



# Factors influencing the adoption of water harvesting technologies among smallholder farming households in Bungoma North Sub-County, Kenya

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## ABSTRACT

Climate variability, rainfall uncertainty, and seasonal dry spells constrain agricultural production and household food security among smallholder farming households. Water harvesting technologies (WHTs) provide an important adaptation option by improving water availability and reducing dependence on unreliable rainfall. However, their adoption may be constrained by technical, economic, physical, institutional, and socio-cultural factors. This study examined the factors influencing adoption of water harvesting technologies (WHTs) among smallholder farming households in Bungoma North Sub-County, Kenya. The study was guided by Rogers' Diffusion of Innovations Theory which provided a framework for understanding the adoption of water harvesting technologies. A descriptive survey design was employed involving 380 smallholder farming households selected through proportionate stratified and random sampling. Quantitative data were collected using structured household questionnaires, while qualitative data were obtained through key informant interviews and four focus group discussions involving 40 participants. Quantitative data were analysed using descriptive statistics and mean ranking in Statistical Package for the Social Sciences (SPSS) version 27, while qualitative data were analysed thematically. Knowledge and skills were ranked as the most influential factor ( $M = 1.79$ ), followed by installation costs ( $M = 2.09$ ), availability of materials ( $M = 2.98$ ), land size ( $M = 4.42$ ), extension services ( $M = 4.73$ ), climate variability ( $M = 5.29$ ), and cultural beliefs ( $M = 6.69$ ). The findings indicate that technical knowledge, economic capacity, and access to materials are important considerations in household adoption of WHTs. The study recommends targeted training, affordable financing, improved access to materials, and strengthened extension support to enhance WHT adoption, climate resilience, and household food security.

**Keywords:** Climate Adaptation; Household Food Security; Smallholder Farmers, Water Harvesting Technologies

## I. INTRODUCTION

Globally, increasing water scarcity, climate variability, and changing rainfall patterns are placing growing pressure on agricultural production and household food security, particularly in communities that depend heavily on rain-fed agriculture. Climate change is intensifying water-related risks, including drought, rainfall variability, and water insecurity, with vulnerable populations experiencing disproportionate impacts on their livelihoods and food security (Intergovernmental Panel on Climate Change [IPCC], 2022). Water is fundamental to agricultural production and food security, while increasing uncertainty in water availability creates additional risks for farming systems and rural livelihoods (Food and Agriculture Organization [FAO], 2020).

Water harvesting technologies (WHTs) provide an important climate adaptation option by enabling households to capture, store, and utilize rainfall for domestic and agricultural purposes. Their adoption can improve water availability, reduce dependence on unreliable rainfall, and support agricultural production during periods of reduced precipitation. However, adoption is not determined by the availability of rainfall alone. Household technical knowledge, financial capacity, land and labour availability, extension support and institutional conditions may influence adoption of water harvesting technologies (Lutta et al., 2020; Irungu et al., 2024; Recha et al., 2015). Evidence from broader climate-smart agriculture studies also suggests that socioeconomic, institutional and biophysical factors can influence technology adoption (Musafiri et al., 2022).

In Kenya, smallholder agricultural production remains highly dependent on rainfall, making farming households vulnerable to variations in the timing, intensity, and distribution of precipitation. Although water harvesting has been

promoted as a strategy for improving water availability and strengthening climate resilience, adoption varies across households and locations. Previous studies have identified socioeconomic, institutional, extension and biophysical factors as important considerations in the adoption of rainwater harvesting and other climate-smart agricultural practices (Irungu et al., 2024; Musafiri et al., 2022). Bungoma North Sub-County presents an important context for examining WHT adoption because it is predominantly agricultural and receives relatively high annual rainfall. However, high annual rainfall does not necessarily ensure reliable water availability throughout the year. Seasonal variations, rainfall variability, and dry spells can interrupt agricultural production and create periods of water stress. Consequently, households may require mechanisms for capturing and storing rainfall when it is available for use during periods of reduced rainfall.

Despite the potential benefits of WHTs, limited localized evidence exists on the factors influencing their adoption among smallholder farming households in Bungoma North Sub-County. Existing studies have largely examined adoption in areas where water scarcity is more pronounced, leaving less evidence from relatively high-rainfall agricultural settings. Understanding the factors that shape household adoption decisions is therefore important for designing interventions that address the specific technical, economic, physical, institutional, environmental, and socio-cultural conditions of farming households in the study area. Therefore, this study examined the factors influencing adoption of water harvesting technologies among smallholder farming households in Bungoma North Sub-County, Kenya.

