecological and socio-economic determinants, and existing knowledge gaps. The review concludes by identifying key research gaps that this study seeks to address, particularly the limited empirical data on RWHT's impact on fodder production and its integration into the livelihood systems of pastoral communities in Habaswein Sub County in Wajir County one of Kenya's ASALs.

2.1 Theoretical Review

Theory refers to a set of generalizations that explain relationships between variables (Al-Ababneh, 2020). This study is grounded in theoretical perspectives that help explain the factors influencing the adoption of rainwater harvesting technologies (RWHT) for fodder production in Habaswein Sub-County, Kenya. Four key theories inform the study: the Theory of Expected Utility, which considers rational decision-making under risk; the Adopter's Perception Theory, which emphasizes how individual attitudes and perceptions influence adoption; Rogers' (2003) Theory of Diffusion of Innovations, which outlines the process through which technologies spread in social systems; and the Sustainable Livelihoods Theory (SLT), which examines how households mobilize different assets to sustain and improve their livelihoods. Among these, the study primarily adopts the Sustainable Livelihoods Theory as its guiding framework, offering a holistic lens through which to analyze the socio-economic, ecological, and institutional factors that influence RWHT adoption and its implications for household resilience and food security in ASAL settings.

2.1.1 Sustainable Livelihood Theory

This study is anchored in the Sustainable Livelihood Theory (SLT), which offers a holistic framework for analyzing how individuals and communities sustain their livelihoods amid environmental and socio-economic challenges. According to Chambers and Conway (1992), a livelihood is sustainable when it can withstand and recover from stresses and shocks, maintain or enhance its assets and capabilities, and ensure future livelihood opportunities. The theory identifies five key capitals: natural, physical, human, social, and financial as essential for household wellbeing and adaptive capacity. In arid and semi-arid lands (ASALs) such as Habaswein in Wajir County.

Natural capital (e.g., soils, water and pasture) are crucial for sustaining livestock-based livelihoods. In arid and semi-arid lands (ASALs) such as Habaswein in Wajir County, natural capital (e.g., soils, water, vegetation, and pasture) is central to sustaining livestock-based livelihoods. Equally important is physical capital, which encompasses infrastructure and tangible assets that support productive activities. In the context of rainwater harvesting, this includes water storage structures (e.g., water pans, sand dams), tools, and equipment that facilitate water access and fodder cultivation. Enhanced physical capital enables households to improve fodder productivity, reduce water-fetching labor, and stabilize livestock feeding during droughts (Scoones, 1998).

Human capital refers to the skills, knowledge, education, health, and labor capacity of individuals, all of which determine their ability to engage productively in livelihood strategies. In this study, human capital is expressed through the technical know-how and awareness of rainwater harvesting techniques, as well as the capacity to manage fodder systems effectively. Access to training and extension services strengthens this capital by building local competencies necessary for adopting and maintaining RWHT systems (Ellis, 2000).

Social capital includes networks, relationships of trust, norms, and associations that facilitate collective action and resource sharing. In pastoralist settings, strong social ties promote communal construction of RWHT infrastructure, coordinated grazing systems, and knowledge exchange. Trust and cooperation among community members and support from institutions such as the World

Food Programme (WFP) and local government are critical in scaling up RWHT interventions and sustaining them beyond project cycles (Pretty, 2003).

Financial capital comprises financial resources such as income, savings, credit, remittances, and other economic assets that enable investment in productive activities. For many households in Habaswein, the availability of financial capital determines the ability to adopt and maintain RWHT. Financial constraints often limit access to construction materials, labor, or transport, thus hindering the uptake of water-saving technologies. However, where RWHT is adopted, it can in turn enhance financial capital through increased livestock productivity, fodder sales, and reduced expenditures on commercial feed (Chambers & Conway, 1992).

Rainwater harvesting (RWH) strengthens physical capital by improving water availability for fodder production, which contributes to financial capital through enhanced livestock productivity and income generation (Chambers & Conway, 1992). Scoones (1998) extended the theory by identifying key livelihood strategies—intensification, diversification, and migration. In ASALs, diversification through fodder production complements traditional pastoralism and reduces vulnerability to climate shocks. This study evaluates how the adoption of RWH supports such diversification and enhances resilience under erratic rainfall conditions. Ellis (2000) emphasized the vulnerability context, which includes external influences such as climate change, weak policies, and market volatility. In ASAL regions, these stressors compound livelihood risks. The study explores how RWH stabilizes fodder supply and mitigates the effects of these external vulnerabilities on livestock-dependent households. Additionally, resilience theory by Folke et al. (2010) supports the need for adaptive strategies. RWH and fodder value chain integration are seen as resilience-building measures that help communities absorb climatic shocks and recover from environmental stress. The Sustainable Livelihood Theory and its extensions provide a robust analytical foundation for understanding the role of RWH in enhancing fodder production, income generation, and climate resilience. By drawing on the SLT, vulnerability analysis, and resilience thinking, this study contributes to bridging knowledge gaps on the socio-ecological factors that influence RWH adoption in Kenya's ASALs. It also supports the design of targeted interventions to promote sustainable livelihoods and reduce vulnerability among pastoralist households.

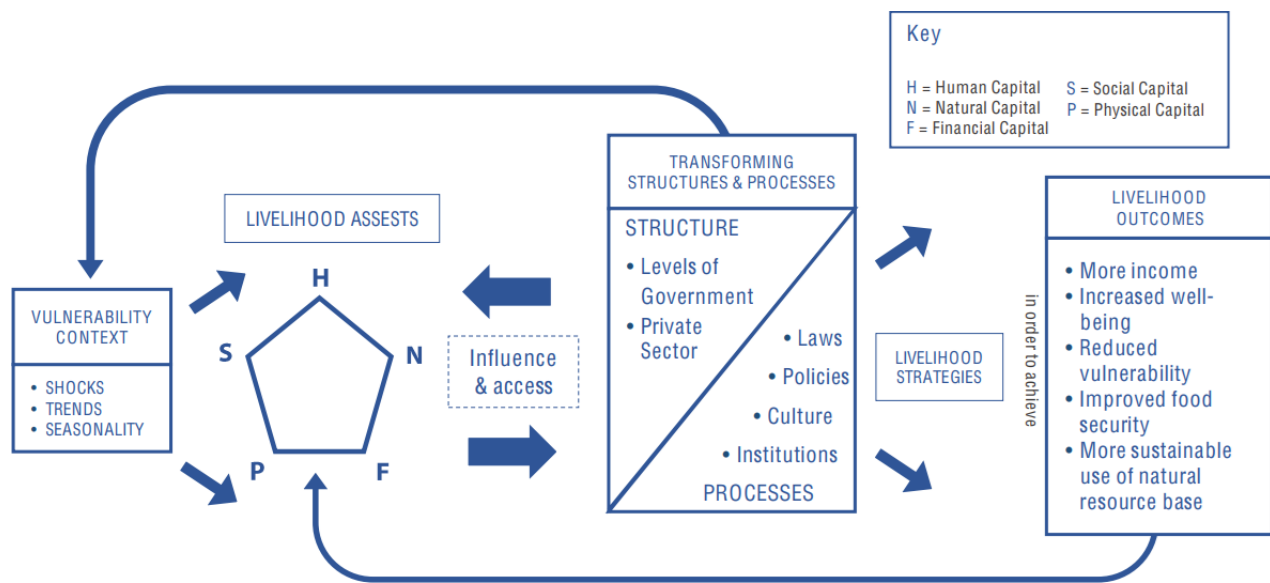


Figure 2.1: Sustainable livelihoods framework (Source: DFID (2000): Research (2025))

2.1.2. Theory of Expected Utility

The Theory of Expected Utility, originally formulated by Daniel Bernoulli (1738), posits that individuals such as farmers act as rational agents who make decisions aimed at maximizing their utility within given constraints. When faced with uncertainty, such as adopting new agricultural technologies, farmers evaluate the expected benefits versus the associated risks and choose the option that offers the highest perceived utility (Schoemaker, 1982). This theory has been widely applied in agricultural decision-making studies, where it helps explain why farmers may or may not adopt innovations like fodder cultivation and marketing. According to Oglethorpe (1995), Babcock and Hennessy (1996), and Gomez-Limon et al. (2004), farmers are more likely to adopt technologies when the anticipated benefits such as improved productivity or income outweigh the risks or costs of adoption. Kassie et al. (2015) further argue that the probability of adoption increases when the expected utility from the technology surpasses that of non-adoption. In the context of this study, pastoral communities in Kenya's ASALs are increasingly engaging in fodder production in response to pasture scarcity and the desire to boost household income. Asfaw et al. (2012) explain that the perceived utility from adopting fodder cultivation acts as a key driver in farmers' adoption decisions. This theory thus provides a valuable framework for assessing the

economic rationale behind fodder production adoption and its potential to enhance household welfare in ASAL regions.

2.1.3 Theory of Diffusion of Innovations

The Theory of Diffusion of Innovations, developed by Everett Rogers (2003), explains how new ideas, technologies, or practices such as rainwater harvesting technologies (RWHT) spread through a social system over time. The theory identifies four key factors influencing diffusion: the innovation itself, communication channels, time, and the social system. These elements collectively shape the trajectory and rate of adoption within communities. At the core of the theory is a five-stage innovation-decision process: knowledge, persuasion, decision, implementation, and confirmation. This process illustrates how individuals move from awareness to evaluation, adoption, and eventual integration of a technology. In the context of this study, these stages help explain how households in Habaswein adopt RWHT for fodder production, from initial exposure to practical application within livestock systems.

However, Rogers (1989) cautioned that diffusion research often assumes a "pro-innovation bias", implying that all innovations are beneficial and will inevitably be adopted. He emphasized the need to view individuals as active agents, influenced by local conditions, risk perceptions, and social norms rather than passive recipients of innovation. Earlier studies validate the model's applicability. For example, Ryan and Gross (1943) documented the adoption of hybrid corn in Iowa, while Griliches (1957) highlighted the role of economic factors in adoption speed. Hägerstrand (1967) added a spatial dimension, demonstrating how innovations diffuse through social and geographic proximity. Applied to RWHT in Kenya's ASALs, the theory helps uncover how community awareness, peer influence, perceived benefits, and access to information affect adoption. It provides a valuable lens for designing effective outreach strategies that can enhance adoption rates, increase fodder availability, and build climate resilience among pastoralist households.

2.1.4 Theory of adopter's perception

The Theory of Adopter's Perception (Fliegel & Kivlin, 1966) posits that individuals' decisions to adopt new technologies are strongly shaped by their perceptions of the innovation's attributes such as usefulness, compatibility, and complexity. Positive perceptions increase the likelihood of

adoption, while negative or uncertain views can hinder it, even if the technology is objectively beneficial. In the context of Kenya's ASALs, how pastoralist households perceive the demands, utility, and complexity of rainwater harvesting technologies (RWHT) and fodder systems significantly affects adoption. This theory also highlights the role of gender dynamics, noting that agricultural technologies often reinforce male dominance in resource access and labour roles. Studies show that while technologies may enhance productivity, they can also shift control of income and assets from women to men, as seen in stabling systems in Senegal (Fisher et al., 2000) and milk market participation in Ethiopia (Lenjiso et al., 2016a). Such shifts influence not just adoption decisions but also household well-being and equity (Doss, 2001; Meinzen-Dick et al., 2009). Even when benefits are understood, adoption may still be constrained by lack of resources, technical skills, or enabling support systems. This theory is therefore essential for this study, as it helps explain how perceptions, gender roles, and access to assets shape the adoption of RWHT for fodder production in Habaswein.

2.2 Empirical review

This section reviews empirical studies on rainwater harvesting technologies (RWHT), with a focus on their application, adoption, and effectiveness in supporting fodder production, particularly in arid and semi-arid lands (ASALs). It draws on global, regional, and local experiences to examine how RWHT has contributed to agricultural resilience, water security, and sustainable livelihoods in climate-vulnerable settings. The review also highlights key factors influencing adoption, including socio-economic, ecological, and technical dimensions, while identifying gaps in evidence especially concerning the integration of RWHT into fodder value chains and pastoral production systems in Kenya. This forms the basis for contextualizing the current study within existing research and justifying its focus on Habaswein, Wajir County.

2.2.1 Water harvesting techniques

Water harvesting techniques are commonly classified into in-situ and ex-situ catchment systems (Hai, 1998). In-situ techniques involve capturing rainwater directly where it falls, typically through small-scale interventions that enhance soil moisture and crop productivity by guiding runoff from higher to lower parts of a field (Reij & Steeds, 2003). These techniques are particularly suitable for dryland farming in Kenya's ASALs, where rainfall is low and erratic. In-situ methods in Kenya

include negarims (micro-catchments) and trapezoidal bunds, which are effective in arid areas like Turkana and Kyuso for establishing fruit trees and growing crops like sorghum and grasses (Thomas, 1997). Zai pits, which are small, organic-matter-enriched planting holes, have also been widely adopted in semi-arid areas for their ability to conserve water and rehabilitate soils (MOA, 2011). These water harvesting structures support climate adaptation, enhance fodder production, and contribute to sustainable agriculture by improving water retention, reducing runoff, and enabling productive use of degraded land in Kenya's drylands.

2.2.2 Zai (planting) pits

The Zai technique, a traditional and climate-resilient water harvesting method, originated in Burkina Faso and has gained prominence as an effective solution for restoring degraded and crusted soils in arid and semi-arid regions. Zai pits are small planting basins typically 20–30 cm in diameter and 10–20 cm deep, dug during the dry season into hardened or compacted soils, often referred to as hardpans (Reij et al., 2009). Once dug, the pits are filled with organic matter, such as animal manure, compost, or crop residues, which serve dual purposes: enhancing soil fertility and stimulating biological activity. A key ecological feature of the Zai method is that the organic matter attracts termites, which burrow through the soil, creating channels that improve aeration, nutrient cycling, and infiltration capacity (Fatondji et al., 2006). The Zai system is particularly effective in conserving water, as the pits trap runoff, concentrate moisture around plant roots, and reduce the risk of water stress during dry spells. In addition, the pits capture fine sediments and litter, improving soil structure and enabling the gradual rehabilitation of degraded farmland over time (Roose, Kabore & Guenat, 1993). Research and field applications across the Sahel including Niger, Mali, and Northern Burkina Faso demonstrates that Zai pits can double or triple crop yields compared to untreated degraded land. Their scalability and low cost make them particularly attractive for resource-constrained farmers seeking to enhance food security and climate resilience under conditions of erratic rainfall.

2.2.3 Negarim

Negarim micro-catchments are a widely applied water harvesting technique in arid and semi-arid lands (ASALs), especially suited for tree planting and soil conservation under low rainfall conditions. Structurally, Negarims consist of diamond-shaped basins enclosed by earthen bunds,

designed to capture and concentrate surface runoff. At the lowest corner of each basin, a small infiltration pit is constructed to temporarily store runoff, facilitating gradual percolation into the root zone of planted trees (Prinz, 1996; Critchley, Reij & Seznec, 1992). These systems are particularly effective for small-scale afforestation efforts and are commonly used in ASAL regions where multipurpose trees offer environmental and livelihood benefits. In the early years of establishment, the primary benefits of Negarims include soil moisture conservation, reduction in erosion, and increased fodder availability, even before trees reach full productivity (FAO, 2003). While construction of Negarim basins is technically straightforward, it is labour-intensive. Typically, one man-day is needed to construct two standard units, making costs a consideration, especially for larger installations (Critchley et al., 1992). The design and layout of Negarim units are determined by tree species water requirements and site-specific conditions, including soil depth (preferably ~2 meters), slope (1–5%), and average annual rainfall (300–700 mm) (Prinz, 1996). Overall, Negarim micro-catchments contribute to improved water retention, higher tree survival rates, and restoration of degraded lands, offering a practical and scalable solution for climate resilience and sustainable land management in Kenya's drylands.

2.2.4 Trapezoidal bunds

Trapezoidal bunds are a widely used ex-situ rainwater harvesting structure designed to capture runoff from external catchments and enhance soil moisture within enclosed plots. Named for their distinctive trapezoidal layout, these bunds are composed of a base bund connected to two wing walls that extend upslope at an angle of approximately 135 degrees, forming a three-sided enclosure open on the upslope side to allow surface runoff to enter (Critchley et al., 1992; FAO, 1991). These bunds are typically used to enclose areas up to one hectare and are suitable for cultivating a variety of crops, grasses, or trees using the stored water. Overflow from excess runoff is safely discharged around the tips of the wing walls, preventing erosion. The design is particularly effective for semi-arid environments, where rainfall is often too erratic for rain-fed agriculture alone (Prinz, 1996). Although construction is feasible on slopes exceeding 1.5%, this requires substantial earthwork. Trapezoidal bunds are usually implemented in staggered configurations across slopes to maximize runoff capture and reduce water loss. A recommended layout includes 20 meters between adjacent wing tips in the same row and 30 meters between the upper and lower rows to ensure adequate water distribution. However, field practitioners may adjust this layout to suit site-specific

conditions, such as soil type and catchment size. Use of more than two rows is generally discouraged, as runoff tends to diminish for the lower rows, reducing their effectiveness (FAO, 1991). Overall, trapezoidal bunds offer a low-cost, labour-intensive solution for improving land productivity, enhancing fodder availability, and supporting climate adaptation in Kenya's ASALs. Their versatility and suitability for degraded lands make them an integral component of sustainable land management practices in dryland agriculture.

2.2.5 Semi-circular bunds

Semi-circular bunds are a widely recognized rainwater harvesting technique used in arid and semi-arid lands (ASALs), primarily for rangeland rehabilitation, fodder production, and the cultivation of trees and shrubs. Structurally, they are half-moon shaped earth embankments with the tips aligned along contour lines, allowing them to trap and retain surface runoff efficiently (Critchley et al., 1992). In some cases, they are also applied for crop cultivation, though their principal value lies in restoring degraded grazing areas. These bunds are best suited to areas with medium slopes, permeable soils, and scattered bush vegetation, often found in stone-covered landscapes. Their functionality depends on the catchment-to-cultivated area ratio, which can be adapted to serve either short-slope or long-slope water harvesting functions, depending on topography and rainfall characteristics (Prinz, 1996). One of the key advantages of semi-circular bunds is their high efficiency in capturing runoff relative to the amount of earth required for construction. Compared to similar structures like trapezoidal bunds, semi-circular bunds offer a more favorable impounded area-to-bund volume ratio, making them particularly suitable for cost-effective rangeland improvement in resource-constrained ASAL regions (FAO, 1991). The technique is especially recommended in pastoral areas for rapidly enhancing degraded rangelands, promoting natural vegetation regeneration, and boosting fodder availability, which is critical for livestock-based livelihoods. Their simple design, adaptability, and proven impact on biomass growth make them a practical option for large-scale implementation in dryland restoration programs.

2.2.6 Contour bunds

Contour bunds are among the most applied in-situ rainwater harvesting (RWH) techniques globally, particularly in dryland and hilly regions, due to their ability to reduce surface runoff, enhance water infiltration, and prevent soil erosion. Constructed along natural contour lines, these bunds are

widely used in countries like India, China, and parts of Latin America, where they support soil conservation and rain-fed agriculture (Sharma et al., 2016; Wani et al., 2009). In India, especially in Rajasthan and Maharashtra, contour bunds are complemented by vegetative barriers or grass strips, improving their stability and water retention. Studies indicate that these structures improve soil moisture, reduce gully erosion, and boost both crop and fodder yields (Wani et al., 2009).

In Sub-Saharan Africa, contour bunds are applied in Burkina Faso, Mali, and Niger as part of agroecological restoration strategies. In Burkina Faso, they are often used alongside Zai pits and organic inputs to rehabilitate degraded rangelands, reduce runoff, and enhance soil fertility—thus improving fodder availability for livestock (Sawadogo, Reij & Stroosnijder, 2017).

In Kenya, contour bunds have been introduced in arid and semi-arid lands (ASALs) such as Machakos, Makueni, Kitui, and more recently in Wajir and Garissa. These initiatives are driven by KALRO, FAO, and WFP under integrated soil and water conservation programs. In ASALs, contour bunds help retain rainwater and reduce erosion, facilitating fodder crop establishment, especially when used with drought-tolerant grasses like *Cenchrus ciliaris* and *Chloris gayana* (Wekesa et al., 2019). However, adoption remains constrained by technical gaps, financial barriers, and limited follow-up support (Mutunga, Onywere & Karanja, 2020).

2.3 Aspects of the adoption of rainwater harvesting technologies.

The adoption of rainwater harvesting technologies (RWHT) is influenced by interplay of social, ecological, technical, and economic factors. According to Goyal (2005), gender roles, biodiversity, soil erosion, and socio-economic dynamics all shape adoption decisions. Despite its demonstrated benefits in improving water access, food security, and land productivity, RWHT remains underutilized in many regions (RWPS, 2005). Scholars like (Fengrui et al., 2000) emphasize that successful implementation depends not only on technology availability but also on local policy frameworks, social dynamics, and community engagement.

2.3.1 Rainfall and soil considerations

Access to safe and reliable water remains a global challenge, despite efforts by engineers, policymakers, and NGOs (Goyal, 2005). The sustainability of water harvesting systems depends

on both technical factors (such as structure design and soil-water conservation) and ecological considerations, including rainfall patterns, amounts and topography. Community participation is also vital, as it ensures ownership, long-term maintenance, and project scalability.

2.3.2 Rainfall influence

Rainfall is a primary determinant of RWHT feasibility. Erickson (2012) underscores the need for long-term, reliable rainfall data—preferably over 10 years—to inform system design. Rainfall quantity, distribution, and seasonality guide decisions on catchment size and storage requirements. Xiaoyan and Ruiling (2002) note water's role in agriculture, while Sharda and Ojasvi (2005) stress the urgent need for water conservation due to the supply-demand gap. Participatory watershed approaches have also shown success in improving cultivation, drought resilience, and groundwater recharge (De Graaf, 2000).

2.3.3 Soil characteristics

Soil texture and structure greatly influence water retention and infiltration. Sivanappa (2007) highlights how poor infiltration, low storage capacity, and high evaporation hinder soil moisture, making water harvesting critical for agricultural sustainability. According to Anschutz (2003), sandy soils allow rapid infiltration, clayey soils retain water longer, and loamy soils offer balanced performance. These distinctions are key for selecting appropriate RWHT for different landscapes.

2.3.4 Socio-economic factors

Cheserek (2013) identifies key socio-economic factors affecting RWHT adoption: gender, education, household income, credit access, and social standing. Wealthier households are more likely to adopt costly systems, while poorer families may rely on simpler or informal options. Pani (2004) reinforces this view, noting that affluent communities are better positioned to manage drought risks and mobilize collective action for water conservation in sectors like agriculture and livestock.

2.3.5 Training and extension services

Prakash (2011) emphasizes the importance of structured training on RWHT systems, technology options, water quality, storage, maintenance, and socio-environmental impacts. Effective training

also addresses broader issues like climate change, sanitation, and household-level water optimization to ensure informed and sustained adoption. Kenya's extension services have transitioned from supply-driven to demand-driven approaches (MoALF, 2003). These services now focus on capacity building, technology transfer, and stakeholder collaboration.

2.4 Methodological and research gaps

Despite the growing recognition of rainwater harvesting technologies (RWHT) as sustainable solutions for enhancing water security and fodder production in arid and semi-arid lands (ASALs), significant methodological and empirical demonstrated gaps still persist in their integration into the fodder value chain (Rockström et al., 2018). Much of the existing literature has concentrated on the technical feasibility and hydrological efficiency of RWHT (Haregeweyn et al., 2015), with limited attention paid to their direct contributions to fodder yield, market linkages, and pastoral livelihoods (Mekonnen, Kassa & Zeleke, 2019). One key gap is the lack of empirical research data on the influence of RWHT on fodder quality, quantity, species composition, and livestock nutrition (Mutunga et al., 2020). Although the technology has been shown to improve pasture regeneration in countries like Ethiopia (Gebregziabher, Namara & Holden, 2016), its specific impact on fodder markets and income generation remains poorly studied. Furthermore, few studies adopt a value chain perspective, leading to fragmented policy recommendations and limited scalability of interventions (Mekonnen, Kassa & Zeleke, 2019).

The role of socio-economic and institutional factors also remains underexplored. Barriers such as high installation costs, insecure land tenure, and limited financial and extension support affect RWHT adoption (Mohamed & Wasonga, 2019). However, there is little research into how these constraints interact with gender dynamics, traditional knowledge, and access to fodder markets. A better understanding of these factors is essential for developing inclusive and sustainable adoption strategies (Mutunga et al., 2020).

Another identified gap hinges on the lack of longitudinal studies that assess the sustainability of RWHT systems across multiple seasons. Most current research relies on short-term evaluations, focusing on water storage capacity rather than long-term outcomes like soil moisture retention, drought resilience, and economic viability of fodder production (Sawadogo, Reij & Stroosnijder, 2017; Fatondji et al., 2016). Policy and institutional gaps further hinder RWHT mainstreaming.

While national policies often address water management broadly, few explicitly integrate RWHT into fodder security strategies (Munyasia et al., 2022). There is limited research evaluating the effectiveness of current policies, incentive structures, and community-based governance models in facilitating RWHT adoption (Mutunga et al., 2020). The absence of comparative studies on RWHT techniques (e.g., Zai pits, water pans) across diverse ecological zones, including Kenya's ASALs like Wajir County, further limits context-specific innovation (Fatondji et al., 2016).

Additionally, while organizations such as the World Food Programme (WFP) have implemented RWHT interventions, few studies assess their long-term sustainability and impact on pastoral resilience (WFP, 2021). Addressing these gaps is vital for evidence-based policymaking and the formulation of context-specific strategies to enhance fodder production, livestock productivity, and climate resilience. This study aims to contribute to this under-researched area by assessing the effectiveness, adoption drivers and barriers, as well as socio-economic impacts of RWHT on fodder production in Habaswein, Wajir County. It seeks to document the factors influencing household decisions to adopt RWHT and provide recommendations for sustainable pastoral development. Table 2.1 provides a synthesis of what literature provides on issues that need more investigations together with the authors that have highlighted the issues some of which have been addressed in this study.

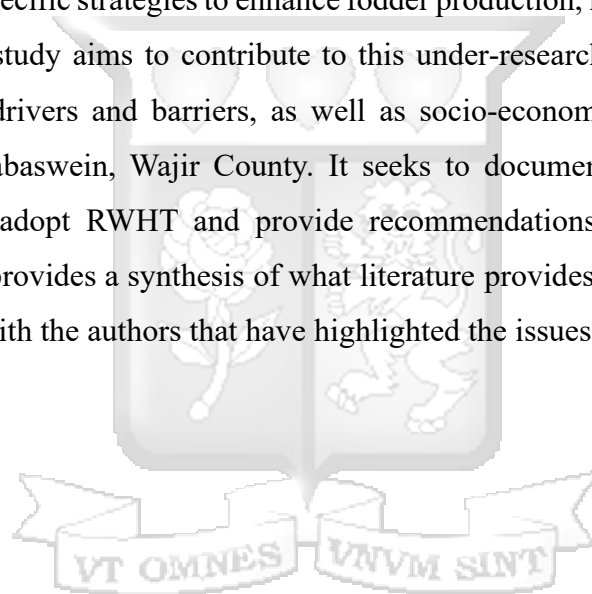


Table 2. 1 : Summary Table of Research gaps and needs

Source	Research deficiencies	Research Gaps	Methodology	Findings
Suzenet et al. (2002)	Lack of information and knowledge, economic and financial constraints, absence of incentives, and institutional and regulatory gaps	Further research is necessary to expand the options for water harvesting technologies and address knowledge gaps among farmers regarding rainwater harvesting technology. Identifying key facilitators for rainwater harvesting, such as financial incentives, training, and extension activities, is crucial. Additionally, implementing unified strategies focused on developing common policies, strategies, and regulations for rainwater harvesting technologies is essential.	Literature review and stakeholder consultations	Identified limited awareness, economic barriers, and institutional gaps in RWH adoption
Mati et al. (2006)	The mapping of areas suitable for implementing rainwater harvesting technologies has impeded progress.	Consider utilizing satellite products to evaluate the potential for water harvesting in remote regions, aiding in climate change adaptation planning related to water resources management. This assessment should be supplemented by community evaluations of water	GIS and remote sensing analysis combined with field validation	Mapped suitable RWH zones; demonstrated the potential of remote sensing for targeting interventions

		resources and the potential utilization of rainwater harvesting systems.		
Kiggundu et al. (2018)	The role of rainwater harvesting (in-situ systems) in enhancing moisture retention and crop/fodder yields	This information will be crucial for optimizing irrigation water needs in systems that integrate irrigated agriculture with rainwater harvesting (RWH) technologies.	Field surveys and participatory rural appraisals	Highlighted weak integration of in-situ RWH in agricultural planning and poor community involvement
Kiggundu et al. (2018)	The influence of climate change on rainwater harvesting systems and water resources	Anticipated climate change effects on the hydrological cycle are likely to have extensive consequences on water availability. This knowledge is essential for crafting sustainable strategies to adapt rainwater harvesting (RWH) and irrigation practices for the benefit of smallholder farmers.	Climate modelling and trend analysis	Projected increased variability in rainfall; stressed need for adaptive RWH practices
Kiggundu et al. (2018)	Embracing innovations for sustainable and effective water	While relevant innovations have been tested in controlled environments, they have yet to be tested with smallholder farmers to enhance food security and incomes amid climate change.	Case studies and pilot demonstrations in selected ASAL regions	Demonstrated that local innovations can significantly improve water productivity when properly supported

	harvesting and utilization	Additionally, even in cases where innovations are being adopted, appropriate recommendations are lacking. It is imperative to showcase techniques suitable for various agroecological zones.		
Kiggundu et al. (2018)	Socio-economic and institutional considerations related to rainwater harvesting (RWH) and small-scale irrigation technologies.	The choice of site for the reservoir, design considerations, material acquisition, structure implementation, and management are significantly impacted by the socio-economic factors and institutional frameworks of a specific region. There is a necessity to examine how these factors influence the adoption, management, and long-term viability of infrastructure within a given area.	Policy review and expert interviews	Found limited policy alignment between water harvesting strategies and fodder value chain development

Source: Research (2025)

2.5 Conceptual Framework

This conceptual framework illustrates the interrelationships among the key variables examined in the study. It provides a structured lens through which to investigate the factors influencing the adoption of Rainwater Harvesting Technologies (RWHT) in Habaswein Sub-County. Grounded in insights from a comprehensive review of theoretical and empirical literature, the framework serves as a guiding model for the research, addressing notable gaps in both theory and practice. As noted by Bogdan and Biklen (2003), a conceptual framework connects abstract theoretical constructs to observable phenomena, thereby clarifying the causal pathways under investigation. In this study, RWHT functions as the independent variable, influencing dependent outcomes such as fodder availability, household income, and pastoral resilience (Florian, 2006). The following sections provide a synthesis of the explored dependent variables (i.e., type of RWHT used, ecological factors, socio-economic factors, and training) considered important for the adoption of the RWHT in this study. The adoption of RWHT on the other hand is considered to contribute to enhanced livelihoods, increased household financial incomes, enhanced household food security, healthier livestock and more vibrant trade in fodder. These outcomes contribute to household climate resilience and sustainable livelihoods.

2.5.1 Rainwater Harvesting Technologies

In India, contour bunds and farm ponds have increased soil moisture and fodder yields (Sharma et al., 2016), while Israel's use of micro-catchments and runoff harvesting has reduced evaporation and improved infiltration (Schwartz, Weisbrod & Yakirevich, 2017). In Australia, no-till farming and stubble retention have enhanced water-holding capacity and pasture growth (Barron et al., 2019). Despite these successes, challenges such as high installation costs, limited awareness, and soil variability remain barriers to adoption (Rockström et al., 2018). In Sub-Saharan Africa, in-situ RWH plays a critical role in sustaining pastoral livelihoods. Techniques like Zai pits and demi-lunes in Niger, and stone bunds in Burkina Faso, have restored degraded rangelands and increased fodder availability (Fatondji et al., 2016; Sawadogo, Reij & Stroosnijder, 2017). However, widespread adoption is limited by land degradation, financial constraints, and technical knowledge gaps (Mekonnen, Kassa & Zeleke, 2019). In Ethiopia, although watershed management programs have promoted in-situ RWH, challenges persist due to labour intensity, land tenure insecurity, and climate variability (Haregeweyn et al., 2015). In-situ rainwater harvesting (RWH) techniques such

as contour bunds, Zai pits, and infiltration trenches are vital for enhancing soil moisture retention and boosting fodder production in arid and semi-arid lands (ASALs) (Sharma et al., 2016). Their adoption is shaped by a combination of ecological, socio-economic, and policy-related factors across global, regional, and local scales (Rockström et al., 2018).

In Kenya's ASALs, including Wajir County, techniques such as micro-basins, contour ridges, and Zai pits have been adopted to mitigate drought effects and improve fodder supply (Mohamed & Wasonga, 2019). Integration of Zai pits with drought-tolerant fodder species has improved livestock feed availability (Wekesa et al., 2019). Nevertheless, adoption is hindered by labour demands, financial limitations, low awareness, soil erosion, and weak extension services (Mutunga, Onywere & Karanja, 2020; Wario, 2021; FAO, 2021). Successful integration of in-situ and micro-catchment RWH techniques into the fodder value chain is contingent on ecological suitability, socio-economic conditions, institutional support, and technical capacity (Rockström et al., 2018). Addressing these constraints through policy incentives, capacity-building, and community-based innovations is essential for achieving sustainable fodder production and climate-resilient pastoral livelihoods in ASAL regions (Fatondji et al., 2016).

2.5.2 Ecological Factors

The effectiveness of rainwater harvesting technologies (RWHT) in supporting fodder production in arid and semi-arid lands (ASALs) is significantly shaped by ecological factors such as climate variability, soil type, topography, and vegetation cover (Schwartz et al., 2017). Soil characteristics are particularly critical, as sandy soils demand different interventions than clayey soils due to differences in permeability and water retention (Al-Adamat, 2012). In regions with high evapotranspiration, additional water conservation methods are essential (Rockström et al., 2018). In Niger, traditional techniques such as Zai pits and demi-lunes have improved pasture regeneration, while in Ethiopia, watershed management integrated with RWHT has enhanced soil moisture and mitigated drought effects, despite persistent challenges like soil erosion and land degradation (Fatondji et al., 2016; Mekonnen, Kassa & Zeleke, 2019; Haregeweyn et al., 2015). In Kenya's ASALs, including Wajir County, erratic rainfall, high evaporation, and degraded sandy soils hinder RWHT performance. Innovative solutions such as sand dams, lined reservoirs, and the use of drought-tolerant grasses are required to strengthen the fodder value chain (Mohamed & Wasonga, 2019; Wekesa et al., 2019; FAO, 2021). Overall, successful RWHT adoption depends on

site-specific ecological adaptations, sustainable water management, and climate-smart agricultural practices to improve resilience and fodder security in ASAL regions (Fatondji et al., 2016).

2.5.3 Socio-Economic Factors

The adoption of in-situ and micro-catchment rainwater harvesting (RWH) techniques in arid and semi-arid lands (ASALs) is heavily influenced by socio-economic factors including financial capacity, land tenure security, access to technical knowledge, policy support, access to financial resources, gender, and community participation (Mekonnen, Kassa & Zeleke, 2019; Mohamed & Wasonga, 2019). These factors manifest differently at global, national, and local levels, shaping how RWH is integrated into livestock and fodder production systems (Mutunga et al., 2020; Munyasia et al., 2022).

Developed countries like Israel and Australia have achieved high adoption rates due to strong institutional support, financial incentives, and advanced technologies (Schwartz, Weisbrod & Yakirevich, 2017). In contrast, developing regions, including South Asia and Sub-Saharan Africa, face challenges such as inadequate infrastructure, limited funding, and low awareness (Rockström et al., 2018). In India, government subsidies and community programs have improved RWH adoption in fodder-scarce regions like Rajasthan and Maharashtra (Kumar, Sharma & Singh, 2018), although land insecurity, installation costs, and socio-cultural resistance still constrain progress (Sharma et al., 2016). In Kenya's ASALs, socio-economic constraints such as poverty, limited financial capital, and land tenure insecurity hinder the adoption of water harvesting structures like water pans, sand dams, and infiltration pits (Mutunga, Onywere & Karanja, 2020; Mohamed & Wasonga, 2019). Communal land tenure systems often discourage individual investment in long-term RWH infrastructure, while traditional pastoral mobility patterns conflict with the fixed nature of such installations (Wekesa et al., 2019). Despite these challenges, NGO- and donor-led interventions, including those by FAO and WFP, have demonstrated the value of RWH for improving fodder production and livestock feed security (FAO, 2021). At the local level, particularly in Habaswein, Wajir County, high poverty rates severely limit pastoralists' ability to invest in RWH infrastructure (Mohamed & Wasonga, 2019). Dependence on external food aid and commercial feeds reduces the perceived urgency of adopting local RWH solutions. Moreover, the lack of targeted credit schemes, low technical capacity, and inadequate extension services further discourage adoption (Wekesa et al., 2019; Mutunga et al., 2020).

2.5.4 Training and Extension Services Factors

The adoption of rainwater harvesting technologies (RWHT) in the fodder value chain within arid and semi-arid lands (ASALs) is significantly influenced by technical factors, particularly the availability of training and extension services. These services enhance awareness, build technical capacity, and equip farmers with skills necessary for the effective implementation and maintenance of RWH systems (Rockström et al., 2010; Sharma et al., 2016). However, inadequate extension support and limited technical training often hinder adoption, especially in resource-constrained settings (Mutunga, Onywere & Karanja, 2020).

Globally, countries like Israel and Australia have successfully scaled RWHT adoption through robust extension networks and investment in farmer training programs (Schwartz, Weisbrod & Yakirevich, 2017). Similarly, in India, government-led initiatives have trained smallholder farmers in techniques such as check dams and farm ponds, improving fodder security (Sharma, Singh & Kumar, 2016). Conversely, in Sub-Saharan Africa, weak extension infrastructure has limited RWHT adoption (Rockström et al., 2018). For example, in Ethiopia, a shortage of trained officers has hampered watershed-based RWH interventions (Gebregziabher, Namara & Holden, 2016), while in Niger and Burkina Faso, community-driven training programs have been instrumental in scaling up Zai pits and demi-lunes (Fatondji et al., 2016).

In Kenya, particularly in ASAL regions, limited extension capacity severely restricts RWHT dissemination. Most pastoralists and small-scale fodder producers lack access to guidance on selecting appropriate techniques, designing effective systems, and maintaining structures like water pans and sand dams (FAO, 2021). Government extension efforts often overlook ASAL-specific needs, while NGO-led initiatives, though impactful, remain limited in scale (Mohamed & Wasonga, 2019; WFP, 2021). At the local level in Habaswein, Wajir County, technical challenges are compounded by a shortage of agricultural officers, lack of vocational training, and reliance on indigenous knowledge. The absence of demonstration farms and practical training opportunities contributes to low awareness and scepticism toward RWHT (Wekesa et al., 2019; Mutunga et al., 2020). Without structured programs to support skill development, many installations fail due to poor construction and maintenance practices.

To overcome these barriers, increased investment in extension networks, localized training programs, and the creation of model RWHT projects is essential. Such efforts would build a skilled local workforce, promote knowledge transfer, and enhance the long-term sustainability of fodder production in ASALs (Fatondji et al., 2016). Addressing technical barriers must go hand-in-hand with tackling related socio-economic challenges, including financial constraints, land tenure insecurity, and limited policy support, to unlock the full potential of RWHT for climate-resilient pastoral livelihoods (Mekonnen, Kassa & Zeleke, 2019; Munyasia et al., 2022).

2.5.5 Study Variables

This study investigates the factors influencing the adoption and effectiveness of rainwater harvesting technologies (RWHT) in the fodder value chain within arid and semi-arid lands (ASALs), with a focus on Habaswein Sub-County, Wajir County. The research is guided by a set of independent, dependent, moderating, and extraneous variables that interact to shape RWHT outcomes. The independent variables include ecological factors (such as soil type and rainfall patterns), socio-economic characteristics (e.g., income, land tenure, education), access to training and extension services, and stakeholder support. Additionally, moderating variables such as policy support, community participation, and institutional frameworks may strengthen or weaken the relationships between the independent and dependent variables. The study also acknowledges potential extraneous variables, including demographic differences, prior project exposure, and market access, which could influence outcomes but are not directly measured. By analyzing these variables, the study aims to generate actionable insights for promoting sustainable fodder systems and climate resilience in ASALs.

2.5.5.1 Independent Variables

According to Mugenda and Mugenda (2019), variables in a study are critical components that help explain observed outcomes. In this research, the adoption and effectiveness of rainwater harvesting technologies (RWHT) within the fodder value chain in arid and semi-arid lands (ASALs) are shaped by a set of key independent variables namely, ecological factors, socio-economic characteristics, training and extension services, and stakeholder support. Ecological factors such as soil type, rainfall patterns, topography, and evaporation rates determine the physical feasibility and performance of RWHT. For instance, structures like Zai pits and semi-circular bunds perform best in sandy loam soils and areas with gentle slopes, but high evaporation and erratic rainfall

demand site-specific adaptations (Mekonnen, Kassa & Zeleke, 2019; Rockström et al., 2018). Socio-economic variables—including household income, education level, land tenure security, and credit access—affect the likelihood of RWHT adoption. Households with secure land tenure and higher income are more willing and able to invest in long-term water infrastructure. Conversely, low income and insecure tenure are persistent barriers in marginalized pastoral communities (Mohamed & Wasonga, 2019; Munyasia et al., 2022).

Training and extension services are pivotal for equipping farmers with technical knowledge and skills. Participation in structured training enhances awareness, proper installation, and maintenance of RWHT. However, in places like Habaswein, poor access to extension support and vocational programs limits local technical capacity (Sharma et al., 2016; Mutunga et al., 2020). Stakeholder support services—including inputs from government agencies, NGOs, and development partners like WFP—create an enabling environment for adoption. Programs such as Food Assistance for Assets (FFA) have promoted infrastructure development, capacity building, and input provision, thereby increasing community engagement and sustainability (WFP, 2022).

These independent variables directly affect two dependent variables: Adoption of RWHT, measured by household adoption and continued use, which depends on ecological fit, financial ability, access to knowledge, and institutional support (De Graaff et al., 2008; Rockström et al., 2010). Effectiveness, which reflects the contribution of RWHT to improved fodder production, livestock productivity, water-use efficiency, and household income and resilience. Success is linked to appropriate technology selection, regular maintenance, and strong community ownership (Fatondji et al., 2016).

2.5.5.2 Dependent Variables

According to Mugenda and Mugenda (2019), a dependent variable is one that is influenced or changed by other factors, often referred to as independent variables. In this study, the adoption and effectiveness of rainwater harvesting technologies (RWHT) within the fodder value chain in Habaswein Sub-County, Wajir County, are treated as dependent variables shaped by ecological, socio-economic, and institutional factors. Adoption refers to the extent to which pastoralist and agro-pastoralist households have embraced technologies such as Zai pits, contour bunds, semi-circular bunds, and other micro-catchment systems. It is assessed through stages of awareness, trial,

and continued use (De Graaff et al., 2008). Factors such as land tenure security, income level, education, and access to training and extension services play a pivotal role in facilitating adoption (Sharma et al., 2016; Mohamed & Wasonga, 2019). However, in ASAL regions like Habaswein, adoption remains limited due to financial constraints, low awareness, and weak institutional outreach (Munyasia et al., 2022).

Effectiveness, on the other hand, measures the extent to which RWHT contributes to improved fodder production and enhanced resilience of livestock-based livelihoods. Key indicators include soil moisture retention, fodder yield, water-use efficiency, and household income stability. Studies show that well-designed and maintained RWHT systems can reduce livestock mortality, enhance pasture regeneration, and decrease reliance on distress livestock sales during droughts (Rockström et al., 2010; Fatondji et al., 2016). In Habaswein, technologies like Zai pits, particularly when used with mulching and organic matter, have shown promise in improving infiltration and soil fertility on sandy soils (Mekonnen, Kassa & Zeleke, 2019). Yet, effectiveness is conditional on proper application, ecological suitability, and ongoing maintenance. The interaction between independent variables—such as ecological suitability, socio-economic characteristics, training and extension support, and stakeholder engagement—and these dependent outcomes determines the scalability and sustainability of RWHT in ASALs. Integrated and context-specific strategies are therefore essential to strengthen fodder systems, promote pastoral resilience, and guide evidence-based policy interventions in drought-prone environments. The conceptual framework is illustrated below (Figure 2.2).

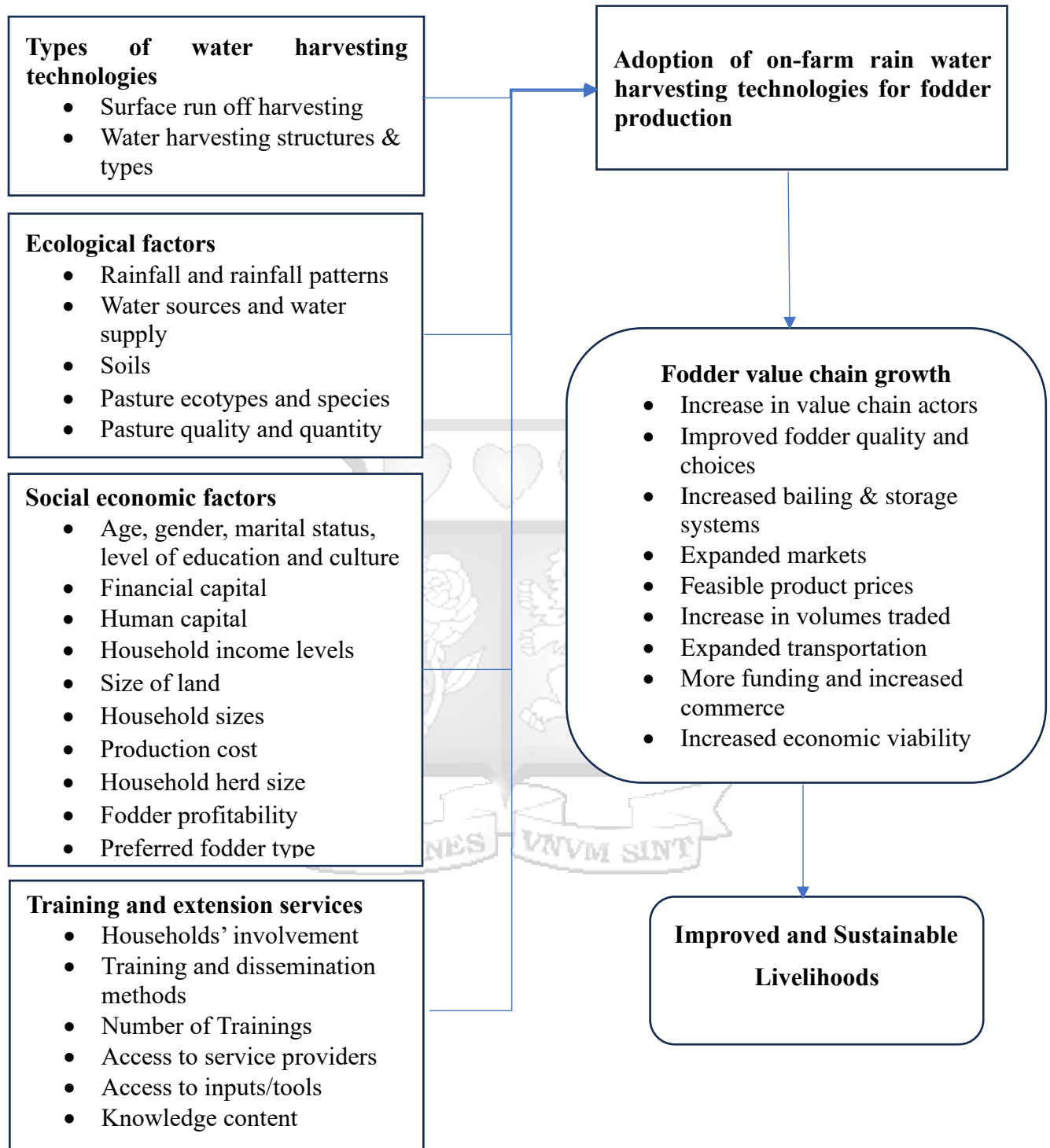


Figure 2.2 :A conceptual framework in this study. Source: Research (2025)

Table 2. 2 Data Analysis Matrix

Objective	Variable indicator	Scale of Measurement	Data Analysis	Software
Assessing the ecological factors	Rainfall Drought Soils	Frequencies/ counts	Descriptives Cross-tabulations and chi-square test with z-proportion tests ANOVA (technology land area x soil type x site model) regression) GLM (generalised linear model)	SPSS (cross-tabulation and z-proportion tests) GLM – R software
Assessing socioeconomic factors in RWHT adoption in the fodder value chain	Age, education level, labour source, number of farming years, household size, economic endowment (farm and non-farm income), TLU, land under crop production, marital status, occupation, education	Quantitative and categorical data	Descriptives Cross-tabulations and chi-square test with z-proportion tests GLM (generalised linear model) regression	SPSS (cross-tabulation and z-proportion tests) GLM – R software
To assess the impact capacity building on the adoption of Rainwater Harvesting Technologies (RWHT)	Types of extension services Number of trainings attended	Qualitative and numeric data	Descriptives Cross-tabulations and chi-square test with z-proportion tests Regression between number of trainings and technology land area	SPSS, R, and Genstat for means separation

Source: Research (2025)

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the methodology utilized in the study, covering aspects such as the research design, target population, sample sizes, and data collection and data analysis methods. It further discusses the sampling procedure and research instruments, evaluating their validity and reliability.

3.2 Philosophy of Research

A philosophy pertains to beliefs guiding the gathering, analysis, and utilization of data regarding a phenomenon. Wang (2012) and Bajpai (2011) assert that it addresses the origin, essence, and progression of knowledge. The choice of research philosophy is fundamental in determining the approach, methodology, and interpretation of findings in any study (Saunders, Lewis & Thornhill, 2019). In assessing the influence of rainwater harvesting (RWH) within the fodder value chain in Habaswein, Wajir County, the study adopts a pragmatist research philosophy, integrating both postpositivist, pragmatic and interpretivist paradigms.

Pragmatism is appropriate for this research as it allows for the combination of quantitative and qualitative methods to provide a comprehensive understanding of RWH's impact on fodder production, livelihoods, and climate resilience whose analysis combines quantitative and qualitative analysis (Creswell & Creswell, 2018). This approach recognizes that no single method can fully capture the complexities of socio-ecological systems in arid and semi-arid lands (ASALs) (Tashakkori & Teddlie, 2010). From a postpositivist perspective, the study quantifies the effectiveness of RWH techniques in improving fodder production, measuring variables such as water retention rates, fodder yield, and economic benefits for pastoral communities. This aligns with empirical research principles, emphasizing objective data collection and statistical analysis (Bryman, 2016). On the other hand, an interpretivist lens is essential in understanding the perceptions, experiences, and decision-making processes of local farmers and pastoralists regarding RWH adoption. This approach acknowledges the social and contextual factors influencing technology adoption, such as cultural attitudes, policy frameworks, and extension services (Lincoln & Guba, 1985).

3.3 Research Design

A research design is a strategy to conclusively address the research questions (Ranganathan and Aggarwal 2018). It comprises methodology and instruments to gather and analyze data accurately to test the hypothesis or answer research questions. This study adopted a mixed method research design combining quantitative and qualitative data to fully answer the research questions. The quantitative and qualitative data were collected, analyzed, and converged using the parallel convergence triangulation model during the data interpretation phase (Mugenda & Mugenda, 2019). The mixed method design was preferred as it permits the researcher to utilize concurrent procedures, merging both qualitative and quantitative methods to comprehensively analyse the study phenomenon. Furthermore, the mixed-method design was chosen for its ability to generalize the findings from the targeted population and produce standardized data from a representative sample, thus providing numerical insights into the adoption of rainwater harvesting technologies in fodder production.

3.4 Study Population and Sampling

3.4.1 Population of the Study

The target population for this study consisted of pastoral and agro-pastoral households in Habaswein Sub-County, Wajir County, who were beneficiaries of the World Food Programme's (WFP) Food Assistance for Assets (FFA) initiative. These households had adopted various rainwater harvesting technologies (RWHT) and were actively involved in fodder cultivation.