### 1.1 Statement of the Problem

Despite efforts to promote climate-resilient agricultural practices and improve water management, smallholder farming households in Bungoma North Sub-County continue to depend substantially on rainfall for agricultural production. Although Bungoma receives relatively high annual rainfall, variations in rainfall distribution can affect agricultural production (County Government of Bungoma, 2018). Water harvesting technologies (WHTs) can help households capture and store rainfall for use during periods of reduced precipitation; however, their adoption among smallholder households remains uneven (Lutta et al., 2020; Irungu et al., 2024).

Previous studies have associated WHT and rainwater harvesting (RWH) adoption with socioeconomic conditions, land and labour availability, extension and institutional support, and household characteristics (Lutta et al., 2020; Irungu et al., 2024; Recha et al., 2015). However, limited evidence exists on the role of cultural beliefs and other socio-cultural factors in WHT adoption. Existing studies have examined factors influencing the adoption of water harvesting and other climate adaptation technologies, but much of the available evidence has focused on areas where water scarcity is more pronounced (Lutta et al., 2020; Mutschinski & Coles, 2023). Consequently, there is limited localized evidence on the relative importance of these factors among smallholder farming households in relatively high-rainfall areas such as Bungoma North Sub-County.

This gap in evidence limits the ability of agricultural and development stakeholders to design interventions that address the specific constraints faced by households in adopting WHTs. Understanding these factors influencing adoption is therefore important for informing targeted training, financial support, access to materials, extension services, and other interventions aimed at improving household capacity to harvest and utilize rainwater (Irungu et al., 2024; Lutta et al., 2020). This study therefore examined the factors influencing the adoption of water harvesting technologies among smallholder farming households in Bungoma North Sub-County, Kenya.

### 1.2 Research Objective

The objective of the study was to examine the factors influencing the adoption of water harvesting technologies among smallholder farming households in Bungoma North Sub-County, Kenya.

## II. LITERATURE REVIEW

### 2.1 Theoretical Review

Diffusion of Innovations Theory, developed by Rogers (2003), explains how new ideas, practices, or technologies are communicated and adopted over time within a social system. The theory identifies the innovation, communication channels, time, and social system as key elements influencing the adoption process. It further describes five stages through which individuals may pass when making an innovation decision: knowledge, persuasion, decision, implementation, and confirmation.

The theory is relevant to this study because water harvesting technologies are innovations that households must understand, evaluate, and decide whether to adopt. The theory therefore provides a basis for examining the factors influencing household adoption of water harvesting technologies, which is the specific objective of this study. Knowledge and skills relate to the knowledge stage of the innovation-decision process, while extension services provide

communication channels through which households receive information and technical guidance about the technologies. Installation costs, availability of materials, and land size represent conditions that may facilitate or constrain households' ability to proceed from consideration to actual adoption. Climate variability may influence households' perceived need for water harvesting, while cultural beliefs may shape perceptions and acceptance of the technologies within the social system.

Thus, Diffusion of Innovations Theory provides an appropriate framework for explaining how technical, economic, physical, institutional, environmental, and socio-cultural factors may influence household decisions to adopt water harvesting technologies. The theory directly supports the study objective by providing a basis for examining why some households may be more able or willing than others to adopt water harvesting technologies for improving household food security.

## 2.2 Empirical Review

### 2.2.1 Economic and Financial Factors

Economic and financial conditions can influence the ability of smallholder farming households to adopt water harvesting technologies. Installation costs, household income, access to credit and the affordability of required materials may determine whether farmers can invest in water harvesting facilities. Some technologies require relatively high initial investments, which may constrain adoption among households with limited financial resources. Irungu *et al.* (2024), in a study of smallholder farmers in Murang'a County, Kenya, found that socioeconomic factors significantly influenced the adoption of different rainwater harvesting practices. Similarly, Mutschinski and Coles (2023) emphasized the importance of investment, technical support and institutional conditions in promoting rainwater harvesting among smallholders in Kenya. Lutta *et al.* (2020) found that monthly income, livelihood, land tenure, social-group membership and labour availability were associated with WHT adoption among agro-pastoralists in southeastern Kenya. These findings indicated that farmers' financial capacity and the costs associated with establishing water harvesting systems were important considerations in understanding adoption. However, the reviewed studies were conducted in different geographical and livelihood contexts and did not specifically focus on Bungoma North Sub-County. This study therefore examined how economic and financial factors affected the adoption of water harvesting technologies for household food security in Bungoma North Sub-County.