3.4.2 Sampling

To determine the appropriate sample size Yamane's (1967) formula was used. This formula provides a simplified approach to calculating sample size by considering population size and a given margin of error. Yamane (1967) proposed the following formula for determining a representative sample size:

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

Where:

n = required sample size

N = total population size

e = margin of error (typically set at 5% or 0.05 for a 95% confidence level)

For this study, the target population (N) of fodder-producing and livestock-keeping households in Habaswein is 420. This sampling strategy is informed by data from World Food Programme (WFP). (2019). End of Project Report: Food Assistance for Assets (PRRO200736), as outlined in Table 3.1.

Applying the formula with a 5% margin of error (0.05):

$$n = \frac{N}{1 + N(e^2)} = \frac{420}{1 + 420(0.05^2)} = 205$$

Table 3. 1: Sample size matrix

Village	Target population	Sample size
Zeitun	100	43
Sabena	100	42
Tarakley	150	62
Injir	70	58
Total	420	205

Source: End of Project Report: Food Assistance for Assets (PRRO200736),

The variation of sample size with level of confidence and level of acceptable error is illustrated in Table 3.2 (derived from Goodchild et al., 1994).

Table 3. 2: Relationship between sample size, confidence intervals, and acceptable error

Level of acceptable error	A = 0.10 (90% confidence)	A = 0.05 (95% confidence)	A = 0.01 (99% confidence)
	Number of samples		
0.01	2,704	4,330	8,656
0.02	676	1,082	2,164
0.03	300	481	962
0.04	169	271	541
0.05	108	173	346
0.07	55	88	176
0.10	27	43	87
0.15	12	19	38
0.20	7	11	22
0.25	4	7	14

Source: (derived from Goodchild et al., 1994).

The selection of 205 households was through a stratified and systematic approach that ensured representativeness while maintaining a balance between statistical rigor and logistical feasibility. By incorporating a diverse set of participants, the study was able to provide comprehensive insights into the influence of RWH on fodder production and pastoral resilience in Habaswein, Wajir County.

3.5 Procedures of Data Collection

The study utilized a self-administered structured questionnaire for quantitative data collection in a survey and a key informant interviews and focused group discussions for qualitative insights. The questionnaire gathered standardized data on various aspects of adoption of rainwater harvesting technologies while the key informant interviews and focused group discussions provided in-depth qualitative perspectives. This combination allowed a comprehensive examination of the factors that influence adoption of rainwater harvesting technologies.

The survey tool was organized into four main parts aligned with the study objectives. To ensure representativeness and minimize selection bias, this study employed a multi-stage sampling technique. The first stage was the clustering of the farmers into three villages including Kibilay, Ndege and Uthole that had a population of 420 farmers incorporated in the United Nations World Food Programme Food Assistance for Assets (FFA) project. The second stage was the random selection using the farmer lists in each village in an Excel spreadsheet. The Excel randomizer function was used to randomly select and list the farmers in each village that would be included in

the study. Out of the more than 400 farmers in the FFA project, 205 households involved in fodder production and pastoralism in Habaswein Sub-County were selected. The approach was designed to capture diverse socio-economic and ecological conditions influencing the adoption of Rainwater Harvesting Technologies (RWHT). In the first stage, Habaswein Sub-County was stratified into distinct clusters based on settlement patterns, livelihood activities (pastoralism, agro-pastoralism, and fodder cultivation), and participation in the World Food Programme's Food Assistance for Assets (FFA) initiative. This stratification enabled the study to ensure that variations in RWHT adoption could be examined across different socio-economic and environmental contexts (Creswell & Creswell, 2018). Within each stratum, simple random sampling was applied to select households. A sampling frame of eligible households defined as those participating in fodder production, livestock keeping, or both was developed using beneficiary lists provided by the WFP and the Wajir County Department of Agriculture. From these lists, households were randomly selected using a random number generator to eliminate subjective selection and ensure each household had an equal probability of being chosen (Bryman, 2016). This method allowed for the inclusion of both RWHT adopters and non-adopters, enabling comparative analysis of adoption factors. It also ensured that the final sample of 205 households, calculated using Yamane's (1967) formula for sample size determination, achieved statistical representativeness at a 95% confidence level with a 5% margin of error. By incorporating random sampling within a stratified framework, the study ensured a balanced, unbiased representative sample. This strengthened the reliability and generalizability of findings related to the adoption and effectiveness of RWHT in the context of ASAL livelihoods.

3.5.2 Focused Group Discussions

The study conducted 12 focused group discussions (FGDs) to capture diverse perspectives from local communities, including smallholder farmers, pastoralists, and women's groups involved in fodder production. FGDs were crucial in understanding community-level experiences, socio-economic barriers, and behavioural factors influencing RWHT adoption (Krueger & Casey, 2015). Each FGD consisted of 8-12 participants, with a total of 120 respondents. The distribution of FGDs was as follows; 4 FGDs with pastoralist communities to assess their perceptions of RWHT and its impact on livestock productivity, 3 FGDs with smallholder fodder farmers to understand their experiences with in-situ and micro-catchment techniques, 3 FGDs with women's self-help groups engaged in fodder production and water conservation initiatives 2 FGDs with youth groups and local

entrepreneurs involved in the fodder value chain, such as transporters and traders. The decision to conduct 12 FGDs was based on data saturation principles in ensuring that all relevant themes were thoroughly explored while maintaining manageable discussion sizes (Guest, Namey & Mitchell, 2017).

3.5.3 Key Informant Interview Guide

Key informant interviews (KIIs) were conducted to gather qualitative insights from knowledgeable individuals regarding the factors influencing the adoption of Rainwater Harvesting Technologies (RWHT) for fodder production in Habaswein Sub-County. The key informants included purposively selected individuals' agricultural extension officers, water resource managers, government officials, and NGO representatives, who possess valuable insights into Rainwater Harvesting Technologies (RWHT) within their respective organizations. The KII guide was developed by the researcher based on the study objectives and informed by the existing literature on adoption of Rainwater Harvesting Technologies (RWHT). Through these interviews, data were collected to explore factors influencing the adoption of Rainwater Harvesting Technologies (RWHT), as well as to identify strategies for improving fodder production in Habaswein. Key informant interviews were valuable as they provided unique perspectives and insights that complemented quantitative data, offering a comprehensive understanding of the factors influencing the adoption of Rainwater Harvesting Technologies (RWHT) for fodder production in Habaswein Sub-County. Key Informant Interviews (KIIs) were conducted to gather in-depth insights from stakeholders directly involved in rainwater harvesting (RWH) and the fodder value chain. The interviews targeted experts, policymakers, extension officers, and community leaders with specialized knowledge on water conservation, pastoral livelihoods, and fodder production in arid and semi-arid lands (ASALs) and as according to (Bryman, 2016). A total of 24 KIIs were carried out, comprising; 5 agricultural and livestock officers from Wajir County and national government agencies 5 representatives from non-governmental organizations (NGOs) involved in climate resilience and food security projects 5 local leaders (chiefs and elders) with extensive knowledge of traditional water management practices, 4 researchers/academics specializing in ASAL development and fodder production, 5 private sector actors in the fodder value chain, such as traders and cooperatives.

3.7 Research Quality

The quality of this study was upheld through careful attention to both internal reliability, content validity, and by removing sampling bias that ensured a strengthened design and approach. Several questionnaire tests were conducted and further adjusted to ensure fidelity to purpose for the expected results. The number of data samples (households) surveyed conforms to a rigorous statistical data collection procedure that ensures confidence of the obtained results as presented in section 3.4.2. The 205 data samples collected conforms to a 95% confidence level and a 0.05 error level which are statistically accepted and gives credence to the integrity of the method used. The questionnaires were further translated to the local language for ease of understanding by the respondents. Further to this, the data collection assistants spoke both English and the local language, thereby giving more credence to the data collection methodology. The data analysis software packages and analytical methods also conform to the best tools available for such a study. The level of statistical confidence gives replication of the obtained results to other areas with a very good level of confidence. According to Saunders, Lewis, and Thornhill (2019), ensuring high study quality involves systematically addressing how well a research instrument measures what it intends to measure (validity) and whether it yields consistent results across different contexts and respondents (reliability). The combination of quantitative and qualitative data in a mixed method provided a pragmatic approach to the study where observations made from the quantitative analysis are confirmed and further triangulated and explained by the qualitative analysis results.

3.7.1. Reliability

To ensure internal reliability, the questionnaire was structured using standardized, clearly worded items aligned with the research objectives and conceptual framework. Questions were grouped thematically to ensure logical flow, minimize respondent fatigue, and enhance consistency in interpretation. The use of closed-ended questions with pre-defined response options reduced ambiguity and helped maintain measurement consistency across participants. Pilot testing was conducted with six purposively selected respondents from Kibilay village like the target population but outside the final sample. The pilot enabled the researcher to identify and rectify issues related to clarity, question structure, and potential biases in interpretation. Feedback from the pilot phase was used to revise ambiguous items, improve response scaling, and validate the appropriateness of language and terminology for the local context.

3.7.2. Validity

To strengthen the questionnaire construction validity, each section of the questionnaire was mapped directly to the study's research questions and theoretical constructs specifically those relating to socio-economic, ecological, and institutional factors influencing the adoption of Rainwater Harvesting Technologies (RWHT). This alignment ensured that the instrument captured the intended variables and adequately captured the underlying concepts. Moreover, content validity was enhanced through expert review of the questionnaire by academic supervisors and field specialists in water resource management and agricultural development. This review helped confirm that the tool comprehensively covered all relevant dimensions of the study. By integrating principles of reliability and validity throughout the instrument development process, the study enhanced the credibility, replicability, and accuracy of its findings, ensuring that the data collected would provide meaningful insights into the adoption of RWHT in Habaswein, Wajir County.

3.8 Data Analysis

Quantitative data from household surveys were analyzed using SPSS (Statistical Package for the Social Sciences) to generate descriptive statistics, cross-tabulations, and inferential analyses (Pallant, 2020). Qualitative data from FGDs and KIIs were analyzed using thematic content analysis, identifying key themes related to RWHT adoption and challenges (Braun & Clarke, 2006). Descriptive statistics were used to assess the adoption of technology adoption of *Zai pits*, contour bunds and semi-circular bunds. Cross-tabulations and chi-square tests were used to test adoption levels in Kibilay, Uthole and Ndege villages (sites) using SPSS software. Proportion z-tests were used to test significant differences between adoption levels and sites. 1-way analysis of variance (ANOVA) was evaluated within sites, followed by LSD (least significant difference) using the Genstat software. Regression analyses were used to test between the selected technologies and the household annual fodder income using SPSS software and procedures.

To assess the socio-economic factors of RWHT adoption, chi-square tests were used to associate categorical variables within sites, while One-Way analysis of variance (ANOVA) and LSD tests were used to test mean differences between numeric socio-economic variables in sites. A general linear regression model was used to test the effect of socio-economic, ecological, and the capacity building variables. The explanatory variables included soil type (x_{i1}), weather challenges (x_{i2}), age

(x_{i3}), household size (x_{i4}), residence years (x_{i5}), land area distribution (x_{i6} - x_{i8}), (crop land, fodder land, private land), total livestock units (TLU, x_{i9}), training (x_{i10}), and extension (x_{i11}).

The regression model function is shown in Equation 3.1:

$$y_i = \beta_0 + \beta_{1x_{i1}} + \beta_{2x_{i2}} + \beta_{3x_{i3}} + \dots + \beta_{px_{ip}} + \epsilon \quad \dots\dots\dots \text{Equation (3.1)}$$

where y_i =technology land area, x_i =explanatory variables. β_0 =y-intercept (constant term), β_p =slope coefficients for each explanatory variable, ϵ =the model's error term

Farmer perceptions of determinants for adoption were subjected to descriptives and ANOVAs by site. The means were ranked to determine the most important technology aspects that influenced their adoption. To assess the effect of capacity building on rainwater harvesting adoption, descriptive statistics and cross-tabulations were implemented between types of extension services and sites. The number of trainings attended were regressed with technology land areas to determine the effect of training on technology land areas. Cost-benefit analysis was used to determine the profitability of fodder production. Descriptive statistics were used to assess the fodder production costs related to the crop cycle (including land preparation, planting, harvesting costs), revenue, and fodder profits. 1-way ANOVA (site) was implemented to determine differences in variable costs, revenue and gross margins between sites.

3.9 Ethical Considerations

Ethical compliance was central to the design and execution of this study, ensuring adherence to established principles of research integrity, transparency, and participant protection. Ethical approval for the study was obtained from the Strathmore University Institutional Scientific and Ethical Review Committee (SU-SERC). Further authorization, including a research license, was granted by the National Commission for Science, Technology and Innovation (NACOSTI). Additionally, clearance was secured from the Wajir County Department of Agriculture to ensure alignment with both national regulations and local administrative protocols. Informed consent was obtained from all participants prior to data collection. Each participant received a clear explanation of the study's purpose, the voluntary nature of their involvement, and their right to decline or withdraw at any stage without penalty. Participants were also informed that the information provided would be treated with strict confidentiality and used solely for academic and research purposes. Any

future use or sharing of data would require their explicit written consent. To uphold ethical transparency, participants were recruited using approved consent forms, which emphasized their rights and the protection of their personal information. The process aligned with best practices in research ethics, ensuring respect for autonomy, confidentiality, and the voluntary nature of participation, in accordance with guidelines provided by Bell and Bryman (2007).



CHAPTER FOUR: RESULTS AND FINDINGS

4.1 Introduction

This chapter presents the analysis of data collected on the factors influencing the adoption of rainwater harvesting technologies (RWHT) in fodder production within Habaswein Sub-County. The findings are interpreted with reference to the literature reviewed in Chapter Two and are supported by tables and figures for clarity. The chapter is organized into four main sections, covering: (i) rainwater harvesting technologies; (ii) ecological factors; (iii) socio-economic factors; and (iv) training and extension services. Each section includes a detailed analysis and discussion of the data in relation to the study objectives and research questions. The results are presented thematically to align with the key variables and objectives of the study.

4.2 Response rate

Table 4. 1 Response Rate

Distributed Questions	205
Total Responses received back	205
Response Rate	100%

Source: Research (2025)

Out of 205 targeted sample, the response rate was at 100%. The response rates align with the recommended threshold of 60% for sufficient analysis and reporting, thus ensuring high representativeness and generalization of study findings (Mugenda and Mugenda, 2019).

4.3 Quantitative Analysis

4.3.1 Demographic Characteristics

The following section presents the socio-economic characteristics of respondents, with a focus on both categorical and numerical household attributes, as detailed in Table 4.2 and Table 4.3. socio-economic variables examined included gender, marital status, crops grown, years of residence in Habaswein, occupation, education level, age of the respondent, years of farming experience, monthly net income (Kshs), non-farm income (Kshs), land ownership (in acres), land under crop production, land under fodder, and Total Livestock Units (TLU).

Values are presented as frequencies and column percentages. To assess associations between study sites and these socio-economic variables, Chi-square (χ^2) tests were employed. Where significant associations were identified, column proportion Z-tests were conducted to pinpoint specific differences between site proportions. To interpret these comparisons, column proportions within a row that are followed by different superscript letters (e.g., a, b, c) indicate statistically significant differences at the specified alpha level. The following significance codes were used to denote levels of statistical significance: *ns*=not significant, $p < 0.05$ (*), $p < 0.01$ (**) and $p < 0.001$ (***). These notations aid in quickly identifying which socio-economic variables significantly differ across study sites and where those differences lie.

Table 4. 2: Household socio-economic characteristics by Location in Habaswein (categorical variables)

Parameters		Kibilay	Ndege	Uthole	Pooled	χ^2 test
<i>Sample size (n)</i>		62	58	85	205	
Gender	Female	34ab (54.8)	26b (44.8)	54a (63.5)	114 (55.6)	*
	Male	28ab (45.2)	32b (55.2)	31a (36.5)	91 (44.4)	
Marital status	Divorced	0 (0)	1 (1.7)	1 (1.2)	2 (1)	ns
	Married	59 (95.2)	54 (93.1)	77 (90.6)	190 (92.7)	
	Single	2 (3.2)	0 (0)	3 (3.5)	5 (2.4)	
	Widowed	1 (1.6)	3 (5.2)	4 (4.7)	8 (3.9)	
Crops grown	Fodder	0a (0)	16b (27.6)	0a (0)	16 (7.8)	***
	Food crops	0a b (0)	3b (5.2)	0a (0)	3 (1.5)	
	Crops+Fodder	62a (100)	39b (67.2)	85a (100)	186 (90.7)	
Years resident in Habaswein	1 -10	0a (0)	8b (13.8)	7b (8.2)	15 (7.3)	***
	11- 20	20a (32.3)	17a (29.3)	42b (49.4)	79 (38.5)	
	21-40	17a (27.4)	28b (48.3)	25a (29.4)	70 (34.1)	
	41-50	17a (27.4)	5b (8.6)	6b (7.1)	28 (13.7)	
	> 50	8a (12.9)	0b (0)	5a, b (5.9)	13 (6.3)	
Occupation	Employed	0 (0)	2 (3.4)	0 (0)	2 (1)	ns
	Farming	62 (100)	56 (96.6)	85 (100)	203 (99)	
Education levels	None	56a (90.3)	48a (82.8)	74a (87.1)	178 (86.8)	*
	Primary	3ab (4.8)	8b (13.8)	1a (1.2)	12 (5.9)	
	Secondary	1a (1.6)	2a (3.4)	5a (5.9)	8 (3.9)	
	Tertiary	2a (3.2)	0a (0)	5a (5.9)	7 (3.4)	

Source: Research (2025)

4.3.1.1 Respondent's Gender and study area

The analysed data in Table 4.1 above, shows that female respondents consisted 55.6% of the respondents, while males were 44.4 %, across the study locations. Female respondents made up 55.6% of the sample, with the highest proportion in Uthole (63.5%), followed by Kibilay (54.8%), and Ndege (44.8%). A significant gender difference was observed between Uthole and Ndege. According to Chang et al., (2018), there is significant evidence that gender diversity positively influences adoption of rainwater harvesting technologies (RWHT). This gender distribution has critical implications for the adoption of Rainwater Harvesting Technologies (RWHT) in the study area. The predominance of women among respondents suggests that women would play a central role in agricultural activities, including fodder production, which is closely linked to RWHT. The significantly higher female participation in Uthole implies that site-specific socio-cultural or economic factors may be more contributed to by women's involvement including RWHT-related activities. In such locations, gender-responsive interventions that empower women through targeted training, access to inputs, and leadership in water user groups could enhance RWHT adoption rates (UN Women, 2020). Furthermore, in settings like Ndege with lower female participation, there may be structural or cultural barriers limiting women's engagement, warranting further investigation and tailored approaches. This observation is consistent with broader research indicating that women in arid and semi-arid lands (ASALs) are often at the forefront of household-level water and resource management, particularly in smallholder and subsistence farming systems (FAO, 2011).

In many pastoral communities, resource ownership and land tenure are often mediated through male heads of households, which may impact women's ability to independently adopt or invest in RWHT (Bryan et al., 2018). As such, RWHT programs must consider not only gender representation but also intra-household power relations that affect access to and control over productive resources.

Ultimately, the gender diversity observed in this study underscores the importance of mainstreaming gender in RWHT promotion strategies. Women's substantial involvement presents an opportunity to design and implement inclusive, context-specific, and participatory RWHT models that acknowledge their contributions and address their constraints. Enhancing women's access to extension services, technical skills, and financial resources is likely to improve both the adoption and sustainability of RWHT in pastoral communities.

4.3.1.2 Respondent's crops grown and number of years living in Habaswein

The study revealed that 90.7% of respondents in Habaswein Sub-County engaged in combined food crop and fodder production (Table 4.1), with only 7.8% practicing sole fodder production and 1.5% producing food crops exclusively. A significant association was found between location and cropping system, with all farmers in Kibilay and Uthole engaged in mixed production, compared to 67.2% in Ndege. This variation indicates that cropping practices are spatially influenced, likely reflecting differing access to resources, land suitability, and livelihood strategies. The predominance of integrated cropping systems suggests that farmers in the region are inclined to diversify their production to enhance household food security and reduce climate-related risks a strategy that aligns well with the adoption of RWHT. Integrating food and fodder production demands greater water availability, making RWHT more attractive and necessary. Farmers producing both crops and fodder are more likely to perceive the utility of RWHT in improving water-use efficiency, stabilizing yields, and supporting livestock through reliable forage supply. Hence, combined cropping systems create a stronger incentive for RWHT adoption compared to monoculture practices.

In addition, the study found that most respondents had lived in Habaswein for 11–20 years (38.5%) or 21-40 years (34.1%), with smaller proportions residing for longer periods. A significant association was observed between years of residence and location, where all residents in Kibilay had stayed for more than 11 years, and those in Ndege and Uthole mostly between 11- 40 years. This duration of residence has direct implications for RWHT adoption. Households that have lived in the area for longer are more likely to be familiar with local climatic trends, land productivity, and water scarcity issues, making them more aware of the benefits of water conservation practices. Moreover, longer-term residence is often correlated with greater social integration, accumulated farming experience, and sometimes improved land tenure security—all factors known to positively influence the adoption of agricultural innovations like RWHT (Bryan et al., 2018; Kassie et al., 2015). Such farmers may have also had prior exposure to development programs such as WFP's Food Assistance for Assets (FFA), further increasing their likelihood of adopting new technologies.

Predominance of combined cropping systems and the long duration of residence among respondents underscore key factors that potentially facilitate RWHT adoption. Farmers who are both diversified in production and well-settled in the community may have stronger motivations and better

capabilities to invest in water harvesting technologies. These insights highlight the importance of tailoring RWHT promotion strategies to cropping patterns and residency characteristics, ensuring that extension efforts and resource allocation are context-specific and equity-oriented

4.3.1.3 Respondents education levels

The study found a significant association between education levels and location, though most respondents across all sites had no formal education (86.7%). Only 5.9% had attained primary education, while 3.9% and 3.4% had reached secondary and tertiary levels, respectively. Notably, the proportion of respondents with primary education was significantly higher in Kibilay (4.8%) and Ndege (13.8%) compared to Uthole (1.2%), while other education levels did not vary significantly by site. These findings have important implications for the adoption of Rainwater Harvesting Technologies (RWHT). Education enhances farmers' capacity to access, interpret, and apply technical information, which is essential for adopting and maintaining RWHT effectively (Kassie et al., 2015). Higher education levels are often associated with greater awareness of environmental risks, better understanding of water-saving techniques, and increased openness to innovation (Asfaw et al., 2012). The low levels of formal education across the study area suggest that literacy-related barriers may hinder the adoption of RWHT, especially where technologies require technical understanding or engagement with extension materials. However, areas like Ndege, with relatively higher proportions of educated individuals, may present more favourable environments for knowledge-based interventions. Therefore, tailored capacity-building and training programs that use visual aids, demonstrations, and local languages are critical to bridge knowledge gaps and foster adoption in low-literacy contexts like Uthole. Moreover, the findings highlight the need for inclusive extension strategies that do not assume formal education, but instead leverage indigenous knowledge and practical demonstrations to support RWHT dissemination.

4.4 Descriptive Statistics on Independent Variables

4.4.1 Rainwater harvesting technologies

The descriptive statistics presented in Table 4.4.1 below provide insights into the level of

Table 4.4 1: shows annual income from fodder and crop generated from RWHT, and the average annual RWHT annual investment by households in Habaswein. Source: Research (2025)

Parameters	Kibilay	Ndege	Uthole	All sites	ANOVA
Age of the respondent	48.5 ±16.3	47.1 ±11.5	45.5 ±13.6	46.8 ±13.9	ns
Years of farming experience	11.7 ±4.6	9.9 ±6.7	11.6 ±5.1	11.2 ±5.5	ns
Monthly net income (Kshs)	4,975.8 b±4,277.7	15,969.1a ±39,903.3	6,870.6b ±6,554.8	8,871.8 ±22,105.8	*
Non-farm income (Kshs)	588.7b ±1,678.0	10,051.7a ±32,752.1	3,823.5b ±3,955.6	4,607.3 ±17,905.3	*
Own land size (Acres)	3.1 ±0.9	3.2 ±0.9	2.9 ±1.1	3.0 ±1.0	ns
Land under crop production (Acre)	2.0 ±0.7	1.8 ±0.6	1.8 ±0.9	1.8 ±0.8	ns
Land under fodder (Acre)	1.0ab ±0.3	1.1a ±0.4	0.9b ±0.4	1.0 ±0.4	*
TLU	14.9 a±17.8	5.6 b±9.4	5.8b ±5.6	8.5±12.2	***

Table 4.4 2: Average RWHT income from crop/fodder production and annual investments in RWHT technologies by locations (Means and standard deviations)

Parameter	Kibilay	Ndege	Uthole	Pooled	ANOVA
Income from fodder (Kshs/HH/yr)	3,802.9 b ±4,071.6	7,789.7a ±26,445.4	3,402.4b ±3,365.1	5,730.6 ±14,728.6	***
Crop income produced using harvested water (Kshs/HH/yr)	3,091.9b ±3,929.8	11,225.9a ±33,712.8	3,368.2b ±3,789.3	5,507.8 ±18,468.2	*
Annual RWHT investment (Kshs/HH/yr)	2,851.6b ±3,710.1	8,419.0a ±9841.6	3,744.7 b±3,602.3	4797.1 ±6470.2	**

Source: Research (2025)

The results showed that the income from fodder and crops using harvested rainfall and the annual investment in RWHT was significantly different between locations. The average income from fodder was highest in Ndege, followed by Kibilay and Uthole, but Ndege recorded significantly different fodder income from other locations. In addition, the mean income from crops was highest

in Ndege, followed by Uthole and Kibilay. The average investments in RWHT was also highest and significantly different in Ndege (Kshs.8,419), relative to Kibilay (Kshs.2,851.6) and Uthole (3,744.7).

Figure 4.1 shows the regression between annual RWHT investments and crop income derived from RWHT investment and the fodder income derived from annual RWHT investments across the three sites.