### 2.2.3 Technical and Knowledge Factors

Technical knowledge and skills are important in enabling farmers to understand, select, install, operate and maintain water harvesting technologies. Farmers require adequate information to determine which technology is appropriate for their farms and how it should be implemented and maintained. Limited technical knowledge may therefore constrain adoption even where farmers recognize the potential benefits of water harvesting. Irungu *et al.* (2024) demonstrated that socioeconomic and institutional characteristics were associated with the adoption of various rainwater harvesting practices among smallholder farmers in Murang'a County. However, the study considered technical knowledge within broader socioeconomic and institutional factors and was conducted outside Bungoma North.

Mutschinski and Coles (2023) emphasized the importance of technical support and institutional capacity in promoting rainwater harvesting in Kenya. The study highlighted the importance of farmers having the capacity to use such technologies but does not specifically establish how technical knowledge affects household-level adoption in Bungoma North. From the perspective of the Diffusion of Innovations Theory, knowledge is an important initial stage in the innovation-decision process because individuals must first become aware of an innovation and understand its basic functions before considering adoption (Rogers, 2003). However, it remains unclear how these technical knowledge and skills influence WHT adoption among smallholder households in Bungoma North Sub-County. Therefore, the present study focused specifically on technical knowledge and skills as factors influencing the adoption of water harvesting technologies among smallholder farming households in Bungoma North Sub-County.

### 2.2.4 Physical and Resource Factors

Physical and resource conditions may affect the feasibility of adopting different water harvesting technologies. Land size is particularly relevant because some technologies, such as water pans, ponds and other surface-storage structures, require adequate space for construction. The availability of construction materials and other physical resources can also affect the ability of households to establish and maintain water harvesting systems. Recha *et al.* (2015) found that the number of rainwater harvesting and conservation techniques practiced by farmers in Tharaka Sub-County was influenced by arable land size, among other socioeconomic factors. The study further showed that different types of water harvesting and conservation technologies were practiced according to local conditions. Land availability and access to appropriate materials are relevant physical factors when examining WHT adoption in Bungoma North Sub-

County. The present study addressed these contextual gaps by examining physical and resource factors affecting WHT adoption among smallholder households in Bungoma North Sub-County.

### 2.2.5 Institutional and Extension Factors

Institutional support and extension services can facilitate farmers' access to information, technical advice, training and other resources required for adopting water harvesting technologies. Extension officers can help farmers understand appropriate technologies, installation procedures, operation and maintenance requirements, while government agencies and development organizations can provide technical or financial support. Irungu *et al.* (2024) found that institutional factors significantly influenced the adoption of several rainwater harvesting practices among smallholder farmers in Murang'a County. Lutta *et al.* (2020) also reported the role of institutional interventions in supporting the adoption of water harvesting technologies among agro-pastoralists in southeastern Kenya. In addition, Recha *et al.* (2015) also documented institutional efforts supporting the adoption of micro-catchment and macro-catchment techniques in Tharaka Sub-County. These findings suggest that the availability and accessibility of extension and institutional support can shape farmers' capacity to adopt water harvesting technologies. However, the reviewed studies were conducted in different geographical and livelihood contexts and provide limited evidence on how institutional and extension support affects WHT adoption among smallholder farming households in Bungoma North Sub-County. It remains unclear how access to extension services, training and institutional support influences adoption in the study area. This study addressed this gap by examining institutional and extension factors affecting the adoption of WHTs in Bungoma North Sub-County.

### 2.2.6 Environmental and Climate-related Factors

Environmental conditions and perceptions of climate variability may influence farmers' decisions concerning water harvesting. Rainfall variability, seasonal dry periods, drought and uncertainty in water availability can increase the perceived need for technologies that capture and store water for later use. Mutschinski and Coles (2023) examined rainwater harvesting in Kenya in the context of climate resilience and highlighted the importance of improving water security and availability in rural communities facing climate-related challenges. The study provided evidence of the relevance of climate-related conditions to rainwater harvesting, although it did not specifically establish how individual environmental factors influence household-level adoption in Bungoma North Sub-County. Similarly, Lutta *et al.* (2020) situated water harvesting adoption within the context of unpredictable rainfall, drought and water shortages affecting agricultural and pastoral production in southeastern Kenya. The study provided useful evidence from a semi-arid livelihood context, but its findings may not fully reflect the experiences of smallholder farming households in Bungoma North.