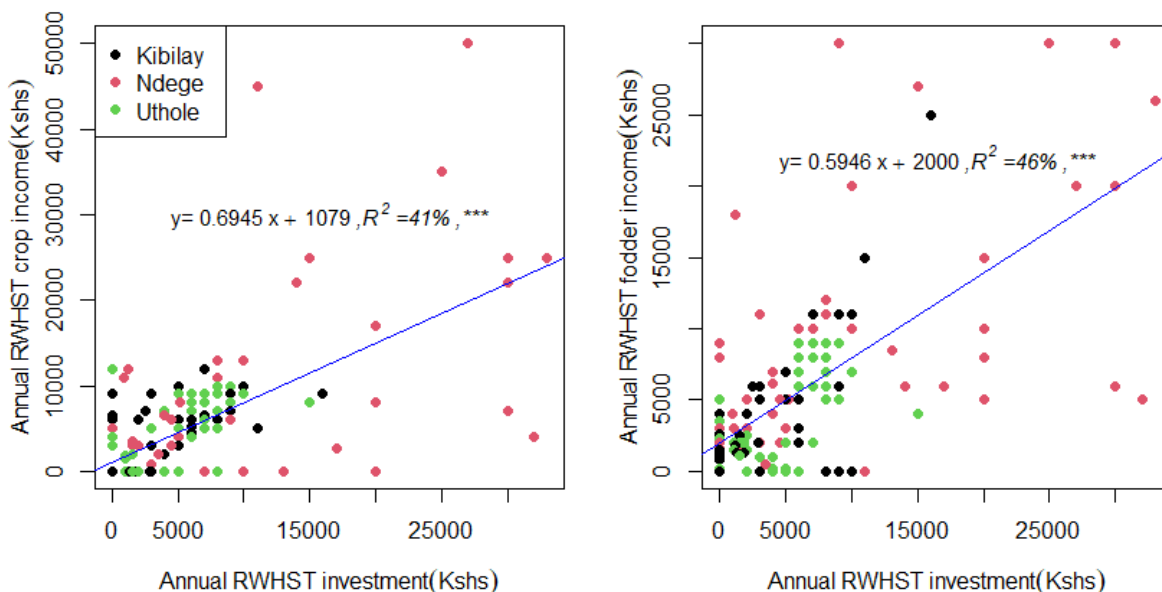


Figure 4.3: Regression between annual RWHT investment, crop and fodder income from RWHT investment Source: Research (2025)

The regression model between annual RWHT investments and annual RWHT crop income was linear and positively regressed (Figure 4.1). The annual crop income increased by 69.5 cents, for each Ksh.1 investment on average, given an intercept crop value of Kshs.1,079. In addition, the annual fodder income increased by 59 cents for each Ksh.1 invested in RWHT, with a higher intercept value of Ksh.2,000 in fodder income based on the amount of money invested. The difference in the intercept base on the regression analysis means that investments in fodder create higher initial returns (Kshs 921) compared to other crops farming though the rate of returns per Kenya Shilling invested in crops is at a higher rate for every Kshs invested in fodder. The results also showed that there was higher variation in Ndege compared to Kibilay and Uthole locations.

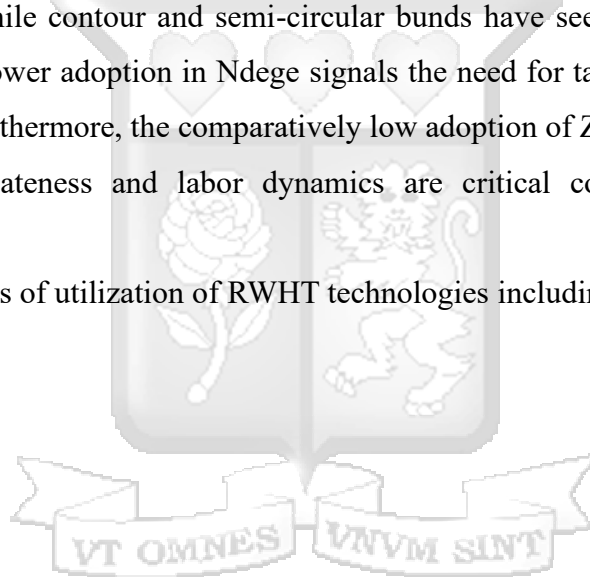
4.5 Descriptive Statistics on Independent Variables

4.5.1 Rainwater harvesting technologies

a) Levels of utilization of RWHT technologies

Zai pits adoption percentage was lowest in Kibilay (50%), (Table 4.6) while Ndege and Uthole recorded higher adoption rates for *Zai pits*. Contour bunds adoption was much higher in Uthole and Kibilay (nearly all farmers), relative to Ndege (81% of farmers), which recorded lower adoption rates. The adoption pattern for semicircular bunds was also similar to that of contour bunds, with Kibilay and Uthole recording higher adoption rates, relative to Ndege location. There were significant differences in adoption rates of all technologies by locations. The spatial variation in RWHT adoption underscores the necessity of context-sensitive approaches to scaling climate-resilient technologies. While contour and semi-circular bunds have seen widespread adoption in Kibilay and Uthole, the lower adoption in Ndege signals the need for targeted support to enhance access and awareness. Furthermore, the comparatively low adoption of Zai pits in Kibilay suggests that technology appropriateness and labor dynamics are critical considerations in adoption decisions.

Figure 4.2 shows the levels of utilization of RWHT technologies including *Zai pits*, contour bunds, and semi-circular bunds.



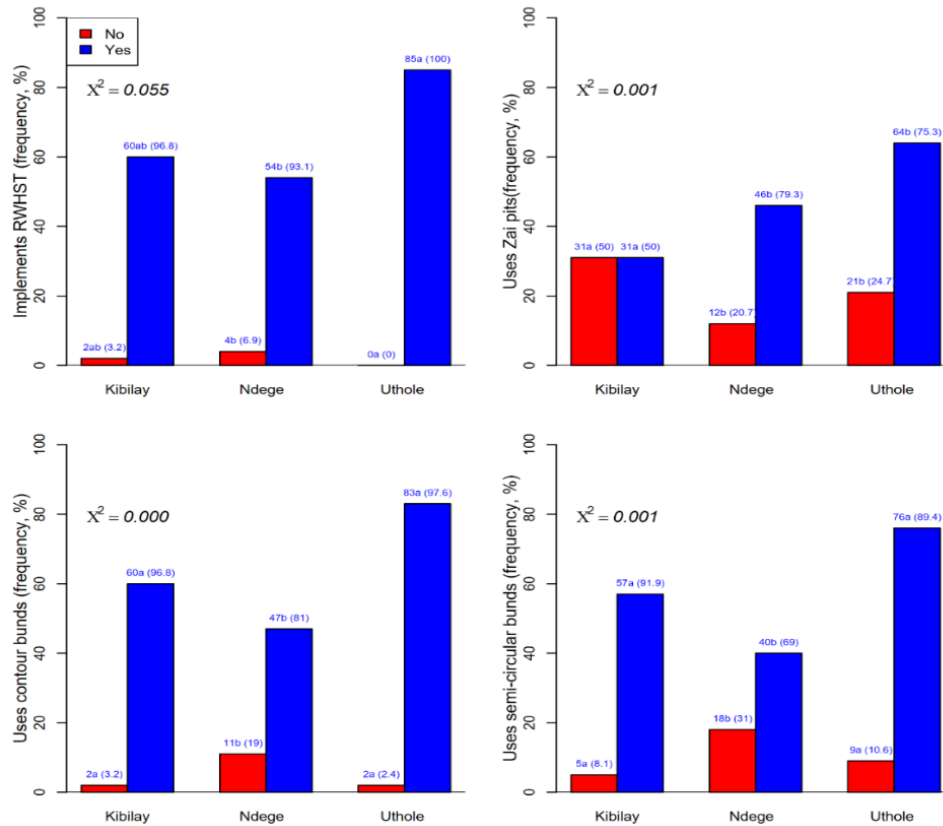


Figure 4.4: Farmers who use RWHT grouped by location *Source: This Research 2025*

b) RWHT technologies and land size

Table 4.5 1: Average land areas with RWHT in Habaswein, grouped by location

RWHT area	Kibilay	Ndege	Uthole	Pooled	ANOVA
Zai land area (acre)	0.7 b±0.5	1.1 a ±0.6	0.8b ±0.5	0.9 ±0.5	***
Contour bunds area (acre)	1.2 ±0.5	1.2 ±0.8	1.1 ±0.6	1.2 ±0.6	ns
Semi-circular bunds area (acre)	1.2 ±0.5	1.1 ±0.8	1.0 ±0.5	1.1 ±0.6	ns
Total RWHT land area (acre)	3.1 ±1.2	3.4 ±1.7	2.9 ±1.3	3.1 ±1.4	ns

Source: Research 2025

The mean areas under *Zai pits* were significantly different by locations, while that for contour bunds, semi-circular bunds and land area under the three technologies were not significantly different (Table 4.6). For *Zai pits*, the mean land area was largest in Ndege (significantly different from all

locations), followed by Uthole and Kibilay. The mean total land area under RWHT was also highest in Ndege, followed by Kibilay and Uthole, though there were no location differences (Table 4.6).

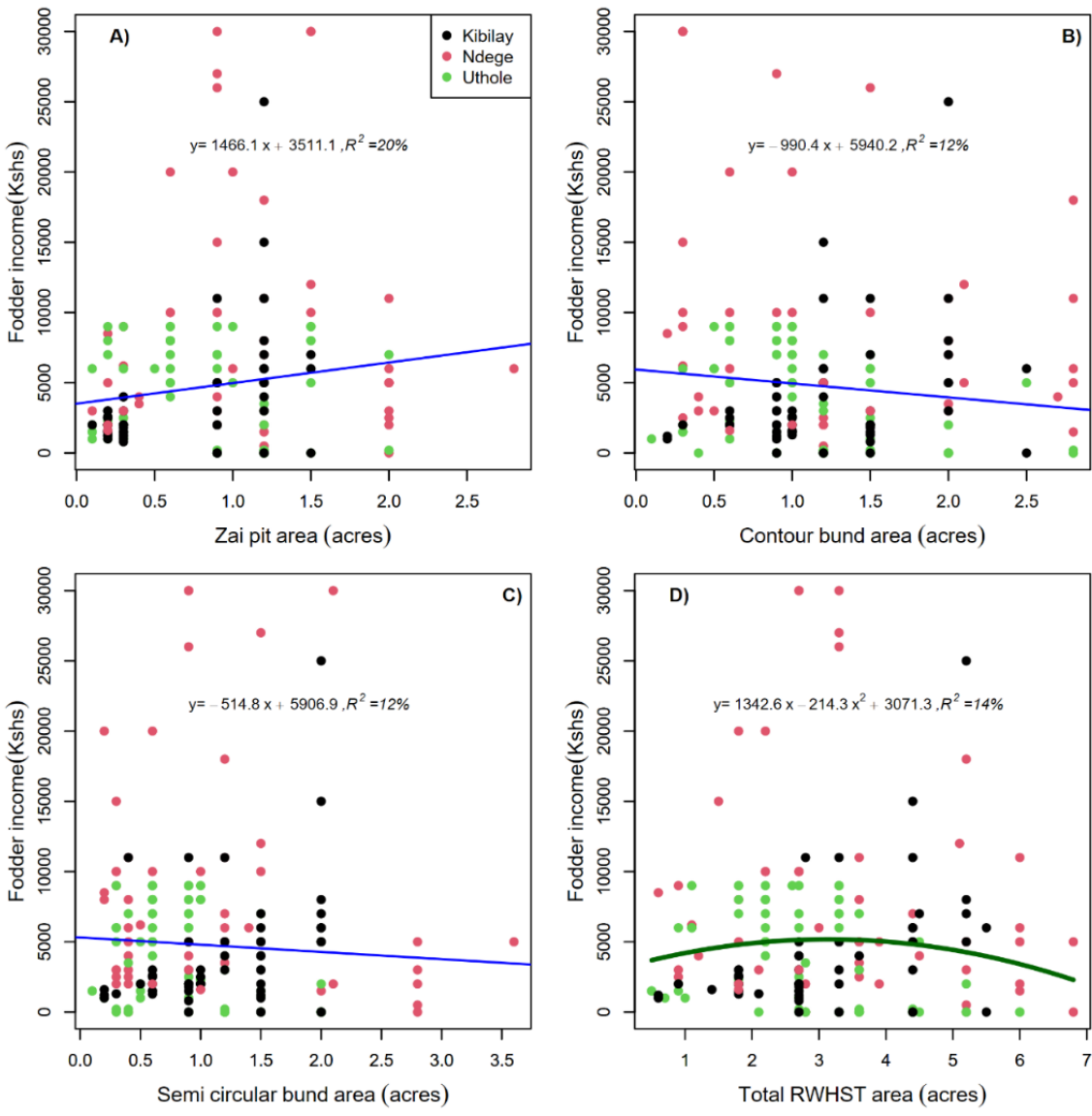


Figure 4.5: Regression between RWHT land sizes (Zai pit, Contour bund, Semi-circular, and total RWHT land area) and fodder income, grouped by location. Source: Research 2025

The regression model of *Zai* pit land area and annual fodder income (Figure 4.3) showed that increasing land area by 1 acre, increased the annual fodder income by KShs.1,466 per increase in

unit land area (in acres) on average (Figure 4.3 (A)). The trends for contour bunds and semi-circular bunds were weakly negative (Figures 4.3 (B) and 4.3 (C), suggesting lack of a relationship, while the total RWHT land area recorded a polynomial regression Figure 4.3 (D) with the annual fodder income. There was an increase in total fodder income by Kshs.1,342 per increase in unit land area (in acres) up to a total land area of 3.5 acres, after which a decline rate of Kshs.214 per increase in unit land area (in acres) was observed for each acre increment under RWHT. These results show that the type of RWHT structure matters in the study area with the Zai pits showing a positive correlating returns based on the number of acres put under the structure.

The study offers valuable insights into the relationship between land area under rainwater harvesting technologies (RWHT) and annual fodder income in Habaswein Sub-County, highlighting important implications for the scalability and effectiveness of these technologies in arid and semi-arid lands (ASALs). Zai pits emerged as the most economically promising technology. Their adoption was highest in Ndege, where households also had larger land areas allocated to them. A positive regression trend showed that each additional acre under Zai pits increased annual fodder income by approximately Kshs. 1,466, indicating strong financial returns when scaled appropriately especially in sandy soils and labour-accessible environments (Fatondji et al., 2016). In contrast, contour and semi-circular bunds showed no significant income gains with increasing land area. Despite their benefits in erosion control and soil moisture conservation, their economic impact appears to be indirect or delayed. These technologies may thus be better suited for ecological restoration rather than immediate livelihood enhancement. The analysis also revealed diminishing returns beyond 3.5 acres of total RWHT land area, with income beginning to decline at a rate of Kshs. 214 per additional acre. This suggests a threshold beyond which the efficiency of RWHT investments declines, likely maybe due to constraints in labour, inputs, or maintenance capacity. These findings underscore the need for context-specific, technology-appropriate RWHT strategies. Zai pits should be prioritized in high-potential areas like Ndege, while bund-based systems may require better alignment with environmental conservation goals. Extension services should guide farmers to optimize rather than maximize RWHT coverage, and policies must tailor interventions to reflect local agro-ecological and socio-economic realities.

4.5.2 Socio-economic factors and RWHT adoption

Table 4.7 shows the generalized linear regression model of factors affecting RWHT adoption by farmers in Habaswein using a gaussian model that was based on land areas under the various technologies, and the total land area under RWHT.

Table 4.5 2: GLM regression model of RWHT land areas with socio-economic, ecological and institutional factors

Parameters	Zai land (β , sig)	Contour bunds (β , sig)	Semi-circular bunds (β , sig)	Total RWHT area (β , sig)
(Intercept)	0.171	-0.254	-0.138	-0.221
Soil type: Sandy	-0.198*	0.014	0.011	-0.172
Soil type: Sandy-loam	-0.230*	0.183	0.307*	0.260
Weather challenges: Erosion	-0.069	-0.265	0.451	0.117
Weather challenges: Flooding	-0.094	-0.534*	-0.071	-0.698
Age	0.002	0.002	0.004	0.008
Education years	-0.009*	0.001	0.006	-0.002
HH size	0.008	0.014	0.006	0.027
Habaswein yrs	-0.122***	-0.058	-0.057	-0.237**
Own land	0.444***	0.344***	0.220**	1.008***
Crop land	-0.138*	0.012	0.081	-0.044
Fodder land	-0.097	0.121	0.064	0.087
Fodder years	0.005	-0.011	-0.004	-0.011
TLU	-0.001	0.000	0.002	0.001
Number of trainings	0.036*	0.089***	-0.042.	0.083*
Number of extension services	0.023	-0.025	0.102***	0.100*

Source This Research 2025

The Generalized Linear Model (GLM) regression analysis conducted in this study provides critical insights into the factors influencing the extent of adoption of rainwater harvesting technologies (RWHT), specifically Zai pits, in Habaswein Sub-County. The findings highlight the interplay between ecological, socio-economic, and institutional variables in shaping the land area allocated to RWHT by farmers. One of the key findings is that soil type significantly affects the land area under Zai pits. Farmers with sandy or sandy-loam soils installed Zai pits on smaller plots compared to those with clay soils. On average, sandy soils reduced Zai pit coverage by 0.198 acres, while sandy-loam soils reduced it by 0.203 acres. This suggests that infiltration and water retention characteristics inherent to different soil types influence farmers' decisions on the extent of RWHT

use. Sandy-loam soils, with better water-holding capacity, appear more favourable for Zai pit application, highlighting the need for soil-specific recommendations and support mechanisms.

The study found that both education level and years of residence in Habaswein were negatively associated with the land area under Zai pits. For each additional year of education, the area declined by 0.009 acres, while each extra year lived in the area reduced the land under Zai pits by 0.122 acres. These findings challenge the assumption that more educated or long-settled farmers are more likely to invest in RWHT. Instead, it may reflect a preference for alternative methods or a sense of stagnation among longer-term residents, indicating the need for renewed engagement and tailored outreach strategies for these groups. The strongest positive predictor of RWHT adoption was land ownership. Each additional acre owned resulted in a 0.444-acre increase in land under Zai pits, a 0.344-acre increase for contour bunds, and a 1-acre increase across total RWHT area. This reinforces the critical role of secure land tenure and access in motivating farmers to invest in sustainable land and water management practices. Programs targeting communal or tenant farmers may need to incorporate tenure-sensitive approaches to encourage wider adoption. Training and extension services also played a vital role in RWHT adoption. Each additional training session attended led to a 0.036-acre increase in Zai pit area, 0.089 acres for contour bunds, and 0.083 acres in overall RWHT coverage. Similarly, access to diverse extension services positively influenced the area under semi-circular bunds and total RWHT, with each additional service type contributing an extra 0.1 acres. These results demonstrate the tangible impact of capacity-building and knowledge dissemination on the scale of technology adoption.

Qualitative findings from Key Informant Interviews (KIIs) underscore the pivotal role of socio-economic factors including income levels, gender, education, and access to credit as influencing the adoption of Rainwater Harvesting Technologies (RWHT) in Habaswein, Wajir County. There was unanimous agreement among respondents that RWHT significantly improves fodder yields, enhances livelihood diversification, increases household income, and improves water access for agricultural use. Despite these benefits, the high cost of infrastructure, lack of affordable financing, and limited technical capacity pose major barriers to adoption. Installation costs that include: labour, materials, transportation, fencing, and design are often prohibitive. Larger systems such as water pans can cost millions of Kenyan shillings, while even small-scale installations require substantial investment. As a result, implementation frequently depends on multi-stakeholder support, including

contributions from development partners, county governments, and community-based programs like WFP’s Food Assistance for Assets (FFA).

Social factors based on the Focused Group Discussions (FGDs) also shape adoption. While community ownership is often promoted, challenges such as leadership conflicts and gender inequalities, especially women’s limited access to land and finance, constrain inclusive participation. Nevertheless, RWHT has demonstrated notable livelihood impacts, including better livestock health, improved milk and meat production, and a reduction in seasonal migration and livestock losses during droughts. From an economic perspective, many farmers reported emerging financial benefits, such as reduced reliance on commercial feed and income from fodder sales with some earning up to Kshs 15,000, indicating RWHT’s potential to offer meaningful financial relief. Socially, RWHT is widely regarded as beneficial, with strong community acceptance driven by visible improvements in crop yields, water availability, and livestock productivity. Importantly, the increased supply of fodder has not disrupted local markets; instead, it has strengthened regional supply chains and stimulated market activities in areas like Guruta, Sericho, and Hadado. Even non-commercial users benefit from cost savings. The positive reception of RWHT—supported by institutions like WFP, World Vision Kenya, and county governments reflects a collective endorsement of its role in promoting resilience and economic stability in ASAL communities.

4.5.3 Ecological factors and RWHT adoption

Table 4.5.4 shows the ecological factors hypothesised to affect the adoption of rainwater harvesting technologies. The results show that the main ecological factors that influenced technology adoption in Habaswein included rainfall seasonality, followed by drought incidences, soil properties, while forestation demands were the least important (Table 4.5.3).

Table 4.5 3: Ecological Factors influencing adoption of RWHT by location

Ecological factors	Kibilay		Ndege		Uthole		Total	
	n	%	n	%	n	%	n	%
Rainfall seasonality	62	100.0	58	100.0	84	98.8	204	99.5
Drought incidences	61	98.4	46	79.3	85	100.0	192	93.7
Soil properties	31	50.0	18	31.0	35	41.2	84	41.0
Forestation demands	11	17.7	1	1.7	5	5.9	17	8.3

Ecological factors	Kibilay		Ndege		Uthole		Total	
	n	%	n	%	n	%	n	%
Total cases	62		58		85		205	

Source: This Research 2025

Rainfall seasonality was identified as the most important ecological factor in all sites that influenced RWHT adoption, followed by drought incidences, soil properties and forestation demands based on the results of the total frequencies reported in Table 4.5.3. In Kibilay location, forestation demands were considered as an important factor compared to Ndege and Uthole which did not consider this as an important parameter, relative to other sites. These findings demonstrate that ecological factors play a pivotal role in shaping the adoption and scale of rainwater harvesting technologies (RWHT) in Habaswein Sub-County. Among the ecological variables examined, rainfall seasonality emerged as the most influential factor across all sites. This reflects the strong link between erratic rainfall patterns and the perceived need for water conservation technologies among pastoral and agro-pastoral communities (Rockström et al., 2018). Other key ecological considerations included drought incidence, soil characteristics, and forestation demands. Notably, in Kibilay, forestation was rated as a particularly important ecological driver, underscoring how localized environmental needs can shape adoption behaviours (Mekonnen, Kassa & Zeleke, 2019). Table 4.5.4 shows the farmers evaluation of the influence of the ecological factors on the establishment and adoption of RWHT.

Table 4.5 4: Farmers agreement that ecological factors are important for the establishment of RWHT by locations

Agreement	Kibilay	Ndege	Uthole	All sites
Generally, agree	21a (33.9)	7b (12.1)	21ab (24.7)	49 (23.9)
Moderately, agree	0a (0)	23b (39.7)	7c (8.2)	30 (14.6)
Strongly, agree	41a (66.1)	28b (48.3)	57a (67.1)	126 (61.5)
All responses	62 (100)	58 (100)	85 (100)	205 (100)

Source: Research (2025)

While ecological factors were not frequently cited as primary influences on the adoption of Rainwater Harvesting Technologies (RWHT), a subset of key informants acknowledged their importance in enhancing land productivity, resilience, and soil erosion control findings that align with Rockström et al. (2010). However, several ecological challenges were identified, including

erratic rainfall, drought, sedimentation of structures, invasive species like *Prosopis juliflora*, pest outbreaks, floods, and locust invasions, all of which inhibit effective adoption (Kassam et al., 2011).

In ASAL regions, where rainfall variability is acute, the demand for site-specific RWHT solutions has grown significantly (Oweis & Hachum, 2006). Soil types particularly sandy and erosion-prone soils—require tailored adaptations (Critchley & Siegert, 1991), while land degradation from overgrazing and poor land use has further amplified runoff and vulnerability (Reij, Tappan & Smale, 2009). In this context, RWHT emerges as a crucial strategy for restoring degraded rangelands and improving soil water retention, especially under the mounting pressures of climate change (FAO, 2019). Participants reported several environmental benefits from RWHT use, including enhanced soil moisture, greener vegetation, and improved microclimates. These outcomes contributed to ecosystem regeneration, longer growing seasons, and improved fodder quality. While some informants noted increased biodiversity, others raised concerns about higher insect and predator activity due to denser vegetation. Perceptions on RWHT's effect on water sources varied. Some observed reduced pressure on communal water points due to localized harvesting, while others noted minimal direct impact. Importantly, RWHT-supported areas reported fewer wildlife-livestock conflicts around pasture and water points, indicating improved resource availability.

Despite climate-related constraints such as drought and low water availability, informants expressed strong optimism about RWHT as a tool for climate adaptation and environmental restoration. They stressed the need for continued NGO and humanitarian support, alongside technical capacity building and community-led approaches to ensure the sustainability and ecological impact of RWHT interventions.

These findings suggest that ecological suitability, particularly soil type and rainfall dynamics, is central to RWHT adoption success. Consequently, interventions must be ecologically tailored, ensuring that the recommended technologies match the local biophysical conditions. Furthermore, incorporating broader environmental goals, such as reforestation initiatives observed in Kibilay, can enhance community engagement and program relevance (Wekesa et al., 2019). By accounting for these ecological findings, RWHT programs can be better designed to promote sustainable fodder production, enhance water security, and strengthen climate resilience in Kenya's arid and semi-arid lands (ASALs).