Research from Ethiopia has also shown that farmers' perceptions of climate-related risks and the benefits of climate-smart agricultural innovations are associated with their adoption decisions (Meshesha *et al.*, 2022). However, evidence from Ethiopia may not directly explain adoption behaviour among Kenyan smallholder farmers because of differences in environmental and agricultural contexts. Nevertheless, climate variability alone may not result in adoption because farmers also require the financial, technical and physical capacity to implement appropriate technologies. Environmental and climate-related conditions are therefore considered alongside other factors in explaining WHT adoption in Bungoma North Sub-County. The reviewed studies had limited evidence on how rainfall variability, drought and water availability influence WHT adoption in the specific context of Bungoma North. The present study addressed this gap by examining environmental and climate-related factors alongside other determinants of WHT adoption among smallholder farming households in the study area.

### 2.3 Socio-Cultural Factors

Socio-cultural factors can influence the acceptance of agricultural innovations by shaping farmers' attitudes, preferences, social interactions and established practices. Cultural beliefs, social norms and community experiences may either facilitate or constrain the introduction and use of new technologies. The Diffusion of Innovations Theory recognizes the social system as an important component of the innovation-decision process because adoption occurs within a social environment where individuals interact and exchange information (Rogers, 2003). Empirical evidence from Kenya also demonstrates that adoption of water harvesting and conservation practices is associated with characteristics of farmers and their livelihood contexts (Recha *et al.*, 2015; Lutta *et al.*, 2020). The findings indicated that adoption is influenced by farmer and livelihood characteristics; however, the studies did not specifically examine how cultural beliefs and social norms influence WHT adoption among smallholder farming households in Bungoma North Sub-County. The importance of specific cultural beliefs may vary across communities and agricultural settings. Consequently, this study considered socio-cultural factors, particularly cultural beliefs, as a context-specific factor that may influence farmers' decisions concerning the adoption of water harvesting technologies.

### III. METHODOLOGY

#### 3.1 Study Area

The study was conducted in Bungoma North Sub-County, Bungoma County, western Kenya. Bungoma North Sub-County lies between longitudes  $34^{\circ}40'E$  and  $36^{\circ}00'E$  and latitudes  $0^{\circ}39'N$  and  $0^{\circ}53'N$  of the Equator. It covers an area of approximately 191.5 km<sup>2</sup> and has a population density of about 633.5 persons per km<sup>2</sup>. Agriculture is the primary economic activity, with most households depending on smallholder farming for their livelihoods. The area experiences a bimodal rainfall pattern, receiving an average annual rainfall of 1,200–1,800 mm. The long rains generally occur between March and June, while the short rains occur between August and November. Despite receiving relatively high annual rainfall, the sub-county experiences rainfall variability, seasonal dry spells, and localized water shortages that affect agricultural production and household food security. These characteristics make Bungoma North Sub-County an appropriate setting for examining factors influencing the adoption of water harvesting technologies among smallholder farming households.