Table 4.5 5: Mean area (acres) under RWHT by soil types in Habaswein

RWHT	Clay	Sandy	Sandy-Loam	Pooled	ANOVA
Zai pit area	1.0a ±0.5(18)	1.0a ±0.3(105)	0.6b ±0.7(82)	0.9 ±0.5(205)	***
Contour bund area	1.0b ±0.3(18)	1.3a ±0.6(105)	1.1ab ±0.7(82)	1.2 ±0.6(205)	*
Semi-circular bund area	0.7b ±0.3(18)	1.1a ±0.6(105)	1.0a ±0.7(82)	1.1 ±0.6(205)	*
Total RWHT area	2.6b ±0.8(18)	3.4a ±1.2(105)	2.7b ±1.6(82)	3.1 ±1.4(205)	***

Source Research 2025

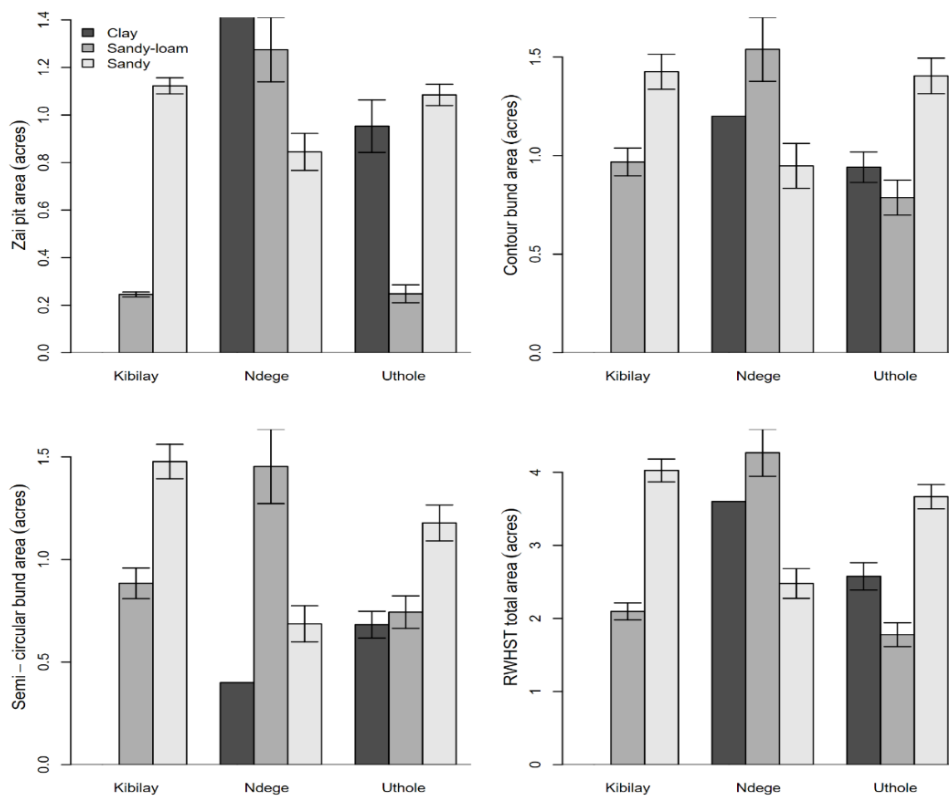


Figure 4.6: Mean land area under RWHT by soil type and location

The mean *Zai pit* land area in Kibilay was different between soil types (Figure 4.6), with more average *Zai pit* land area under sandy soils compared to sandy loams. In Ndege, there was a significant difference in mean *Zai pit* land area between sandy-loams and sandy clay soils (Table 4.9). The differences in Uthole indicated that clay and sandy loam soils recorded similar *Zai pit* land area means, while this was significantly less in Sandy loam soils. The contour bund mean area was

significantly higher in Kibilay-sandy soils, relative to Kibilay sandy loams because the error bars did not overlap.

The study findings underscore the critical role of soil type in influencing the scale and extent of adoption of rainwater harvesting technologies (RWHT) such as Zai pits and contour bunds in Habaswein Sub-County. In Kibilay, farmers allocated significantly larger land areas to Zai pits on sandy soils compared to sandy loams, suggesting that sandy soils offer more favorable physical conditions, such as easier digging and higher infiltration, which make Zai pit construction more viable and effective (Fatondji et al., 2016). In contrast, the lower allocation in sandy loam soils could be attributed to practical constraints like reduced water retention or higher labor intensity. A similar pattern was evident in Ndege, where significant differences in average Zai pit land area were observed between sandy loam and sandy clay soils, indicating that even moderate shifts in soil composition influence land-use decisions and perceived RWHT effectiveness (Mekonnen, Kassa & Zeleke, 2019). In Uthole, land areas under Zai pits were comparable in clay and sandy loam soils, while significantly less land was allocated to sandy soils, suggesting that local perceptions or ecological constraints may override the typical advantages associated with sandier textures.

With respect to contour bunds, farmers in Kibilay allocated more land under sandy soils compared to sandy loams, a statistically significant finding given the non-overlapping error bars in the data. This confirms that sandy soils in Kibilay may provide more favorable conditions for the wider application of contour bunds, which rely on runoff management and soil stability (Sharma et al., 2016; Haregeweyn et al., 2015). These findings imply that soil-specific strategies are necessary for promoting RWHT adoption. Extension services must tailor recommendations based on soil type, guiding farmers on the most appropriate and efficient technologies for their land. For instance, Zai pits may be promoted more aggressively in sandy regions, where both performance and farmer acceptance are likely to be higher. Conversely, areas with less favourable soils may require additional technical support, subsidies, or labour-saving innovations to encourage adoption.

4.6 Capacity building and rainwater harvesting adoption

4.6.1 Type of extension and adoption of RWHT

Table 4.6.1 shows the types of extension services received by farmers in Habaswein locations.

Table 4.6 1: Type of extension received by numbers and percent households in Habaswein locations

Extension themes	Response	Kibilay	Ndege	Uthole	Total	X ² test
Farm level preparation	No	19a (30.6)	15ab (25.9)	14b (16.5)	48 (23.4)	*
	Yes	43a (69.4)	43ab (74.1)	71b (83.5)	157 (76.6)	
Fertilizer sources and application	No	24a (38.7)	27a (46.6)	40a (47.1)	91 (44.4)	ns
	Yes	38a (61.3)	31a (53.4)	45a (52.9)	114 (55.6)	
Seed sources and application	No	28a (45.2)	23ab (39.7)	22b (25.9)	73 (35.6)	*
	Yes	34a (54.8)	35ab (60.3)	63b (74.1)	132 (64.4)	
Pesticide sources and application	No	31a (50)	33a (56.9)	44a (51.8)	108 (52.7)	ns
	Yes	31a (50)	25a (43.1)	41a (48.2)	97 (47.3)	
Market demand	No	25a (40.3)	30a (51.7)	47a (55.3)	102 (49.8)	ns
	Yes	37a (59.7)	28a (48.3)	38a (44.7)	103 (50.2)	

Source: This Research (2025)

The results highlight that extension services play a pivotal role in the adoption and successful implementation of rainwater harvesting technologies (RWHT) for fodder production in Habaswein Sub-County. Farm-level preparation emerged as the most widely accessed extension service, reaching 76.6% of respondents. This was followed by services related to seed sources and application (64.4%), fertilizer use (55.6%), and market demand information (50.2%). Pesticide-related extension support had the lowest access rate, at 47.3%.

Access to extension services varied significantly across study locations. Uthole recorded the highest proportion of farmers accessing farm-level preparation (83.5%), significantly higher than Kibilay (69.4%) and marginally above Ndege (74.1%). Uthole also had the highest access to seed-related extension services (74.1%), followed by Ndege (60.3%) and Kibilay (54.8%). In contrast, pesticide and market demand-related services showed no significant differences between locations, remaining consistently under 60% in all areas.

These findings suggest that location-specific disparities in extension service delivery influence RWHT adoption levels. Areas with greater access to preparatory and agronomic support such as Uthole is likely to experience higher adoption rates due to improved farmer readiness and informed decision-making (Mutunga, Onywere & Karanja, 2020). The lack of extension exposure in Kibilay may limit the effective utilization of RWHT due to knowledge and technical support gaps. Additionally, the limited access to market and pesticide-related extension services across all sites indicates a need to expand extension curricula. A more integrated approach that includes market orientation, pest management, and water-use efficiency would support more resilient and productive fodder systems, especially in ASAL regions where resource constraints are prevalent (FAO, 2021; Rockström et al., 2010). The findings underscore the necessity for equitable and comprehensive extension service provision to facilitate RWHT adoption. Targeted capacity building and improved outreach can help bridge the existing knowledge gaps and enhance RWHT outcomes in ASAL counties such as Wajir.

4.6.2 Number of Training and adoption of RWHT

The study findings highlight the significant impact of farmer training on the adoption and expansion of rainwater harvesting technologies (RWHT) in Habaswein, Wajir County. A positive and statistically significant association was observed between the number of training sessions attended by farmers and the size of land allocated to various RWHT practices. Specifically, each additional training attended by a farmer led to an average increase of 0.145 acres in land under Zai pits, 0.163 acres under contour bunds, and 0.082 acres under semi-circular bunds. When considering the cumulative land area under all RWHT practices, one extra training session resulted in an average increase of 0.390 acres.

These results imply that training plays a pivotal role in enhancing both the adoption and scale of RWHT implementation. Training likely improves farmers' technical knowledge, practical skills, and awareness of the benefits of these technologies, thereby boosting their confidence and willingness to invest more land into RWHT. In arid and semi-arid areas like Habaswein—where climate variability, limited technical capacity, and water scarcity present persistent challenges—training serves as an essential enabler of sustainable land and water management. Furthermore, the findings suggest that regular and repeated training engagements can significantly amplify the impact of RWHT initiatives. This underscores the importance of integrating robust capacity-building

components into agricultural extension programs targeting ASAL regions. Training not only helps farmers understand how to construct and maintain RWHT structures effectively, but also motivates them to expand adoption based on evidence of improved fodder production and water-use efficiency. The results confirm training is a critical driver of technology adoption and resource optimization in dryland agriculture. Strengthening training delivery—especially through localized, practical, and participatory approaches—can therefore accelerate the adoption of RWHT, improve fodder availability, and enhance the resilience of pastoralist communities in ASALs (Fatondji et al., 2016; Sharma et al., 2016; Mutunga, Onywere & Karanja, 2020).

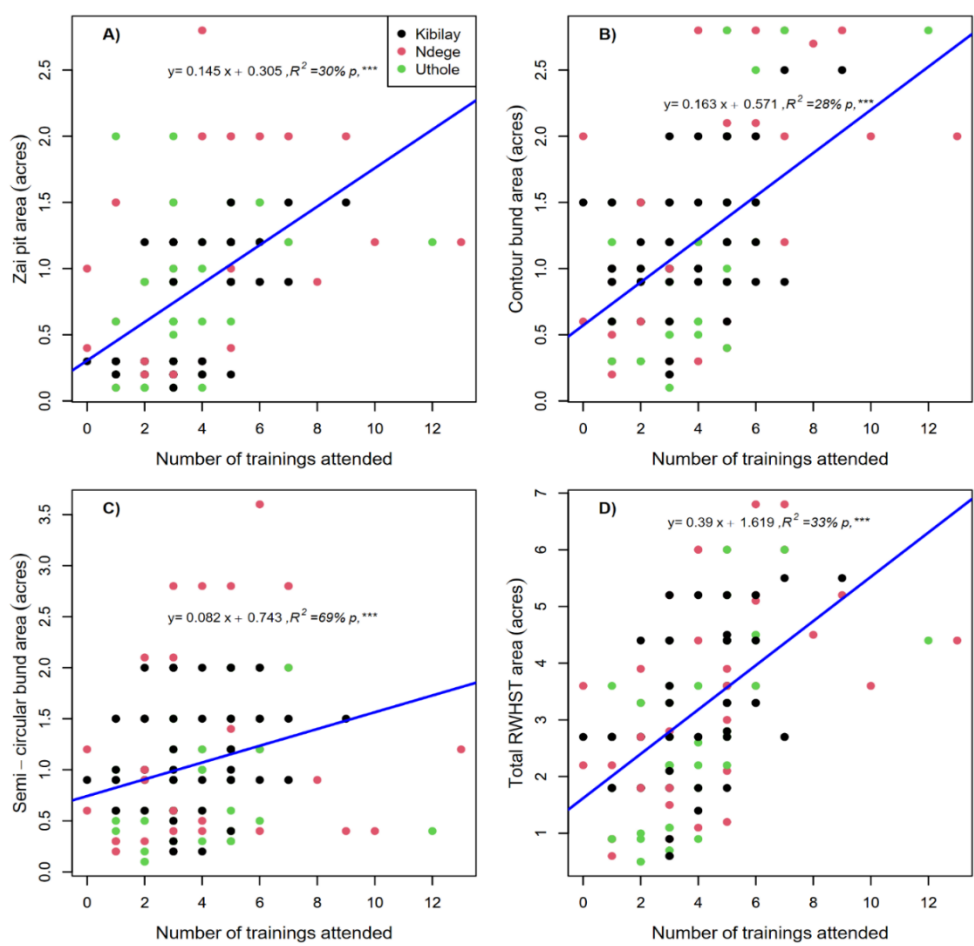


Figure 4.7: Regressions between number of trainings attended and land area under RWHT adoption in Habaswein. Source: Research (2025)

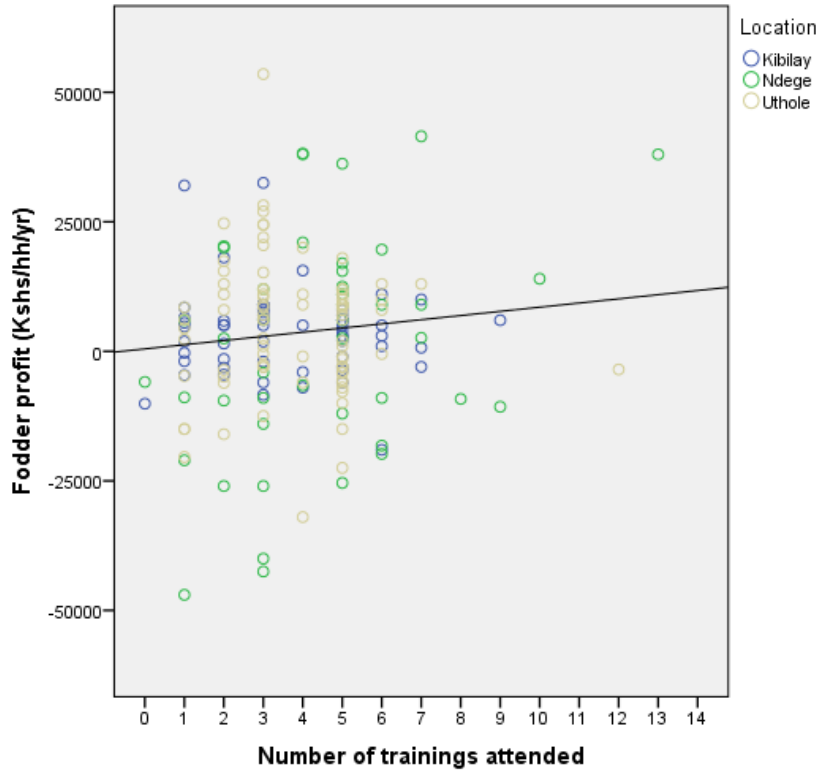


Figure 4.8: Regressions between number of trainings and fodder profits

Figure 4.8 shows that increased training frequency was associated with higher fodder profits in Habaswein. The study found that each additional training session attended by farmers resulted in an average increase of Kshs. 804.6 in annual fodder profits per household, highlighting the critical role of training in enhancing the effectiveness and profitability of rainwater harvesting technologies (RWHT). This strong positive relationship ($y = 477.4 + 804.6x$) underscores the value of capacity-building interventions in arid and semi-arid lands (ASALs), where improved technical knowledge and skills contribute significantly to better use of RWHT for fodder production (Mutunga, Onywere & Karanja, 2020). These findings demonstrate that training not only improves technology adoption but also leads to tangible economic benefits, making it a strategic tool for improving household resilience and food security. Farmers who receive regular training are more likely to adopt and scale up RWHT practices effectively, thereby increasing their returns from fodder-based livelihoods (FAO, 2021; Rockström, Barron & Fox, 2010). The results suggest that investment in extension services and ongoing farmer education should be prioritized in RWHT implementation strategies across Kenya's ASALs.

The key informant interviews and focus group discussions revealed that training and extension services play a vital role in promoting the adoption of Rainwater Harvesting Technologies (RWHT) in Habaswein Sub-County. Many participants acknowledged that training had positively influenced awareness, decision-making, and technical proficiency among farmers. Those who had access to structured training—primarily delivered by the Ministry of Agriculture, the World Food Programme (WFP), World Vision Kenya (WVK), and Mercy Corps—reported enhanced understanding of water conservation, better management of RWHT structures, and improved agricultural productivity.

However, access to formal training was reported to be uneven. A significant number of farmers had not received direct training, highlighting a gap in structured capacity-building approaches. This shortfall was seen as a limiting factor in the wider and more effective adoption of RWHT. Participants emphasized that training improved farmers' ability to select suitable technologies, maintain RWHT infrastructure, and optimize fodder production. Training was also cited as crucial for sustaining system functionality and maximizing benefits.

In the absence of formal training, community-based knowledge exchange emerged as a critical alternative. Participants described how farmer-to-farmer learning, informal village meetings, and farmer field schools served as platforms for sharing techniques and experiences. These grassroots learning channels have helped spread RWHT practices, especially in areas underserved by government and NGO-led extension services. Despite ongoing training initiatives, participants noted several unmet needs. These included practical training in soil and water conservation, integrated fodder management, technical design and maintenance of RWHT systems, value addition, and marketing strategies. Access to tools, inputs, and financial support was also identified as essential to sustain adoption. Key support networks—such as WFP, WVK, Mercy Corps, and the County Government—were recognized for providing not only training but also resources through programs like cash transfers and food-for-work initiatives. Community contributions, such as shared tools and labor, were noted as additional mechanisms reinforcing adoption and system maintenance.

4.6 Fodder value chain profitability

Table 4.6 2: Average livestock distribution among farms in Habaswein by location

Livestock type	Kibilay	Ndege	Uthole	Pooled	ANOVA
Cattle #	15.3a ±16.2(29)	7.8b ±9.7(5)	5.8b ±4.2(22)	10.9 ±13.0(56)	*
Sheep #	26.9a ±25.7(61)	18.6b ±17.3(48)	18.2b ±11.9(80)	21.1 ±19.0(189)	*
Goats #	23.6a ±28.7(60)	18.5a ±15.2(47)	21.6a ±20.6(79)	21.4 ±22.4(186)	ns
Poultry#	4.8a ±3.2(10)	3.5a ±2.7(8)	5.9a ±3.7(15)	5.0 ±3.4(33)	ns
Camels #	7.6a ±3.1(18)	7.8a ±11.4(11)	4.3a ±1.4(9)	6.9 ±6.5(38)	ns
TLU	14.9a ±17.8(62)	5.9b ±9.5(55)	5.9b ±5.6(84)	8.6 ±12.3(201)	***

Source: This Research (2025)

The findings of the study Table 4.6.2 illustrate the critical relationship between livestock ownership and the adoption of rainwater harvesting technologies (RWHT) in Habaswein Sub-County, Wajir County. On average, households owned 10 cattle, 21 sheep and goats, 7 camels, and 5 poultry, demonstrating a strong dependence on livestock for income, food security, and overall livelihoods in arid and semi-arid land (ASAL) contexts. Significant differences were observed in livestock ownership across the study locations, with Kibilay recording the highest mean number of cattle (15.3) and sheep (26.9), compared to lower ownership in Ndege and Uthole. This was also reflected in Total Livestock Units (TLUs), which were significantly higher in Kibilay (14.9 TLU) than in Ndege and Uthole (both 5.9 TLU). These findings have several implications for RWHT adoption. Areas with higher livestock holdings, such as Kibilay, face increased pressure on water and pasture resources, making RWHT interventions more urgent and potentially more impactful. In these locations, technologies like zai pits, contour bunds, and semi-circular bunds can help mitigate water scarcity and support year-round fodder availability, thereby enhancing livestock productivity and reducing reliance on emergency feed or sales during drought (Rockström, Barron & Fox, 2010).

The widespread ownership of small ruminants, such as sheep and goats, which are more adaptable to dry conditions, emphasizes the role of RWHT in maintaining forage supply for diverse livestock types. This aligns with findings by FAO (2021), which noted that access to consistent water and feed sources improves resilience and household economic stability in pastoral communities. The location-based variation in livestock numbers suggests a need for tailored RWHT interventions. For instance, larger systems may be warranted in high TLU areas, while more modest, cost-effective

structures may suffice in regions with lower livestock density. Moreover, the presence of multiple livestock species reinforces the multifunctional benefits of RWHT—not only in sustaining animal production but also in supporting diversified livelihood strategies (Mutunga, Onywere & Karanja, 2020). Livestock ownership patterns significantly influence RWHT demand and adoption. By aligning water harvesting technologies with local livestock needs, stakeholders can enhance the effectiveness, adoption, and sustainability of RWHT interventions in Kenya’s ASALs.

The study demonstrates that the adoption of rainwater harvesting technologies (RWHT) has significantly influenced the reseeded and wild collection of fodder grasses among farmers in Habaswein Sub-County, with important implications for pasture regeneration, fodder diversity, and livestock feed security in Kenya’s arid and semi-arid lands (ASALs). High adoption rates of RWHT appear to create favorable micro-environments for the establishment and regeneration of key fodder species. Nearly all farmers in Uthole (100%), Kibilay (96.8%), and Ndege (91.4%) had reseeded *Eragrostis superba*, with a statistically significant difference between Uthole and Ndege. This suggests that RWHT infrastructure in Uthole has been particularly effective in supporting reseeded efforts. Similarly, reseeded of *Cenchrus ciliaris* was consistently high across all sites (93.1%–98.8%), showing no significant location differences, which may reflect the broad adaptability of the species and its compatibility with RWHT-supported fodder systems (Wekesa et al., 2019).

In contrast, reseeded rates for *Chloris roxburghiana* and *Enteropogon macrostachyus* were considerably lower and more variable. Kibilay recorded the highest reseeded proportions for both species (50%), followed by Uthole and then Ndege, with significant differences between the locations. These variations imply that while RWHT improves the physical conditions for reseeded, adoption of certain species may also depend on localized extension support, cultural preferences, or perceived fodder value. Wild collection of fodder grasses followed a similar trend. *Eragrostis superba* was collected by all Uthole farmers, 96.8% in Kibilay, and 91.4% in Ndege, with significant differences between Uthole and Ndege. Collection rates for *Cenchrus ciliaris* were similarly high and consistent across sites. However, wild collection of *Chloris roxburghiana* and *Enteropogon macrostachyus* was significantly more common in Kibilay than in Uthole and Ndege. This pattern suggests that the ecological restoration facilitated by RWHT, particularly in areas with more advanced adoption like Kibilay, leads to a wider distribution of diverse fodder grasses across the landscape (Mutunga, Onywere & Karanja, 2020; FAO, 2021).

These findings underscore the critical role RWHT plays in supporting both cultivated and naturally regenerated fodder systems. They also highlight the need for site-specific strategies that combine RWHT infrastructure with targeted extension services to promote the use of underutilized, drought-resilient fodder species. The integration of RWHT into the broader fodder value chain therefore offers a sustainable pathway to enhancing feed availability and livestock productivity in ASALs.