#### LOCATION CONTEXT MAP

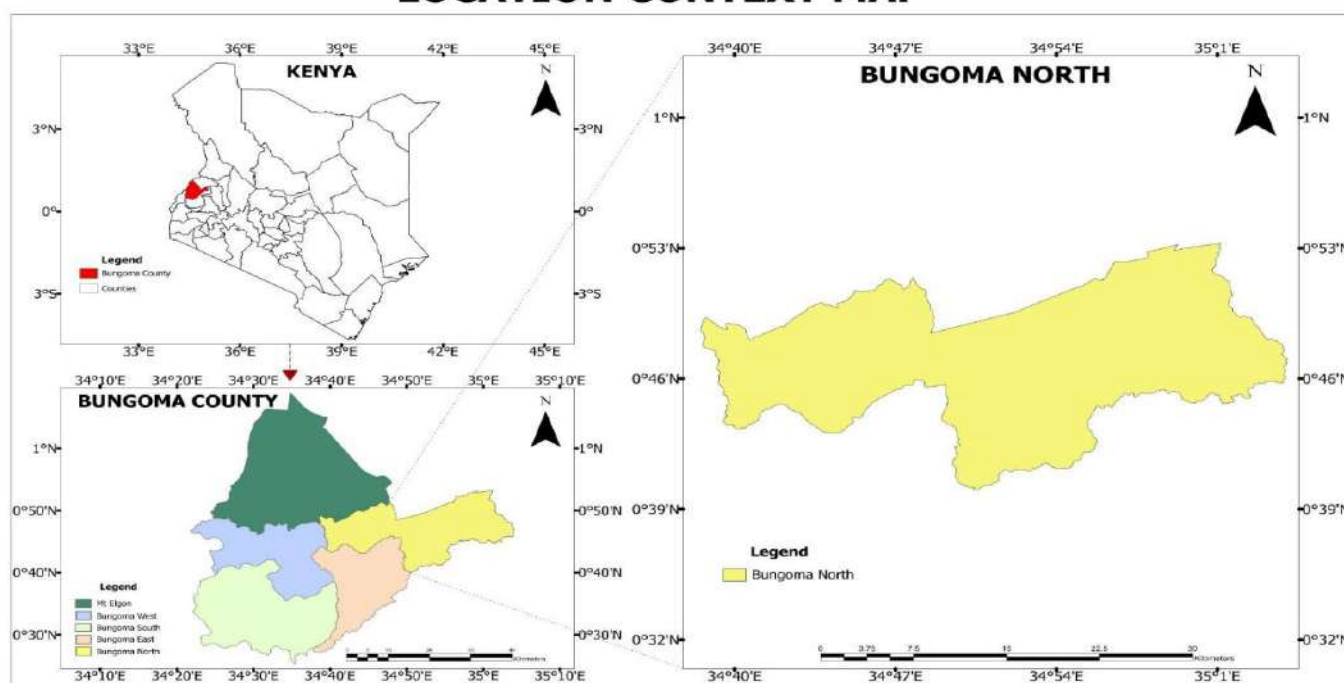


**Figure 1**  
*Map of the Study Area*

#### 3.2 Research Design

The study employed a descriptive survey research design to determine the factors influencing adoption of water harvesting technologies among smallholder households in Bungoma North Sub-County. The design facilitated the collection of both quantitative and qualitative data from smallholder farming households and other key stakeholders, enabling the study to describe existing practices, conditions, and perceptions related to water harvesting technologies. Both quantitative and qualitative data enabled triangulation of findings and provided a more comprehensive understanding of household experiences and perceptions regarding water harvesting technologies.

#### 3.3 Target Population

The study targeted household heads in Bungoma North Sub-County together with key stakeholders involved in the promotion and implementation of water harvesting technologies for household food security. The target population included household heads, Sub-County Agricultural Officers, Sub-County Irrigation Officers, Ward Agricultural Extension Officers, local administrative officers, representatives of women's groups, and non-governmental organizations (NGOs). These categories of respondents were selected because they possess relevant knowledge and practical experience regarding water harvesting technologies and household food security. According to the 2019 Kenya Population and Housing Census (KPHC), Bungoma North Sub-County had a population of 121,317 people and a total

of 24,998 households (KNBS, 2019). Table 3.2 presents the distribution of the population across the wards of Bungoma North Sub-County.

**Table 1**

*Distribution of population and number of households by wards in Bungoma North Sub-County, Kenya*

| Ward         | Population    | Number of Household |
|--------------|---------------|---------------------|
| Milima       | 20255         | 4246                |
| Mbakalo      | 16910         | 3407                |
| Naitiri      | 22025         | 4559                |
| Kabuyefwe    | 22770         | 4555                |
| Kibisi       | 19919         | 4057                |
| Mkuyuni      | 19438         | 4174                |
| <b>Total</b> | <b>121317</b> | <b>24998</b>        |

Source: KNBS, 2019

### 3.4 Sampling Techniques and Sample Size

Bungoma North Sub-County comprises six administrative wards. Two wards, Milima and Mbakalo, were purposively selected based on their dependence on smallholder agriculture and the presence of water harvesting practices. According to the Kenya National Bureau of Statistics (KNBS, 2019), Milima Ward had 4,246 households, while Mbakalo Ward had 3,407 households, giving a combined household population of 7,653 households. The two selected wards therefore constituted the sampling frame for the household survey. The sample size for household heads was determined using Yamane's (1967) formula for finite populations at a 5% level of precision:

$$n = N / [1 + N(e)^2]$$

$$n = 7,653 / [1 + 7,653(0.05)^2] \approx 380$$

Thus, a sample of 380 household heads was selected for the household survey. The sample was distributed proportionately between Milima and Mbakalo wards according to their respective household populations. Milima Ward contributed 211 households, while Mbakalo Ward contributed 169 households, giving a total sample of 380 households.