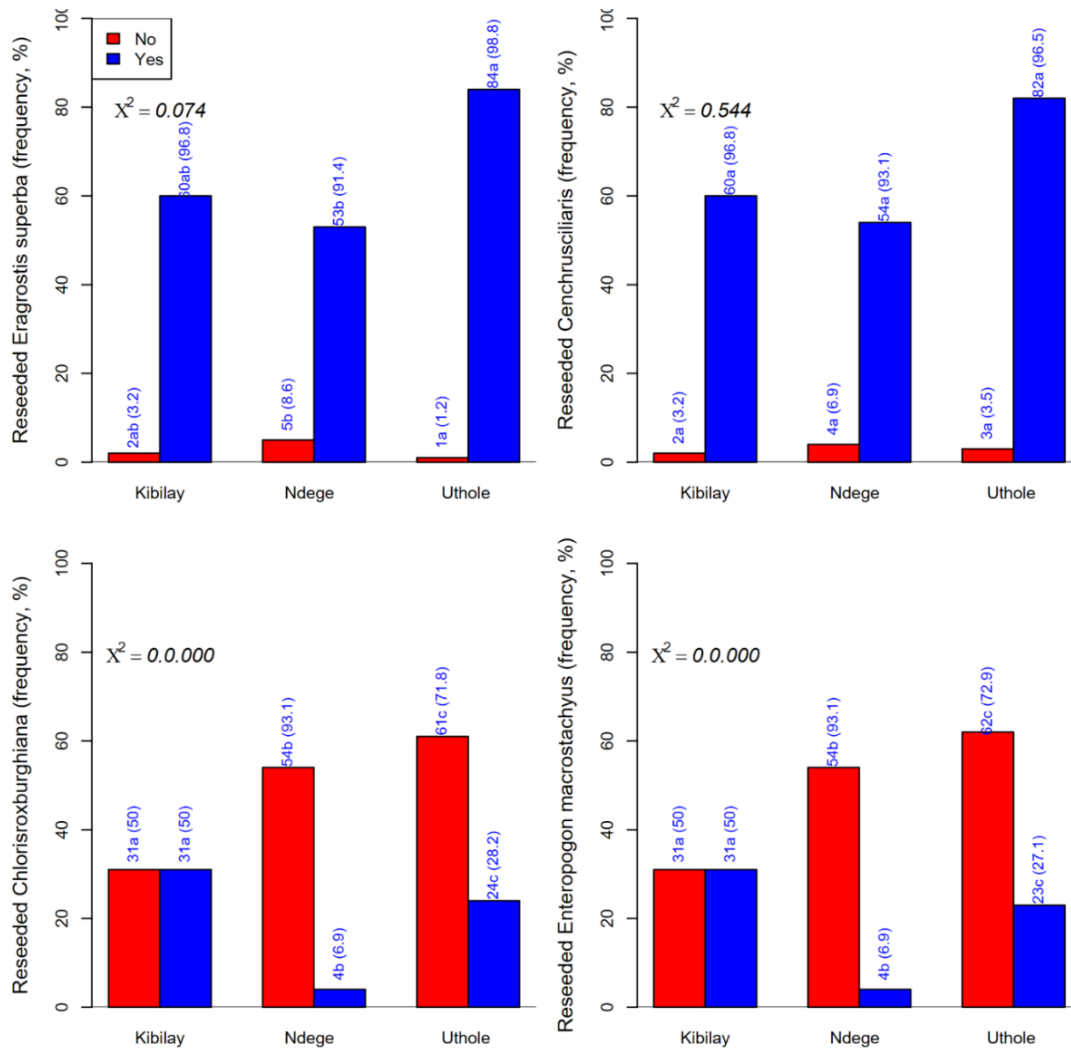


Figure 4.9: Reseeded fodder grasses by farmers in Habaswein locations. Source: Research (2025)

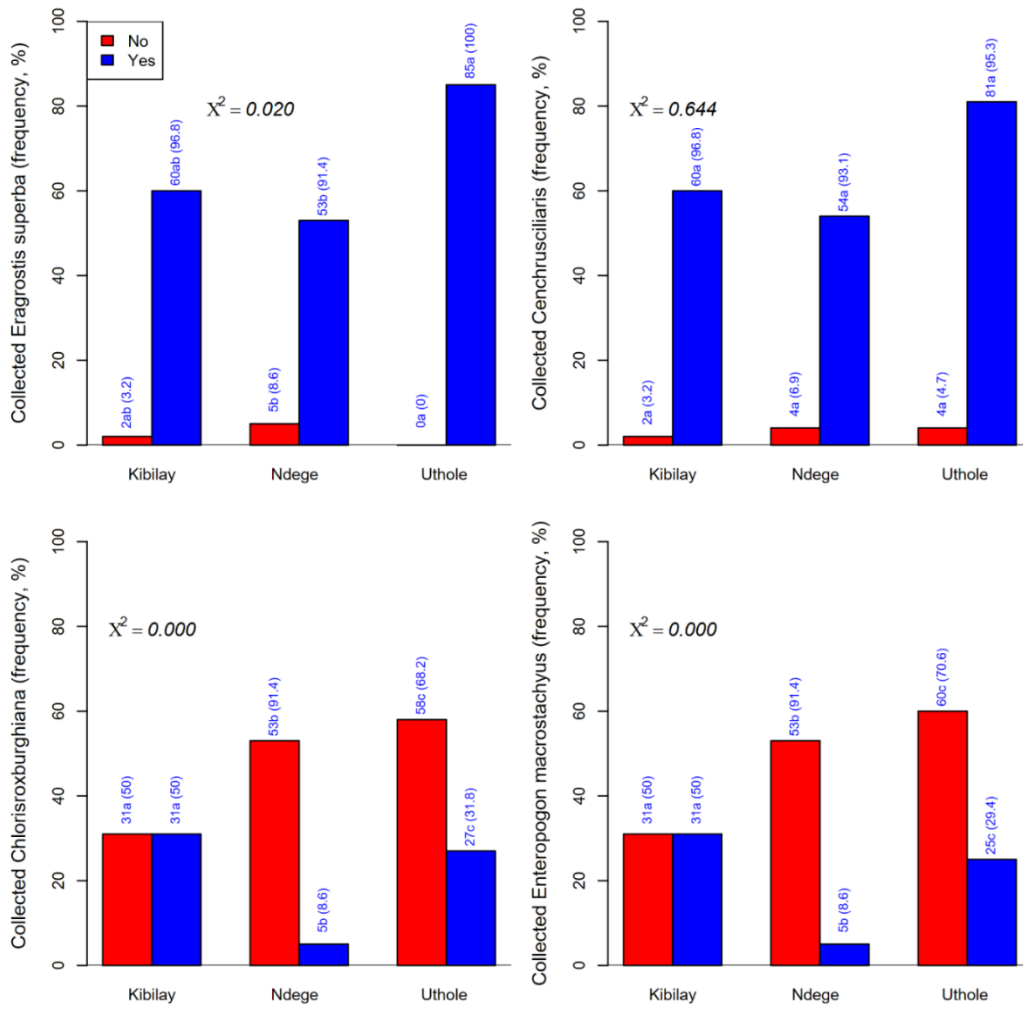


Figure 4.10: Harvested fodder grasses by farmers in Habaswein locations. Source: This Research (2025)

Table 4.6 3: Average fodder variable costs and profit by location (Values are arranged as means, followed by standard deviations and number of cases). Source: Research (2025)

Activity	Variable costs and profit (Kes.)				
	Kibilay	Ndege	Uthole	Pooled	ANOVA
Land clearing total cost	3,150.9 ±959.5 (53)	12,507.4±22,988.4 (47)	3,877.3 ±2,145.4 (75)	5,975.1 ±12,561.6 (175)	0.000
Land preparation total cost	1,801.4 ±993.8 (37)	9,385.8 ±16,570.1 (26)	3,282.4 ±2,304.5 (68)	4,075.4 ±7,953.2 (131)	0.000
Planting total cost	1,357.1 ±780.0 (28)	2,942.9 ±4,516.5 (21)	1,346.2 ±935.6 (26)	1,797.3 ±2,558.9 (75)	0.052
Weeding total cost	1,185.2 ±622.5 (27)	2,445.8 ±2,591.1 (24)	1,150.0 ±438.5 (30)	1,545.7 ±1,572.1 (81)	0.003
Manure application total cost	1,133.3 ±571.3 (30)	1,475.0 ±1,356.3 (10)	1,069.0 ±578.2 (29)	1,155.8 ±734.0 (69)	0.317
Harvesting total cost	1,387.1 ±989.2 (31)	2,616.7 ±2,974.1 (18)	1,451.6 ±1,386.6 (31)	1,688.8 ±1,805.3 (80)	0.044
Transportation total cost	2,326.6 ±1,348.1 (44)	3,147.6 ±4,380.4 (21)	2,193.4 ±1,525.5 (61)	2,399.0 ±2,220.1 (126)	0.229
Storage total cost	1,472.3 ±617.7 (47)	4,633.3 ±13,847.4 (18)	1,427.4 ±504.1 (62)	1,898.4 ±5,232.5 (127)	0.056
Irrigation total cost	1,762.5 ±1,523.5 (36)	3,186.7 ±5,276.1 (15)	2,178.6 ±1,854.1 (35)	2,180.2 ±2,677.4 (86)	0.226
Haulage total cost	1,000.0 ±0.0 (24)	1,909.1 ±2,222.8 (11)	1,115.4 ±431.5 (26)	1,213.1 ±1,006.1 (61)	0.034
Mowing cost	2,812.9 ±1,067.6 (31)	19,100.0 ±37,003.3 (24)	3,820.4 ±1,946.7 (49)	7,046.2 ±18,763.0 (104)	0.001
Bundling cost	3,474.1 ±1,223.8 (29)	3,655.6 ±2,675.7 (36)	4,471.4 ±5,159.4 (49)	3,960.1 ±3,754.9 (114)	0.446
Hauling cost	1,115.2 ±387.4 (33)	1,456.0 ±1,345.7 (25)	1,151.4 ±662.7 (37)	1,218.9 ±838.0 (95)	0.255
Storing cost	1,480.6 ±631.7 (62)	5,374.8 ±8,840.0 (50)	1,724.7 ±1,197.3 (77)	2,610.3 ±4,883.8 (189)	0.000
Fodder variable expenses	15,422.9 ±4,579.6 (62)	36,684.0±45,597.5 (58)	18,455.9 ±8,666.4 (85)	22,695.8±26,407.0 (205)	0.000
Fodder produced	78.1 ±24.3 (62)	89.2 ±69.0 (58)	82.1 ±21.2 (84)	82.9 ±41.4 (204)	0.331
Fodder used	55.7 ±18.3 (62)	54.7 ±49.0 (58)	62.1 ±19.7 (84)	58.1 ±30.8 (204)	0.283
Fodder sold	22.3 ±8.8 (62)	35.8 ±34.3 (56)	21.2 ±7.6 (79)	25.7 ±20.5 (197)	0.000
Fodder sale income	5,133.1 ±1,377.3 (62)	7,391.1 ±6,827.0 (56)	5,447.5 ±1,747.6 (79)	5,901.0 ±3,973.5 (197)	0.003
Fodder value	19,108.9±6,816.8 (62)	18,824.1±14,240.4 (58)	23,656.6±13,233.1 (83)	20,887.0±12,152.6 (203)	0.025

The study shows that while rainwater harvesting technologies (RWHT) contribute positively to fodder production in arid and semi-arid lands (ASALs), the economic outcomes of these interventions vary significantly by location (Table 4.6.3). Specifically, total variable costs for fodder production operations differed across sites, with Ndege incurring the highest average cost at Kshs. 36,684, followed by Uthole at Kshs. 18,455, and Kibilay at Kshs. 15,423. Despite these cost variations, the volume of fodder produced and used was statistically similar across all locations, suggesting that differences in profitability are more closely tied to economic efficiency than production output. Importantly, mean annual fodder profits per household showed significant variation: Uthole reported the highest profits at Kshs. 4,699, followed by Kibilay with Kshs. 3,746, while Ndege recorded the lowest at Kshs. 1,428. These findings indicate that even where RWHT adoption levels may be high, the returns on investment are not uniform and depend heavily on local socio-economic dynamics, cost management practices, and possibly market access conditions.

The implication is that RWHT interventions should be contextualized to local economic conditions. In regions like Uthole, where profitability is highest, RWHT may be well integrated with market systems and supported by efficient production and cost structures. Conversely, in areas like Ndege, high input costs coupled with lower returns suggest inefficiencies in implementation or limited market access, warranting targeted support to improve cost-effectiveness and income generation. These findings align with Mugenda and Mugenda (2019), who emphasize the importance of considering both economic and contextual variables when assessing the impact of agricultural interventions. Moreover, they underscore that while RWHT supports resilience and sustainability, its adoption must be economically viable to ensure long-term adoption by smallholder farmers. Strategic support, such as training on cost management and improved market linkages, is crucial for maximizing the livelihood benefits of RWHT across Kenya's ASALs.

4.7 Adoption of Rainwater harvesting technologies for fodder production

4.7.1 Adoption stats in the three Habaswein Villages

Table 4.7 1: Adoption status of RWHT by households in Habaswein locations

Technology	Adoption status	Kibilay	Ndege	Uthole	All sites	χ^2 test
Zai pits	Pipeline	30a (96.8)	36b (78.3)	52b (81.3)	118 (83.7)	*
	Adopted	1a (3.2)	10b (21.7)	12b (18.8)	23 (16.3)	
Contour bunds	Pipeline	18a (30)	25b (53.2)	30ab (36.1)	73 (38.4)	*
	Adopted	42a (70)	22b (46.8)	53ab (63.9)	117 (61.6)	
Semi-circular bunds	Pipeline	33ab (57.9)	16b (40)	55a (72.4)	104 (60.1)	**
	Adopted	24ab (42.1)	24b (60)	21a (27.6)	69 (39.9)	

Source Research 2025

The study revealed significant location-based differences in the adoption status of rainwater harvesting technologies RWHT (table 4.7.1), including Zai pits, contour bunds, and semi-circular bunds in Habaswein Sub-County. A chi-square test showed a statistically significant association between location and adoption status for all three technologies, indicating that both the willingness to adopt (pipeline adoption) and actual implementation vary notably across areas (Creswell & Creswell, 2018). For Zai pits, most farmers (83.7%) were in the pipeline stage, with actual adoption at only 16.3%. Kibilay exhibited the highest proportion of pipeline adopters (96.8%) but the lowest actual adoption rate (3.2%). Conversely, Ndege and Uthole had higher actual adoption rates (21.7% and 18.8%, respectively), suggesting more advanced implementation in these locations. This implies that while awareness and interest are widespread, actual adoption may be constrained by technical, financial, or labor-related barriers (Mutunga, Onywere & Karanja, 2020).

For the contour bunds, 61.6% of respondents had adopted the technology, with a significant variation across locations. Kibilay led in adoption (70%), followed by Uthole (63.9%), while Ndege had the lowest adoption rate (46.8%) but a higher share of pipeline adopters (53.2%). This pattern suggests that perceived effectiveness, community mobilization, or localized support services influence the speed of adoption (Rockström et al., 2018). The semi-circular bunds, had 60.1% pipeline adoption which was also dominant, while 39.9% had implemented the structures. Uthole recorded the highest adoption (72.4%), followed by Kibilay (57.9%) and Ndege (40%). These

differences may reflect varying agro-ecological conditions, extension access, or prior exposure to RWHT initiatives (Mohamed & Wasonga, 2019). These findings emphasize the importance of context-specific and technology-specific interventions. High pipeline adoption areas like Kibilay (for Zai pits) present an opportunity for targeted support to translate intent into practice, while areas like Uthole can be leveraged as demonstration sites to scale up adoption. Addressing location-specific barriers such as limited extension support, technical skills, and resource constraints is essential to maximize the impact of RWHT in arid and semi-arid regions (Fatondji et al., 2016; WFP, 2021).

4.7.2 Reasons for the adoption of the RWHT

Table 4.7 2: Mean rating of decision-making influences for RWHT adoption

Location	Kibilay	Ndege	Uthole	Across site	ANOVA Significance	Rank
Parameter						
Technology expansion will be helpful	1.8a	1.3b	1.5b	1.5	**	1
Construction was easy on the farm	1.6a	1.3b	1.7a	1.6	**	2
There was support from WFP and other organizations	1.8	1.5	1.6	1.6	ns	2
I can earn extra money because of the technology	1.9a	1.7a	1.4b	1.6	**	2
Through the technology I will have improved livestock	1.9	1.5b	1.4b	1.6	**	2
The training language was easy to understand	2.0b	1.4b	1.8a	1.7	***	6
Extension services were available	2.0a	1.5b	1.7b	1.7	*	6
Fodder market is available	2.0b	1.4	1.9b	1.8	**	8
The technology is adequate to mitigate during drought	1.8	1.9	1.9	1.9	ns	9
The learning time was adequate	2.1	1.8	2.0	2.0	ns	10
Fodder demand was available	2.0	1.8	2.0	2.0	ns	10
I witnessed how farmers were helped elsewhere	2.2	1.9	1.9	2.0	ns	10
The technology is adequate for fodder cultivation and works on my land	2.1	1.9	2.1	2.0	ns	10
How the technology was passed on to me	2.2a	2.2a	1.9b	2.1	*	14
Observation and learning by practice were easy	2.3	2.1	2.1	2.1	ns	14
Funding resources were available to procure inputs	2.2	2.0	2.1	2.1	ns	14
The mode of message diffusion was easy to understand	2.2a	1.9b	2.4a	2.2	**	17
The presentation and learning materials were well elaborated	2.2	2.3	2.1	2.2	ns	17
Tools were available	2.4a	2.0b	2.5a	2.3	***	19

Likert scale from 1 to 5 was used (Table 4.7.2), where 1 (SA) represents strong agreement whereas 5 means the respondent strongly disagrees. A Likert scale is a rating scale used to measure survey participants' opinions, attitudes, motivations, and more. It uses a range of answer options ranging from one extreme attitude to another, sometimes including a moderate or neutral option. Values are presented as mean scores. The study reveals that farmers' decisions to adopt rainwater harvesting technologies (RWHT) in Habaswein Sub-County are influenced by a combination of technical, institutional, and economic factors. Among these, the perception that “technology expansion will be helpful” received the highest overall mean rank across all study locations. This suggests that farmers strongly believe in the broader benefits of RWHT and see its potential to enhance productivity and resilience when scaled up. Such a perspective underscores the importance of developing supportive policies and programs that facilitate the expansion of RWHT through community-based and government-led initiatives. Other highly ranked factors influencing adoption included the ease of construction, which reflects the practical considerations farmers take into account when deciding whether to invest labor and resources in new technologies. Institutional support, particularly from organizations such as the World Food Programme (WFP), was also cited as a key motivator, indicating that external facilitation significantly contributes to adoption decisions—especially where material support, training, or demonstrations are provided.

Economic incentives emerged as another strong driver. Farmers rated the potential for additional income and improved livestock productivity as important reasons for adopting RWHT, showing that tangible benefits in terms of fodder yield and animal health play a central role in influencing adoption. Furthermore, the availability of extension services and the use of local languages in training sessions were seen as essential, pointing to the need for accessible and culturally appropriate knowledge transfer mechanisms. Fodder market access was also highlighted, suggesting that adoption is not only shaped by on-farm considerations but also by opportunities for income generation through market linkages. Additional factors such as the method of technology transfer, the channels through which information is disseminated, and the availability of basic tools for implementation were rated as significant. These findings emphasize the importance of effective communication strategies and logistical support in promoting adoption.

4.7.3 Reasons for investing in RWHT

Figure 4.4. presents the main reasons for investing in RWHT in Kibilay, Ndege and Uthole locations.

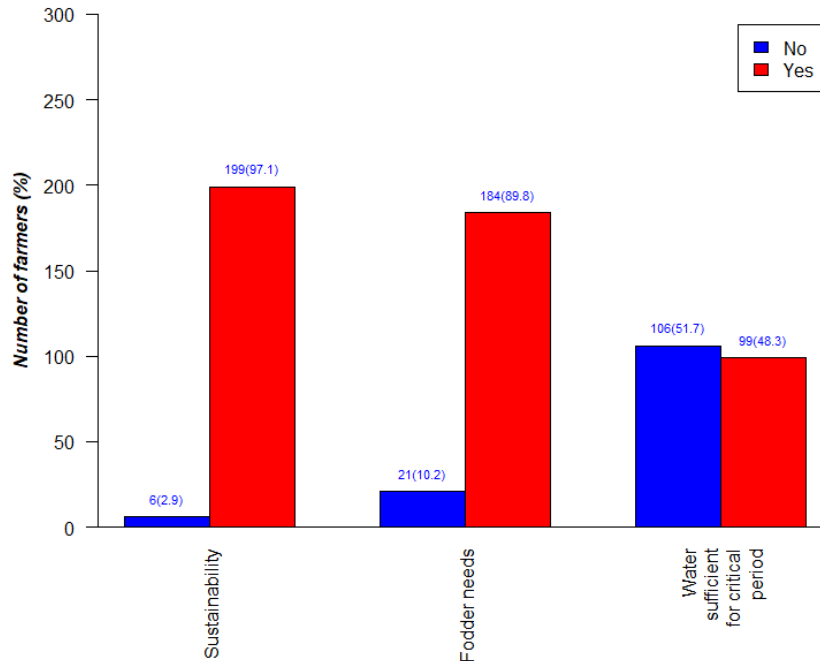


Figure 4.11: Reasons for investing in RWHT by farmers in Habaswein:

The main reasons for investing in RWHT by respondents in all locations was sustainability demands (Figure 4.11) followed by fodder needs by 90% of the respondents, while water needs during critical periods was rated at 50% by the respondent households. The RWHT technologies were also rated by farmers on a Likert scale of 1 (low) to 5 (high) (Figure 4.12). This strong association between RWHT and fodder needs underscores the importance of framing such technologies not merely as water management solutions, but as essential tools for enhancing pastoral livelihoods and resilience. It also reflects a growing awareness among pastoral communities of the long-term ecological benefits of RWHT, including improved soil moisture retention, pasture regeneration, and landscape sustainability.

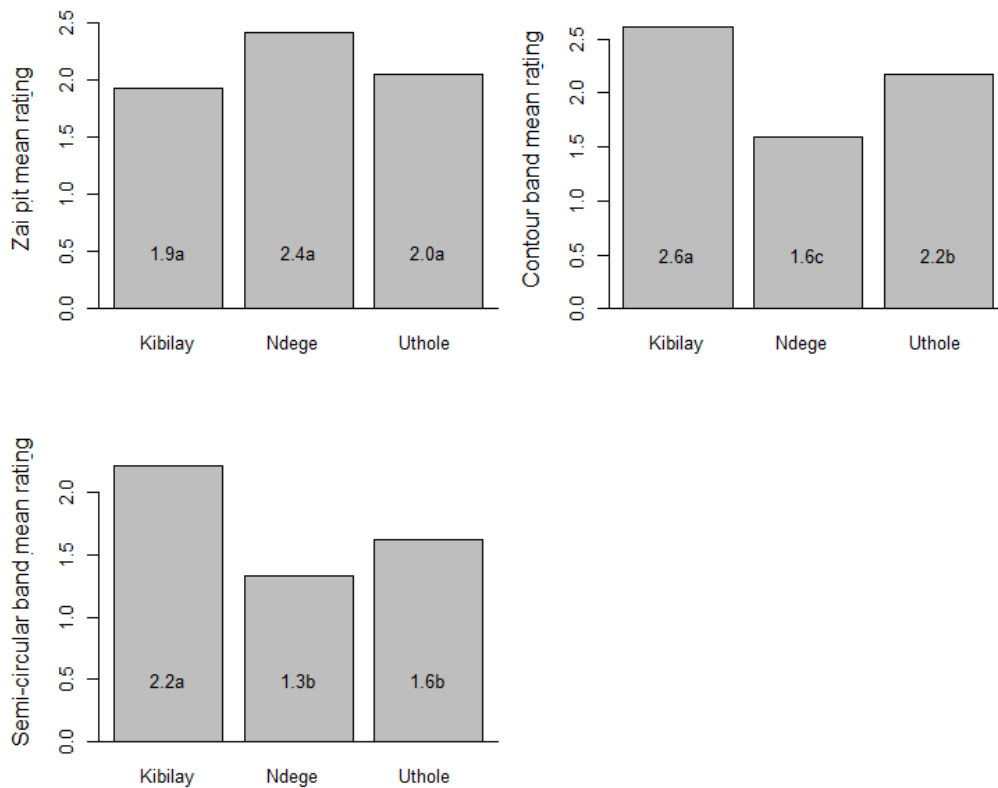


Figure 4.12: Mean rating scale (1-5) of RWHT technologies by location (means followed by different letters are significantly different) Source: Research 2025

The mean rating of *Zai pits* was not significantly different across the three locations (Figure 4.12), but farmers in Ndege location rated *Zai pits* highest with a value rating of 2.4 followed by Uthole at 2.0 and Kibilay with a value of 1.9. There was a significant difference in the rating of contour bunds by location, with all the sites showing differences. Ndege recorded the lowest contour bund mean score (1.6), followed by Uthole (2.2) and Kibilay with the highest rating (2.6). Ndege and Uthole location farmers did not record significant differences in semi-circular bund ratings, but the farmers rated them significantly lower than farmers in Kibilay location. The analysis of farmer ratings for rainwater harvesting technologies (RWHT) across Habaswein Sub-County provides important insights into user perceptions and the contextual suitability of different interventions. While the mean ratings for *Zai pits* did not differ significantly across locations, farmers in Ndege rated them highest, indicating greater satisfaction likely due to better performance outcomes in that area. This suggests that *Zai pits* are generally well-accepted but are perceived as most beneficial in specific

contexts like Ndege, where adoption has also been higher. Ratings for contour bunds varied significantly by location. Farmers in Kibilay gave the highest scores, followed by Uthole and then Ndege, where the technology received the lowest rating. This pattern implies differing experiences with effectiveness, possibly influenced by land conditions, maintenance support, or implementation quality. Similarly, semi-circular bunds were rated significantly higher in Kibilay than in Ndege and Uthole, pointing to a better fit or more successful outcomes in Kibilay.

Focus Group Discussions (FGDs) revealed that most participants actively practice Rainwater Harvesting Technologies (RWHT), particularly for crop and fodder production activities seen as central to enhancing drought resilience and managing erratic rainfall patterns. Participants demonstrated awareness and application of a variety of RWHT methods, including surface runoff harvesting, rooftop catchments, furrows, and even innovative approaches such as bottled water collection. The motivation behind adoption was largely driven by the need to reduce the impacts of drought, address water scarcity, and increase agricultural productivity findings that align with Mutiso et al. (2020), who emphasized RWHT's role in promoting climate resilience in arid regions. Despite the encouraging levels of awareness and adoption, participants noted several ongoing challenges. These include limited financial resources, inadequate access to tools and technical know-how, labour shortages, weak infrastructure, and livestock-crop conflicts arising from insufficient fencing. In response to these constraints, communities have mobilized local support, secured assistance from the World Food Programme (WFP), non-governmental organizations (NGOs), County Governments, and Constituency Development Fund (CDF) programs. Measures such as erecting fences and hiring watchmen were mentioned as practical steps taken to protect RWHT installations. While community engagement and awareness of RWHT are commendable, participants stressed the need for continued technical and financial support to scale up and sustain these critical interventions. Key Informant Interviews (KIIs) echoed similar sentiments but noted that despite the known profitability of fodder production, the overall adoption of RWHT remains relatively limited. Informants confirmed that farmers are implementing various RWHT approaches, with water pans emerging as the most used technology, reportedly adopted by nearly 60% of the farmers. Contour bunds followed with approximately 30% adoption, while other technologies such as canals, farm ponds, roof catchments, and Zai pits registered less than 15% adoption. According to the Key Informants, the limited adoption is primarily attributed to persistent drought, unreliable

rainfall patterns, and inadequate capacity, coupled with restricted access to both financial and technical resources. These systemic constraints continue to impede the wider adoption and effective integration of RWHT into sustainable fodder production systems.



CHAPTER FIVE:

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a discussion of the study's key findings, draws conclusions, and offers practical recommendations. It also highlights the limitations experienced during the research and proposes directions for future studies.

5.2 Summary of the study structure

The study was systematically structured into five interconnected chapters, each addressing a critical aspect of the research on the adoption and effectiveness of Rainwater Harvesting Technologies (RWHT) in the fodder value chain within Habaswein Sub-County, Wajir County.

Chapter One introduced the study by providing a background to the problem, outlining the challenges of water scarcity, recurrent drought, and limited fodder availability in Kenya's arid and semi-arid lands (ASALs). It clearly articulated the research problem, set out the study objectives and questions, and explained the significance, scope, and limitations of the research.

Chapter Two presented a comprehensive review of the existing literature, both globally and locally, on rainwater harvesting, fodder production, and the various ecological and socio-economic factors that influence the adoption of such technologies. The chapter also discussed the theoretical foundations underpinning the study, including the Sustainable Livelihoods Framework, the Diffusion of Innovations Theory, and the Theory of Expected Utility. A conceptual framework was developed to visually represent the relationships among key study variables and to guide data collection and interpretation.

Chapter Three detailed the methodology used to conduct the research. It described the study design, the sampling strategy, and the data collection methods, which included structured questionnaires, key informant interviews (KIIs), and focus group discussions (FGDs). The chapter also outlined the analytical tools used, such as chi-square tests, regression analysis, and descriptive statistics, to analyze both quantitative and qualitative data.

Chapter Four focused on the presentation and discussion of findings. It was organized around the study's main objectives and variables: socio-economic characteristics, ecological conditions,

training and extension services, and RWHT adoption. Quantitative results were complemented by qualitative narratives from KIIs and FGDs, offering a holistic view of the factors influencing RWHT adoption, land use patterns, economic returns, and challenges faced by the community.

Finally, Chapter Five provided a summary of key findings and draws evidence-based conclusions regarding the role and impact of RWHT on fodder production and resilience in ASAL communities. It offered theoretical, policy, and practical recommendations, advocating for increased investment in training, targeted institutional support, and scalable RWHT interventions tailored to the socio-ecological context of pastoral communities in Kenya's drylands.

5.3 Discussion

5.3.1 Socio-economic characteristics of farmer households

The study found that several socio-economic characteristics including gender, education level, crop systems, household income, land area under fodder, and tropical livestock units (TLUs) varied significantly across the study locations (Ndege, Kibilay, and Uthole) and were closely associated with the adoption and outcomes of rainwater harvesting and storage technologies (RWHST). A higher proportion of male-headed households was found in Ndege, suggesting gender-based disparities in access to resources, which can influence technology adoption, especially in pastoral contexts (Omollo, 2010). Most households engaged in agro-pastoralism, with some location-specific variations in the extent of fodder versus food crop production. Farmers in Kibilay had longer residency in Habaswein, which was associated with greater land and resource investments. Education levels were generally low, but primary education attainment varied significantly by location—an important factor in technology adoption and utilization (Lutta et al., 2020). Households with higher income, more land under fodder, and higher TLU levels were more likely to adopt RWHST, indicating that wealthier households are better positioned to invest in and benefit from these technologies. The study also found substantial variation in fodder value chain outcomes across locations. Ndege recorded significantly higher annual investments in RWHST and greater crop and fodder incomes. Regression analysis confirmed a strong positive relationship between RWHST investment and income returns, with an average return of 69 cents per shilling for crop income and 59 cents for fodder income. These results align with other studies demonstrating that

soil and water conservation techniques improve agricultural productivity, income, and food security (Siraw et al., 2020; Tesfayohannes et al., 2022).

5.3.1 RWHT adoption in Habaswein sub-location

The study revealed that rainwater harvesting and storage technologies (RWHST) in Habaswein Sub-County were adopted at varying stages across different locations. While contour bunds had achieved widespread adoption across all sites, Zai pits and semi-circular bunds remained in the early or “pipeline” stages of adoption. These findings align with the adoption model proposed by De Graaf et al. (2008), which categorizes technology adoption into three phases: acceptance, actual adoption, and continued use. The pipeline phase in this study corresponds to the initial awareness and trial phase described by Rogers and Shoemaker (1971). Multiple factors influenced adoption decisions, including the perceived economic and livestock productivity benefits of the technology, its ease of construction, and the availability of training, extension services, and market access. These are consistent with economic theory and classification models of technology adoption discussed by Bonabana-Wabbi (2002), who highlighted influences ranging from demographic and institutional factors to resource availability, policy, and environmental concerns. Moreover, the study found that resource-intensive technologies like Zai pits and Negarims were less commonly adopted, as reported by Muriu-Ng’ang’a et al. (2017). Farmers tended to adopt simpler, less knowledge-intensive alternatives such as trash lines and grass strips, especially in lower potential zones. Adoption patterns varied by location due to agro-ecological factors such as soil type, slope, and rainfall (Muriu-Ng’ang’a et al., 2017). Additionally, the characteristics of the technology—such as its trialability, compatibility with farmer needs, and observable benefits—were critical to adoption. Farmers were more likely to adopt technologies they could test at a small scale and that fit within their environmental and economic conditions (Mwangi & Kariuki, 2015; Doss, 2003; Mignouna et al., 2011). Perceptions of performance and suitability significantly influenced the adoption process, consistent with findings by Adesina and Zinnah (1993).

5.3.2 Socio-economic factors that impact of RWHT adoption within the fodder value chain

The study found that the adoption of rainwater harvesting and storage technologies (RWHT) in Habaswein Sub-County was significantly influenced by a combination of ecological, socio-economic, and institutional factors. According to the generalized linear regression model, important socio-economic factors included: education level, years of residence, land size, training frequency, and extension access emerged as key determinants of adoption. Larger land sizes were positively associated with adoption, suggesting that farmers with more farmland have greater capacity and incentive to invest in RWHT. Land tenure also had a significant influence. Secure private land ownership encouraged adoption, while communal or insecure tenure often discouraged long-term investments in water harvesting infrastructure. Farmers with secure land tenure demonstrated a higher likelihood of implementing RWHT on a larger scale (Lutta et al., 2020; Ahmed et al., 2013). Interestingly, newer residents in Habaswein were more likely to adopt RWHT than long-term residents. This may be because newer settlers are more open to innovation and more likely to engage in training and extension programs—consistent with findings that younger or more recently settled farmers adopt new technologies at higher rates (Muriu-Ng'ang'a et al., 2017).

5.3.4 Ecological factors affecting the adoption of rainwater harvesting technologies in the fodder value chain

The study identified several ecological factors as key determinants of rainwater harvesting and storage technology (RWHT) adoption in Habaswein. Rainfall patterns, amounts and drought incidences were found to be the most influential, followed by soil properties and forestation demands. Although soil type was cited less frequently overall, its impact varied significantly across locations, suggesting it still plays a location-specific role in technology suitability and adoption. The findings emphasize that weather variability has a greater influence on technology adoption than static factors like soil alone. Similar to trends observed in broader soil conservation literature, the profitability and feasibility of adopting technologies like RWHT in drylands depends heavily on ecological shocks and local agro-climatic conditions (Almekinders & Hardon, 2006). The need for ecological literacy in the adoption of sustainable agricultural practices is also echoed in studies on integrated pest management (IPM), which stress the importance of understanding local environmental conditions for effective implementation (Ehler & Bottrell, 2000; Cruz, 1978). These insights apply equally to RWHT in dryland agro-pastoral systems. Additional evidence shows that

farm conditions such as irrigation access, location, rainfall distribution, and soil type critically shape adoption behaviors. For instance, irrigated farms were quicker to adopt new rice varieties, whereas those with poor water access lagged behind (Kinyangi, 2014). In Habaswein, technologies were more widely adopted on sandy soils, due to their fragile structure and responsiveness to conservation measures. The distribution of soil types across locations further highlights the need for site-specific RWHST solutions to optimize water conservation, fodder productivity, and profitability.

5.3.5 Effect of training and capacity building on rainwater harvesting adoption

The study found that farmer training had a significant and positive impact on the adoption of rainwater harvesting and storage technologies (RWHST) in Habaswein. Specifically, the number of training sessions attended was strongly associated with larger land areas allocated to Zai pits, contour bunds, semi-circular bunds, and overall RWHST coverage. The impact was especially notable for Zai pits and contour bunds, as indicated by regression coefficients. Moreover, training was also positively correlated with fodder profitability, as confirmed through a cost-benefit analysis of the fodder system in the study area. These findings support previous research by Chesterman et al. (2019), which showed that farmer participation in training significantly predicted the implementation of soil conservation methods in Ethiopia. Participants not only adopted more conservation techniques but also recorded higher agricultural incomes than non-participants. The results affirm that targeted training programs can significantly enhance technology adoption, fodder productivity, and economic outcomes in Kenya's arid and semi-arid lands (ASALs), with implications for both soil conservation and livelihood improvement. Training and extension services were positively and significantly associated with adoption. The number of training sessions attended, and exposure to diverse extension themes, improved farmers' knowledge and technical capacity, leading to increased adoption of RWHST. Extension services facilitated better understanding of construction, maintenance, and benefits of the technologies, reinforcing adoption outcomes (Magruder, 2018; Muriu-Ng'ang'a et al., 2017).

5.4 Conclusions

It can be concluded from the study that different factors influenced technology adoption in Habaswein Sub-County. The type of RWHT, socio-economic, ecological and training affected the adoption status and intensity. Most significant attributes included: soil type, rainfall, droughts, education, years of residence in Habaswein, land-size, training frequency, and extension access (number of training types attended). The specific ecological factors important for RWHT adoption in Habaswein, included rainfall availability or absence, drought incidences, soil properties and overland water inflows. Soil types influenced the land areas under different technologies types in the study area. The number of RWHT trainings attended by households led to larger farm sizes being put under RWHT use in Habaswein. The findings also established that fodder profits increased by increasing training frequencies in Habaswein locations. The extension training themes that were emphasized included production-related themes, while market-related themes were less emphasized. Better livestock feeding, better health and more access to water were generally considered as factors that contribute generally to mitigating shocks related to erratic and unreliable rainfall and changing weather patterns and climate change. Improved livestock health meant more household incomes, food security and improved livelihoods from livestock and the fodder sales.

5.5 Recommendations

5.5.1 Adoption level of RWHT in Habaswein sub-location

The adoption of RWHT in Habaswein faces several barriers, including inadequate technical knowledge, high initial costs, weak policy frameworks, and climate variability. To enhance adoption, targeted interventions are necessary. Strengthening extension services through increased agricultural officers and localized training programs can improve technical capacity (Mutunga, Onywere & Karanja, 2020). Financial support mechanisms, such as microfinance programs and subsidies, can alleviate cost-related constraints (Ngigi, 2003). Additionally, improving policy coordination among government agencies, NGOs, and private stakeholders can enhance the effectiveness of RWH initiatives (Toulmin, 2009). Community participation is crucial, as integrating indigenous knowledge with modern RWH techniques fosters greater acceptance and sustainability (FAO, 2021). Climate-resilient water storage solutions, such as sand dams and subsurface reservoirs,

are necessary to mitigate the impacts of extreme weather events (Falkenmark & Rockström, 2008). Furthermore, strengthening fodder market linkages by improving storage facilities and cooperative marketing can make RWH investments more economically viable (Mogaka, Gichuki & Liniger, 2006). Implementing robust monitoring and evaluation frameworks will ensure continuous learning and improvement in RWH adoption (Rockström et al., 2010). Addressing these challenges holistically can significantly improve water security and fodder production in Habaswein.

5.5.2 Socio-economic factors that impact of RWHT adoption within the fodder value chain

The adoption of rainwater harvesting technologies (RWHT) in the fodder value chain is influenced by various socio-economic factors, including financial constraints, land tenure security, market access, social structures, gender inclusivity, and climate resilience. High initial investment costs and maintenance expenses hinder smallholder farmers from implementing RWHT, necessitating financial support through subsidies, microfinance, and credit schemes (Ngigi, 2003; Mogaka, Gichuki & Liniger, 2006). Secure land tenure is essential for long-term investments in RWHT, particularly in pastoralist communities where communal land ownership is common (Toulmin, 2009; FAO, 2021). Market access plays a crucial role in adoption, as farmers are more likely to invest in RWHT if they have stable fodder markets. Strengthening cooperative societies, transport infrastructure, and contractual agreements with livestock traders can improve market integration (Rockström et al., 2010; Mbilinyi et al., 2005). Additionally, social capital, including farmer cooperatives and knowledge-sharing platforms, facilitates RWHT adoption by promoting community participation and resource pooling (Mutunga, Onywere & Karanja, 2020). Gender disparities also impact adoption rates, as women and marginalized groups often have limited access to resources and decision-making platforms. Implementing gender-sensitive policies and supporting women's cooperatives can enhance inclusivity (Van der Zaag & Gupta, 2008; FAO, 2021). Furthermore, climate variability affects RWHT effectiveness, requiring climate-smart solutions such as sand dams, subsurface reservoirs, and water-efficient irrigation techniques to enhance resilience (Falkenmark & Rockström, 2008; Glendenning & Vervoort, 2011). Addressing these socio-economic challenges through targeted interventions can enhance RWHT adoption, ensuring sustainable water security and improved fodder productivity in arid and semi-arid lands (ASALs).

5.5.3 Ecological factors affecting the adoption of rainwater harvesting technologies in the fodder value chain

Ecological factors such as rainfall variability, soil properties, topography, vegetation cover, and climate change significantly influence the adoption of rainwater harvesting technologies (RWHT) in the fodder value chain. To enhance RWHT effectiveness in arid and semi-arid lands (ASALs), strategic interventions are necessary. RWHT should be designed to accommodate rainfall variability by incorporating flexible storage systems like sand dams and water pans to ensure year-round water availability (Rockström et al., 2010; Glendenning & Vervoort, 2011). Soil management practices such as contour bunding and agroforestry can improve water infiltration and retention, ensuring sustainability (Bouma & Wösten, 2016). Additionally, site-specific RWHT designs should consider land slope and terrain, with check dams and terraces suited for sloping areas while infiltration pits and ponds are preferable for flat landscapes (Ngigi, 2003; FAO, 2021). Vegetation restoration through rangeland reseeding and fodder tree planting is crucial for improving water retention and reducing soil erosion (Mogaka, Gichuki & Liniger, 2006). Moreover, climate change adaptation strategies, including resilient storage structures, drought-tolerant fodder crops, and early warning systems, are necessary to mitigate the increasing risks of extreme weather events (Falkenmark & Rockström, 2008; Barron & Noel, 2008). Strengthening policy frameworks to support climate adaptation will further enhance RWHT adoption in ASALs. Addressing these ecological factors will promote sustainable RWHT adoption, improve water security, and enhance fodder production in ASAL regions.

5.5.4 Effect of capacity building on rainwater harvesting adoption among households

Capacity building is essential for improving the adoption of rainwater harvesting technologies (RWHT) among households involved in the fodder value chain. Effective training and extension services enhance technical knowledge and provide practical skills for RWHT installation, operation, and maintenance (FAO, 2021). Knowledge dissemination through localized platforms, such as farmer field schools and digital media, facilitates awareness and integration of RWHT into existing agricultural practices (Rockström et al., 2010). Financial literacy training and improved access to credit are necessary to address the financial constraints that hinder RWHT adoption. Partnerships with financial institutions can offer affordable financing options to support household investments in water harvesting infrastructure (Mogaka, Gichuki & Liniger, 2006). Community-based

participatory approaches, including farmer-to-farmer learning and cooperative initiatives, promote knowledge sharing and foster higher adoption rates (Tumbo et al., 2012). To sustain RWHT adoption, policy support and institutional coordination are critical. Governments and development agencies should integrate structured capacity-building programs into national agricultural strategies while enhancing collaboration among stakeholders (FAO, 2021). These interventions will strengthen household capacity, ensuring long-term adoption and sustainability of RWHT in ASAL regions.

5.5.5 Theoretical, Policy, and Practical Contributions of the Study

This study contributes to theory, policy, and practice by offering a comprehensive analysis of the adoption and effectiveness of Rainwater Harvesting Technologies (RWHT) in fodder value chain in arid and semi-arid lands (ASALs), particularly in Habaswein, Wajir County. The recommendation present practical actions that can be implemented by individual and issues that are best served by policy especially those that affect majority of the farmers and can't be implemented by individual farmers. Training is for example provide the govt extension service and the NGOs working in the area. Access to financial resources could be individually responded to but in majority of the cases, external interventions are required to sufficiently support the farmers install the RWHTs. To ease on labour demands, researchers and engineers should innovate tools and machinery that can rapidly install the individual RWHTs in order to overcome the limitations of labour.

5.5.5.1 Theoretical Contribution:

The research strengthens the Sustainable Livelihoods Framework (SLF) by illustrating how RWHT contributes to communities capitals that include: natural capital, physical capital, human, social capital and financial capital; such as improved soil moisture, fodder yields, and household income, thus contributing to pastoral resilience (Chambers & Conway, 1992; Scoones, 1998). Forestation demands also distilled as a determinant in technology adoption driver which is mostly a natural capital factor. It also draws on Rogers' Diffusion of Innovation Theory to explain how RWHT adoption follows a sequence of knowledge, persuasion, decision, implementation, and confirmation, heavily influenced by social learning and observable benefits (Rogers, 2003). The Theory of Expected Utility further informs farmers' adoption decisions, where choices are driven by perceived profitability and risk management (Bernoulli, 1738; Kassie et al., 2015). Additionally, Fliegel and

Kivlin's (1966) Adopter Perception Theory is reflected in findings showing how perceptions of complexity, gender roles, and social norms affect adoption.

5.5.5.2 Policy Contribution:

The findings underscore the need for targeted subsidies and financing mechanisms to address the high cost of RWHT infrastructure (Mohamed & Wasonga, 2019; Munyasia et al., 2022). They also point to land tenure insecurity as a major barrier, calling for policy interventions to enhance land access and ownership, particularly for women. The study highlights the importance of embedding RWHT into broader national adaptation strategies and County Integrated Development Plans (CIDPs) to scale climate-resilient agriculture in ASALs (FAO, 2021). Weak extension supports also emerged as a policy gap, suggesting that governments must invest in sustained, localized, and ASAL-specific agricultural advisory services (Mutunga et al., 2020).

5.5.5.3 Practical Contribution:

Practically, the study demonstrates the importance of training in scaling RWHT adoption. Each additional training session attended by farmers was associated with increased land area under RWHT and higher fodder profits (Mutunga, Onywere & Karanja, 2020). It also highlights the economic viability of Zai pits, especially in sandy soils, and the need to avoid inefficiencies by limiting RWHT land coverage to an optimal scale of around 3.5 acres. Additionally, it affirms that community-based learning platforms such as farmer field schools play a key role in knowledge dissemination where formal training is scarce (Wekesa et al., 2019). Gender-responsive programming is recommended to address existing disparities in resource access and decision-making (Doss, 2001; Meinzen-Dick et al., 2009). Lastly, the study confirms RWHT's role in boosting livestock productivity, reducing drought-related losses, and strengthening local markets, thereby contributing to climate adaptation, economic resilience, and food security (Rockström et al., 2010; Fatondji et al., 2016).

5.6 Limitations of the study

Despite its contributions, this study has several limitations, including potential biases and methodological constraints. The study focused on Habaswein, Wajir County, which may limit the generalizability of the findings to other ASAL regions. While efforts were made to select diverse participants, the reliance on purposive and stratified sampling techniques may have introduced selection bias (Creswell & Creswell, 2018). Additionally, the sample size, although determined using Yamane's formula, may not fully capture the variability in rainwater harvesting (RWH) adoption across different socio-economic and ecological contexts (Yamane, 1967).

Data collected through key informant interviews (KIIs) and focus group discussions (FGDs) relied on self-reported information, which is susceptible to recall bias and social desirability bias (Bryman, 2016). Some respondents may have overstated the benefits of RWH due to expectations of future support, while others may have downplayed challenges to align with prevailing community narratives. Although the study employed a mixed-methods approach to enhance data triangulation, integrating qualitative and quantitative findings presented challenges. Differences in data interpretation, potential inconsistencies between qualitative narratives and survey responses, and the complexity of coding qualitative data may have influenced the depth of analysis (Creswell & Plano Clark, 2017). Additionally, resource and time constraints limited the extent of longitudinal data collection, making it difficult to assess long-term RWH impacts. Limited access to official government reports and institutional data posed challenges in validating some findings. In some cases, inconsistencies between policy documents and ground realities made it difficult to establish a clear link between policy implementation and RWH adoption (Mutunga, Onywere & Karanja, 2020). Moreover, bureaucratic delays in obtaining research approvals may have affected data collection timelines.

The study was conducted within a specific timeframe, which may not fully account for seasonal variations in rainfall and their impact on RWH adoption. Climate change-induced shifts in rainfall patterns may influence RWH effectiveness differently over time, potentially affecting the applicability of findings in the long run (Falkenmark & Rockström, 2008). To address these limitations, the study employed methodological triangulation by combining household surveys, FGDs, and KIIs to enhance the reliability of findings. Sampling strategies were designed to ensure representation of diverse stakeholders, including pastoralists, smallholder farmers, and extension

officers. Furthermore, secondary data sources, such as government reports and previous studies, were used to validate primary findings. Future research could incorporate longitudinal studies and expand the geographic scope to improve generalizability.

5.7 Areas for further study

Future research should explore the long-term socio-economic and environmental impacts of rainwater harvesting technologies (RWHT) within the fodder value chain. While previous studies have focused on adoption barriers, there is a need for longitudinal studies assessing RWHT sustainability, cost-effectiveness, and resilience to climate variability (Rockström et al., 2010). Another key area is the role of policy and governance in scaling up RWHT. Studies should examine the effectiveness of existing policies, identify institutional gaps, and explore innovative policy frameworks that enhance RWHT adoption in ASAL regions (FAO, 2021). Additionally, research should assess how decentralization and community-led initiatives influence the sustainability of RWHT interventions (Mutunga, Onywere & Karanja, 2020). Further investigation is needed on gender dynamics and social inclusion in RWHT adoption. While women play a crucial role in agricultural water management, studies should examine how socio-cultural norms, access to resources, and decision-making power impact their participation in RWHT projects (Van Koppen, Hope & Colenbrander, 2013). Technological innovations and digital solutions for RWHT should also be explored. Research should assess the potential of smart water management tools, remote sensing, and mobile-based advisory services in improving RWHT efficiency and accessibility for smallholder farmers (Mbilinyi et al., 2005). The study also recommends further areas of research, including investigations of exogenous factors such as market and policy factors that may influence RWHT adoption in several ASAL regions in Kenya. Another area to be investigated is that associated with pricing and the supply chains to offer more insights in the potentials of RWHTs from a commercial perspective. This can offer a feed supply sustainability solution during periods of extreme drought in the ASALs.

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APPENDICES

APPENDIX 1: QUANTITATIVE SURVEY TOOL

Interview guide

I am **Edgar Kaniu**, pursuing a Master of Management in Agribusiness at Strathmore University. Currently, I am researching to assess the impact of rainwater harvesting on the fodder value chain in Habaswein Sub County of Wajir County. Your participation will support this study and help improve and plan the future of agricultural capacity building and the fodder value chain in Habaswein. Please be assured that your responses are greatly appreciated and will remain strictly confidential. Participation is voluntary, and you have the option to withdraw at any time; the interview is expected to last approximately 1.5 hours.

Interviewer profile

1. Interviewer Name	
2. Participant ID#	
3. Interview Date (dd/mm/yyyy)	_ _ / _ _ / _ _ _ _
4. The participant agrees for an interview to be digitally recorded	Yes <input type="checkbox"/> No..... <input type="checkbox"/>
5. Time Interview Began (hhmm-24hr clock)	_ _ _
6. Time Interview Ended (hhmm-24hr clock)	_ _ _

Respondent profile

1.1. Interviewing date:/...../..... Respondent Name:

1.3. LocationWard... Village.....

1.5. Relationship of the respondent to the fodder producer: 1) Self.....2) Spouse.....3) Son..... 4).

Daughter.....5) Relative.....

1.6). Age.....Phone No

A. Rainwater water harvesting technologies

1. Please indicate which of the following rainwater harvesting technologies is practiced on your farm and to what extent you have implemented them. Provide your responses in the table below.

Rainwater harvesting method	Do you use this method? Yes or No		In what percentage of your farm area do you apply this method? (%)
<i>Zai pits</i>			
<i>Countour bunds</i>			
<i>Stone bund</i>			
<i>Fanya juu bund</i>			
<i>Contour bunds</i>			
<i>Semi-circular bunds (hoops)</i>			
<i>Trapezoidal bunds</i>			
<i>Soil bund 'fanya chini'</i>			

Provide a concise description of the water harvesting techniques mentioned in question 1, focusing on their sustainability, resource needs, preferred order of implementation, and capacity to store sufficient water during crucial periods.

Rainwater harvesting technology	Sustainability	Resource needs (1-Low; 2-Moderate; 3-High)	Technique effectiveness rating on a scale of 1 to 5 (with 1 least effective and	Is harvested rainwater sufficient for use during critical periods? Yes (1) or No (2)

			5 most effective)	
<i>Zai pits</i>				
<i>Countour bunds</i>				
<i>Stone bund</i>				
<i>Fanya juu bund</i>				
<i>Contour bunds</i>				
<i>Semi-circular bunds (hoops)</i>				
<i>Trapezoidal bunds</i>				

2. What is the current status of the water harvesting technique, and what challenges are encountered during its implementation?

Techniques	Current status (1 = Pipeline; 2= Adoption, 3 = adopted)	Challenges/ Constraints	Challenge mitigation
<i>Zai pits</i>			
<i>Countour bunds</i>			
<i>Stone bund</i>			
<i>Fanya juu bund</i>			
<i>Contour bunds</i>			

<i>Semi-circular bunds (hoops)</i>			
<i>Trapezoidal bunds</i>			

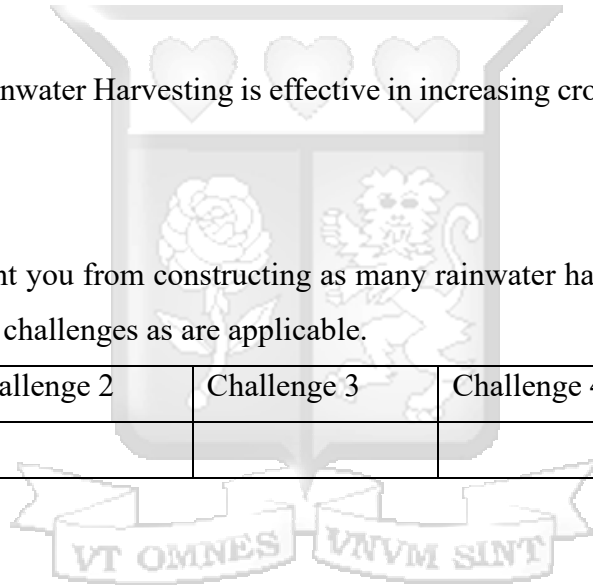
3. Is your community receiving assistance from organizations or institutions in establishing water harvesting techniques? Yes [] No [] Have no idea []

4. If the response to question 3 is affirmative, please specify the organizations involved and the respective water harvesting techniques they are assisting with. Name of organization:

5. Do you believe that Rainwater Harvesting is effective in increasing crop yield on your farm? Yes [] No []

6. What challenges prevent you from constructing as many rainwater harvesting structures as you need? Provide as many challenges as are applicable.

Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5



B. Ecological Factors;

1. How is precipitation distribution in Habaswein? [] bimodal [] Modal [] Any other please specify.....

2. (a) In your perception, does the precipitation sufficiently support fodder/crop cultivation? Yes [] No []

(b). If the answer is No, why and where is water sourced from? Please specify.....

3. What's the predominant soil type in Habaswein? (a)Sandy [] (b) Clay [] (c) Sandy-loam [] (d) Others

4. (a) Any irrigation? Yes [] No []

(b) If irrigated which crops are grown under irrigation?

- i
- ii
- iii

C. Social Economic Factors;

1. Indicate the Gender:- Male Female
2. How old are you? Indicate age bracket :- 20 20 - 30 40 – 50 60 – 70 > 70
- 3 (a) What’s your household size? Less than 3 (b) between 3-5 (c) between 6-8 (d) Over 8
- (b) Are you educated? To what level: - Specify
4. (a) Do you live Habaswein? Yes No
- (b) If so for long in years? <1 1 – 10 11 – 20 21 – 40 41 – 50 > 50 years
5. What do you do for a living? Employed Herding Casual laborer Fodder production Others
6. If Farming, when did you start farming? (years)? <1 1 – 10 11 – 20 21 – 40 41 – 50 > 50
7. What’s farm size in acres? <1 1 – 10 11 – 20 21 – 40 41 – 50 > 50
8. Ownership status (please specify): Owner leased out Worker/ Laborer Squatter Others
9. Do you own land? If so how did you acquire it? bought inheritance Others (specify)
10. What’s the land size for farming cultivation in acres?
11. What do you grow? Food crops fodder
12. Are the crops in pure stand intercropped both?
13. Do you carry out crop production for sale? No Yes
14. If yes, how much land is allocated to ? Pasture Food Crop
15. How much fodder is produced per acre in Kgs? _____
16. How much land is available for fodder in acres? _____
17. What’s your income on average in KES: - < 1000 1001-3000 3001-5000 5001-7000 7001-9000 > 9001
18. In Habaswein Sub-County what are the challenges related to weather do you experience? Flooding Erosion Drought
19. How many animals you have for each of the following: a. Cattle b. Sheep c. goats

] d. Poultry [] e. Camels [] Others []

20. What's the source of your livestock feed Own farm [] unsettled farms [] leased farm [] - farm purchases []

21. Where is rainwater harvesting carried out?

(a) on a Freehold land [] (b) on a Family land [] (c) on leasehold [] (d) on Own land []

22. Is rainwater harvesting carried out in your household? If yes who (a) I [] (b) all [] (c) hired labor []

23. Do you generate revenue? How much annually from your farm yields produced using harvested water, in Kenyan Shillings? (a) less than 5000 [] (b) between Kshs.5001-20,000 [] (c) between Kshs.20,001-50,000 [] (d) above 50,000 []

24. Have you invested in water harvesting technologies, how much annually in Kenyan Shillings < 1000 [] (b) 1001-3000 [] (c) 3001-5000 [] (d) Kshs 5000 []

Adoption of rainwater harvesting Technologies

1. What's your take on the following statements as pertains to what influenced your adoption of RWHT 1-Agree, 2- Moderately Agree, 3- Neutral, 4 – Don't agree, and 5-Disagree.

Factors affecting adoption of Water Harvesting Technologies	1	2	3	4	5
Water harvesting is a viable option for poverty alleviation and addressing household food security.					
The implementation of water harvesting technologies contributes to household development					
Water harvesting technologies when implemented on the farm enables household food supply and provides increased income					
Implementing water harvesting technologies on the farm enhances rural economic development					

2. Have you implemented any rainwater harvesting technique? If your reply is in the affirmative; to what extent do you agree with the following statements as pertains to what influenced your decision to take the action in the scale 1- Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, and 5-Strongly Disagree.

Factors that influenced my implementation of water harvesting technologies and structures (the responding farmer)	1	2	3	4	5
(a) Construction was easy on the farm (i.e., the innovation type)					
(b) How the technology was cascaded to me (language, persuasion, by a group, by family, by seeing, (social context)					
(c) The mode of message diffusion (i.e., barazas, social media, radio, TV, extension agent)					
(d) The learning time was adequate					
(e) Observation and practicing (experimenting)					
(f) Tools were available					
(g) Extension services were made available					
(h) Funding resources were available to procure inputs					
(i) Fodder demand was available					
(j) There was support from WFP and other organizations					
(k) I witnessed how farmers were helped elsewhere					
(l) The technology is adequate fodder cultivation and works on my land					
(m) I can earn extra money because on the technology					
(n) The technology is adequate to mitigate on drought					
(o) Through the technology I will have improved livestock					
(p) Technology expansion will helpful					
(q) Fodder market is available					

D. Training and extension services

1. Have you participated in any training sessions?

2. (a) Yes [] (b) No []

If yes who conducted the sessions

Institution.....

What was the mode of delivery 1. Plenary [] 2. Workshop [] 3. Other []

How many sessions were received last year (2023)

3. From your own perception, does fodder capacity building impact on adoption of water harvesting technologies in this area? (a) Yes [] (b) No []

If yes explain.....

4. To what extent do you agree with the following statements as pertaining to the adoption of the following water harvesting technologies,

Statement	Agree	Moderately Agree	Disagree	Don't Know
Extension services on fodder production are ably provided by the Ministry of Agriculture to farmers.				
There are adequate policies established by the government to guide fodder production				
The Ministry technical staff are adequately skilled to train and supervise water harvesting technologies implementation				
There are government programs and projects geared towards enhancing rainwater harvesting in this region				

5. Kindly identify two challenges experienced in water harvesting technologies implementation.

1: 2:

Fodder value chain

General data

2.1 Name identifier Years.....

2.2 Sex Gender: (1) Male..... (2) Female

2.3 Education: (1) None..... (2) Basic..... (3) Elementary..... (4) Vocational.....

2.4 Certification attained:

2.5 What do you do for a living? (1) Livestock farmer; (2) Crop Cultivation; (3) Conduct Business: (4) Employed; (5) Do menial jobs;(6) Others (specify)

2.6 Which of the above is your major source of livelihood?.....

2.7 What's the size of your family? Adult Male..... Adult female

Children..... Youth

2.8 How much is your land size?.....(acres)

2.9 Do you have animals? 1) Yes.....0) No.....

2.10 If yes, specify below:

Animal	Total number (mature and young ones)	Reason of keeping
Cattle		
Sheep		
Goats		
Donkey		
Camels		
Others(Specify)		
Total		

2.11 Ever experienced drought? (1) Yes.....(0) No.....

2.12 If yes, what was the effects?

2.13 How did you overcome the effects?

2.14 Are there communal grazing reserves? Yes [] No []

3.1 Is fodder grown on your farm? (1) Yes.....(0) No.....

3.2 If No, why not?

3.3 Any grass seeds production? (1) Yes.....(0) No.....

3.4 If No, why not?.....

3.5 If Yes, where did you learn about fodder growing?

3.7 Do you do fodder/seed cultivation or marketing as a group? 1) Yes.....0) No.

3.8 If Yes, what's the name..... When was it formed.....

3.9 Following on question 3.8 above, why did you join the group (1) (2) (3) (4)

3.10 Which type of fodder grass do you cultivate, and which ones do you gather from the wild?

Reseeded/grown	Yes/No	Collected from the wild	Yes/No
i <i>Eragrostissuperba</i>		<i>Eragrostissuperba</i>	
ii <i>Cenchrusciliaris</i>		ii <i>Cenchrusciliaris</i>	
iii <i>Chlorisroxburghiana</i>		iii <i>Chlorisroxburghiana</i>	
iv <i>Enteropogonmacrostachyus</i>		iv <i>Enteropogonmacrostachyus</i>	
v Others (specify)		v Others (specify)	

3.11 Why do you produce the grasses in your above response?

3.12 Any agronomic practices for pasture cultivation?

Land preparation (hand tools, mechanised, herbicides)	Sowing (by hand, mechanised)		Weeding (by hand, mechanised)		Other Management (pests' control, disease control, etc., mechanised harvesting, on-site baling, offsite baling)	

3.13 Where do you source resources necessary, and what was the total cost of these inputs over the past year? Please fill in the table below:

Inputs	External Supplier (1), Self Sourced (2)	Previous Year Amount of money earned in Kshs	Unit cost (Ksh)	Total cost

Farm (acres)				
Farm preparation				
Seeds (Grass)				
Tilling				
Labor				
Equipment and tools				
Seeding				
Water application				
Harvesting				
Haulage				
Capacity building				
Land				

Land 1=Own, 2=Rented, 3=Group, 4=GoK, 5=Others (specify)

3.14 How were the activities below conducted, and what were the associated costs?

Undertaking	Fodder		Seed	
	Ways	Costs (KSh)	Ways	Costs (KSh)
Mowing				
Bundling/Bailing				
Value preposition				
Hauling				
Storing				

3.15 How much fodder/seed got produced past year?

Item	Produced	Utilized	Retailed
Fodder/Hay (Kg)			
Seed (Kg)			

3.16 Enumerate primary challenges you encounter in fodder cultivation, and what strategies can be employed to address them?

Challenges	Suggested strategies
1	
2	
3	
4	

4.1 Is fodder/pasture marketable? (1) Yes..... (0) No.....

4.2 If No, why?.....

4.3 Do you have grass seeds available for sale?

4.4 If No, why?.....

4.5 If yes, who are your customers? Indicate.....

4.6 How are customers distribution points selected?.....

4.7 How is retailing done? (1) Cash..... (2) Credit..... (3) Both.....

4.8 What's the retail price of fodder and seed?

4.9 How is selling price determined?

4.10 What selling expenses were incurred (in Kes) last year?

4.11 Was fodder/seed market demand met?

4.12 Are grazing leas available? (1) Yes..... (0) No.....

4.13 Any challenges fodder selling? If any, how can they be mitigated?

Fodder selling challenges	Suggested solution
1.	
2.	
3.	

5.1 Are there extension services required on fodder production? (1) Yes..... (0) No

5.2 If so, which ones?

Extension services	Source	How often?	Delivery Channel
Farm level			
Input (seeds) Prices			
Other inputs sources			
Market demand & price			

5.4 Ever been trained on cultivation (1) Yes.....(0) No.....

5.5 If yes, on what aspects?

5.6 Is credit available?

5.7 If No, why not?

5.8 If yes, kindly indicate:

Provider	Amount in Kshs	How often	Purpose	Credit terms	Re-paid on time? <i>1=yes,0=no</i>

5.9 If not repaid on time, why?



APPENDIX 2: KEY INFORMANT INTERVIEWS (KIIs) TOOL

1. Interviewer Name	
2. Interviewer Signature	
3. Interview Date (dd/mm/yyyy)	_ _ / _ _ / _ _ _ _
4. The participant agrees to be part of this discussion (Please tick)	Yes <input type="checkbox"/> No..... <input type="checkbox"/>
5. Time Interview Begin (hhmm-24hr clock)	_ _ _ _
6. Time Interview End (hhmm-24hr clock)	_ _ _ _

2.1 Introduction and consent

Good morning/afternoon.

I am **Edgar Kaniu**, pursuing a Master of Management in Agribusiness at Strathmore University. Currently, I am researching to assess the impact of rainwater harvesting on the fodder value chain in Habaswein in Wajir County. The objective of this exercise is to collect information at the Sub-County level on the socio-economic factors, and ecological factors affecting the adoption of rainwater harvesting technologies in the fodder value chain. I am conducting this interview to understand your views on effectiveness of rainwater harvesting for fodder and pasture cultivation while examining the fodder value chain's role in enhancing pastoralists' resilience against drought and climate change. I would like to ask you some questions that should take about 1 to 1.5 hrs of your time. Your participation will support this study and help improve and plan the future of agricultural capacity building and the fodder value chain in Habaswein. Your responses will be kept confidential and used solely for research purposes. Do you consent to participate in this interview?

2.2 Adoption Level of Rainwater Harvesting Technologies (RWHT)

1. Are you familiar with rainwater harvesting technologies (RWHT)?
2. What is your assessment of the current adoption level of rainwater harvesting technologies (RWHT) in Habaswein?
3. Which RWHT are most commonly adopted within the fodder value chain in the region?
4. What factors do you believe contribute to the adoption or non-adoption of RWHT among households involved in fodder production?

5. Are there specific areas within the county where RWHT adoption is higher? If yes, why do you think this is the case?

2.3 Socio-Economic Factors Impacting RWHT Adoption

1. How do socio-economic factors such as income levels, education, and access to credit influence the adoption of RWHT in the fodder value chain?
2. What role do government policies and incentives play in promoting RWHT adoption?
3. How significant are financial constraints hindering the adoption of RWHT among households?
4. What socio-economic benefits have you observed from the adoption of RWHT within the fodder value chain?
5. How does the cost of implementing RWHT affect decision to adopt these technologies?
6. Does the household income level influence farmers ability to adopt RWHT? Yes, or no? If yes, please explain:
7. What role does access to credit or financial assistance play in adoption of RWHT?
8. How do community norms and cultural practices influence the adoption of RWHT in your area?

2.4 Ecological Factors Affecting RWHT Adoption

1. How does the local climate and ecological conditions impact the adoption of RWHT in Habaswein?
2. Are there specific ecological benefits you have observed from using RWHT in fodder production? Yes, or no? If yes, please describe:
3. Are there specific ecological challenges that affect the implementation and sustainability of RWHT in the region? Yes, or no? If yes, please describe:
4. How do RWHT contribute to ecological sustainability and resilience within the fodder value chain?

2.5 Effect of Capacity Building on RWHT Adoption

1. Have you participated in any training or capacity-building programs related to RWHT? Yes, or no? If yes, who organized these programs?
2. What capacity-building initiatives related to RWHT have been implemented in Habaswein?

3. How effective have these capacity-building programs been in promoting the adoption of RWHT?
4. What additional training or support do you think is necessary to improve the adoption of RWHT among households?
5. In your opinion, what role do extension services and local government play in promoting RWHT adoption?

2.6 Fodder Value Chains

1. How do you understand the term “Fodder Value Chain”?
2. Which are the segments of the fodder value chain that you know of?
3. Where do you fall within the fodder value chain? [buyer, seller, producer, advisor, policy maker, others, specify]
4. Who in Habaswein sells their fodder?
5. From your knowledge and experience is fodder selling a profitable business? If yes, why? If no, Why?
6. Do you know of any fodder buyers in Habaswein or elsewhere? Yes or No. if yes, Specify.
7. What is the on-farm profit margin per ton or any other specified measuring units?
8. What is the off-farm profit margin per ton or any other specified measuring units?
9. How is fodder transported from Habaswein to other destinations?
10. Who are the fodder buyers in other destinations? Please provide four of them if you know any
[buyer _____ destination _____ price (Kshs) _____]
11. From your knowledge what is the cost of transporting fodder?

2.7 Conclusion

1. What are your recommendations for improving the adoption and sustainability of RWHT within the fodder value chain in Habaswein, Wajir County?
2. Do you have any additional comments or suggestions related to the adoption of RWHT in the region? Yes, or no? If yes, please describe.

Thank you for your time and valuable insights.

Name of Respondent: _____

Institution: _____

Date (dd/mm/yyyy): |__|_|_|/|__|_|_|/|__|_|_|_|_|

Phone No (optional): _____

List of KII participants



No.	Name	Sub-county	Ward	Contact	Signature
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					



APPENDIX 3: FOCUS GROUP DISCUSSIONS TOOL

1. Interviewer Name	
2. Interviewer Signature	
3. Interview Date (dd/mm/yyyy)	_ _ / _ _ / _ _ _ _
4. The participant agrees to be part of this discussion (Please tick)	Yes <input type="checkbox"/> No <input type="checkbox"/>
5. Time Interview Begin (hhmm-24hr clock)	_ _ _ _
6. Time Interview End (hhmm-24hr clock)	_ _ _ _

3.1 Introduction and consent

Good morning/afternoon.

I am **Edgar Kaniu**, pursuing a Master of Management in Agribusiness at Strathmore University. Currently, I am researching to assess the impact of rainwater harvesting on the fodder value chain in Habaswein in Wajir County. The objective of this exercise is to collect information at the Sub-County level on the socio-economic factors, and ecological factors affecting the adoption of rainwater harvesting technologies in the fodder value chain. I am conducting this interview to understand your views on effectiveness of rainwater harvesting for fodder and pasture cultivation while examining the fodder value chain's role in enhancing pastoralists' resilience against drought and climate change. I would like to ask you some questions that should take about 1 to 1.5 hrs of your time. Your participation will support this study and help improve and plan the future of agricultural capacity building and the fodder value chain in Habaswein. Your responses will be kept confidential and used solely for research purposes. Do you consent to participate in this interview?

3.3 Adoption Level of Rainwater Harvesting Technologies (RWHT)

1. Awareness and Understanding (*General Knowledge and Practices*)

- a) What do you understand by the term rainwater harvesting technologies (RWHT)?
- b) How did you first learn about RWHT?

2. Adoption and Utilization

- a) Are you currently using any RWHT? Yes, or no? If yes, which ones?
- b) How long have you been practicing rainwater harvesting?
- c) What methods of rainwater harvesting are you aware of or using (e.g., rooftop harvesting, surface runoff harvesting, etc)?

- d) What motivated you to adopt RWHT for fodder production?

3. Challenges in Adoption

- a) What challenges did you face when adopting rainwater harvesting (RWHT)?
- b) How have you addressed these challenges?

3.4 Impact on Fodder Production

1. Changes in Fodder Availability

- a) Have you noticed any changes in the availability of fodder since you started rainwater harvesting? Yes, or no? If yes, please describe.
- b) How has the quality and quantity of fodder changed?

2. Fodder Quality and Yield

- a) How has rainwater harvesting impacted the quality of fodder produced?
- b) Have you seen any changes in the yield of fodder crops? Yes, or no? If yes, please describe.

3.5 Socio-economic Factors Impacting RWHT Adoption

1. Economic Factors

- a) What are the costs associated with implementing rainwater harvesting?
- b) How do you finance the implementation of RWHT?
- c) Have you experienced any financial benefits or savings from using RWHT? Yes, or no? If yes, please describe.

2. Social Factors (*Community Perception and Collaboration*)

- a) How is rainwater harvesting perceived within your community?
- b) Have you received any support from your community or local organizations in adopting RWHT? Yes, or no? If yes, please describe.

3. Market Dynamics

- a) How has RWHT adoption affected your income from fodder production and sales?
- b) What impact has RWHT had on the fodder market in your area?

3.6. Ecological Factors Affecting RWHT Adoption

1. Environmental Awareness

- a) What environmental changes have you observed since adopting rainwater harvesting (e.g., soil moisture levels, vegetation cover)?
- b) How have these changes affected your fodder production?
- c) How has rainwater harvesting affected local water resources? Yes, or no? If yes, please describe.

2. Ecological Benefits and Challenges

- a) What ecological benefits have you experienced from using RWHT (e.g. Water Conservation Practices, Sustainable Agricultural Practices etc.)?
- b) Are there any ecological challenges that have hindered the adoption of RWHT? Yes, or no? If yes, please describe.

3.7 Effect of Capacity Building on RWHT Adoption

1. Training and Education

- a) Have you received any training or education on RWHT? Yes, or no? If yes, from whom?
- b) How has this training influenced your adoption and use of RWHT?

2. Knowledge Sharing

- a) How do you share knowledge about RWHT within your community?
- b) What kind of support or training do you think would help improve rainwater harvesting practices?

3. Support Networks

- a) Are there any local groups or organizations that support RWHT adoption? 1 Yes, or no? If yes, how do they assist?

3.8 Future Outlook and Recommendations

1. Future Plans

- a) Do you plan to continue or expand your use of RWHT? Yes, or no? Why or why not?
- b) What are your future expectations for RWHT and fodder production?
- c) What are your future expectations for fodder trade in Habswein Sub-County and Wajir County in general?

2. Recommendations

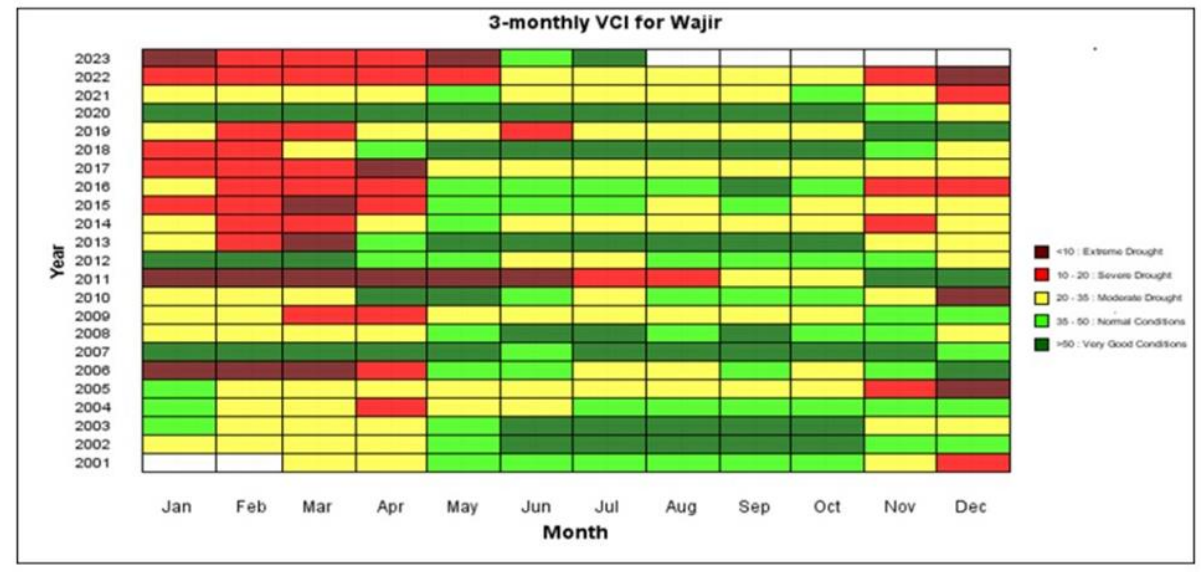
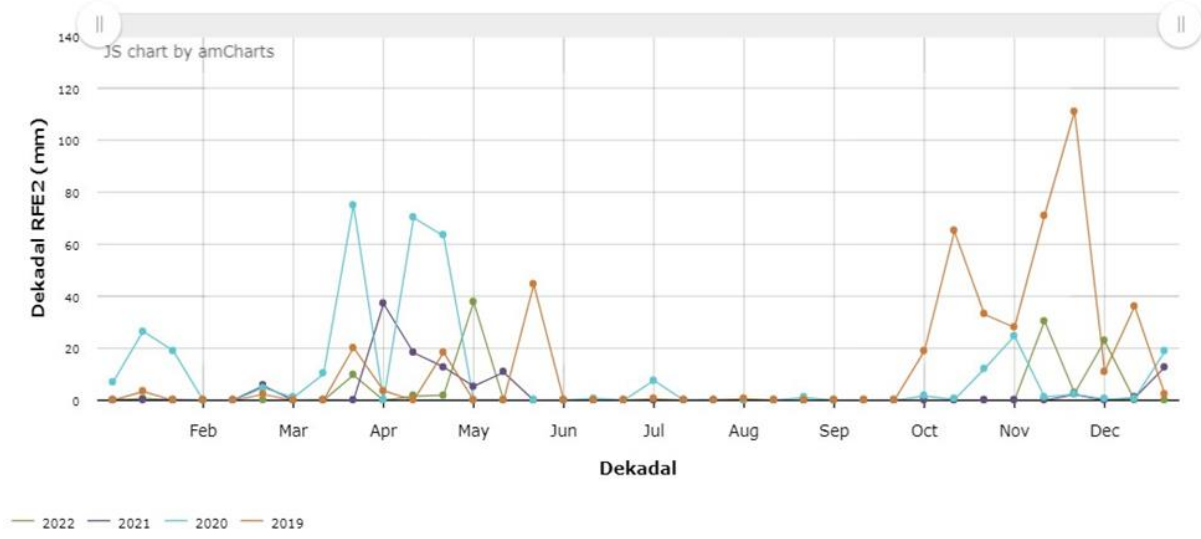
- a) What recommendations do you have for improving the adoption of rainwater harvesting within the fodder value chain?
- b) What policies or programs do you think could support better implementation of RWHT?
- c) What policies or programs do you think could support better trading of fodder in Wajir County and Habaswein Sub-County?

List of FGD participants

No.	Name	Sub-county	Ward	Contact	Signature
1.					
2.					
3.					
4.					
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15.					

APPENDIX 4: 3-YEAR RAINFALL AND VEGETATION INDICES FOR HABASWEIN

Kenya+Wajir+Wajir South+Habasswein+KE10



Average high and low temperatures as well as average monthly rainfall in Habaswein Sub County Wajir County

Month	Average High Temperature (°C)	Average Low Temperature (°C)	Average Rainfall (mm)	Average Evaporation (mm)
January	35	24	4	200
February	36	25	3	200
March	36	25	35	200
April	33	25	87	200
May	33	24	34	200
June	32	23	1	200
July	32	22	1	200
August	32	22	1	200
September	33	23	1	200
October	34	24	67	200
November	32	24	97	200
December	34	24	35	200
Total	33.5	23.75	366	2,400

Note:

Specific monthly evaporation data for Habaswein is limited. However, in similar semi-arid regions of northeastern Kenya, potential evaporation rates are significantly high, often exceeding 2,500 mm annually. This indicates that monthly evaporation can surpass 200 mm, greatly exceeding monthly rainfall amounts. This imbalance underscores the challenges of water retention in the area. The high evaporation rates, coupled with low rainfall, contribute to water scarcity challenges, impacting agricultural practices and water resource management.

APPENDIX 5: REFERENCE PHOTOS



Focused Group Discussion Sessions.



KII Discussion Sessions



APPENDIX 6: APPROVALS AND ETHICS



11th June 2024

Mr Kaniu Edgar,
edgar.kaniu@wfp.org

Dear Mr Kaniu,

RE: Assessing the Influence of Rainwater Harvesting within the Fodder Value Chain in Habaswein, Wajir County

This is to inform you that SU-ISERC has reviewed and **approved** your above **SU-masters** proposal. Your application reference number is **SU-ISERC2244/24**. The approval period is from **11th June 2024 to 10th June 2025**.

This approval is subject to compliance with the following requirements:

- i. Only approved documents including (informed consents, study instruments, MTA) will be used.
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC.
- iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
- iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
- v. Clearance for the export of biological specimens must be obtained from relevant institutions.
- vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.

Before commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) <https://research-portal.nacosti.go.ke/> and obtain other clearances needed.

Yours sincerely,

Mr Ambrose Rachier,
Chairperson; SU-ISERC



REPUBLIC OF KENYA

Ref No: 740108



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Date of Issue: 11/July/2024

RESEARCH LICENSE



This is to Certify that Mr.. Edgar Mwangi Kaniu of Strathmore University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Wajir on the topic: ASSESSING THE INFLUENCE OF RAINWATER HARVESTING WITHIN THE FODDER VALUE CHAIN IN HABASWEIN, WAJIR COUNTY for the period ending : 11/July/2025.

License No: NACOSTI/P/24/37452

740108

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

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