**Table 2**

*Summary of Proportionate Household Sampling in the Selected Wards*

| Ward         | Household heads | Proportionate sampling (Size) |
|--------------|-----------------|-------------------------------|
| Milima       | 4246            | 211                           |
| Mbakalo      | 3407            | 169                           |
| <b>Total</b> | <b>7653</b>     | <b>380</b>                    |

### 3.5 Data Collection Methods

A structured household questionnaire was administered to household heads to obtain quantitative data on factors influencing the adoption of water harvesting technologies. A total number of 4 key informant interviews (KIIs) were conducted with relevant government and local institutional officers, while 4 focus group discussions (FGDs) comprising a total of 40 participants were conducted to obtain community perspectives on the adoption of water harvesting technologies. Secondary data were obtained from various sources, including books, peer-reviewed journals, project reports, county and national government publications, online databases, university library resources, and research reports to provide contextual information and support interpretation of the primary findings.

### 3.6 Data Analysis

Quantitative data were coded, entered, cleaned and analysed using the Statistical Package for the Social Sciences (SPSS) version 27. Descriptive statistics, including frequencies, percentages, means and standard deviations were used and results presented using tables and bar charts. Mean ranking analysis was used to summarize respondents' perceived relative importance of the identified factors influencing adoption. Qualitative data obtained from key informant interviews and focus group discussions were transcribed and analyzed using thematic analysis to complement the quantitative findings.

### 3.7 Ethical Considerations

Ethical approval for the study was obtained from the relevant university ethics review committee before commencement of data collection. Permission to conduct the study was also obtained from the National Commission for Science, Technology and Innovation (NACOSTI) and the relevant county authorities. Participation in the study was voluntary, and informed consent was obtained from all participants before data collection. Respondents were informed of the purpose of the study and their right to decline participation or withdraw from the study without penalty. Confidentiality and anonymity were maintained throughout the research process, and the information collected was used solely for academic purposes.

## IV. FINDINGS & DISCUSSION

### 4.1 Factors Influencing Adoption of Water Harvesting Technologies in Bungoma North Sub-County, Kenya

Respondents were asked to rank seven factors according to their perceived influence on the adoption of water harvesting technologies, with 1 representing the most influential factor and 7 representing the least influential factor. The results are presented in Table 3.

**Table 3**

*Ranked factors influencing adoption of water harvesting technologies in Bungoma North Sub-County, Kenya*

|                           | First choice | Second choice | Third choice | Fourth choice | Fifth choice | Sixth choice | Seventh choice | Mean | Standard deviation |
|---------------------------|--------------|---------------|--------------|---------------|--------------|--------------|----------------|------|--------------------|
| Knowledge/skills          | <b>64.2</b>  | 21.3          | 4.2          | 1.1           | 1.6          | 5.5          | 2.1            | 1.79 | 1.498              |
| Cost of installation      | 26.8         | <b>49.7</b>   | 15.8         | 5.3           | 0.0          | 2.4          | 0.0            | 2.09 | 1.005              |
| Availability of materials | 4.2          | 20.0          | <b>62.4</b>  | 5.0           | 5.0          | 2.4          | 1.1            | 2.98 | 1.001              |
| Land size                 | 1.3          | 0.5           | 9.7          | <b>55.3</b>   | 12.6         | 17.4         | 3.2            | 4.42 | 1.081              |
| Extension services        | 0.3          | 4.2           | 3.9          | 20.0          | <b>59.7</b>  | 9.5          | 2.4            | 4.73 | 0.947              |
| Climate variability       | 1.6          | 3.9           | 2.9          | 12.1          | 18.7         | <b>56.3</b>  | 4.5            | 5.29 | 1.227              |
| Cultural beliefs          | 1.6          | 0.3           | 1.1          | 1.3           | 2.4          | 6.8          | <b>86.6</b>    | 6.69 | 0.997              |

**Note:** M = mean; SD = standard deviation

Knowledge and skills received the lowest mean rank ( $M = 1.79$ ,  $SD = 1.498$ ), indicating that respondents perceived them as the most influential factor. Installation cost ranked second ( $M = 2.09$ ,  $SD = 1.005$ ), followed by availability of materials ( $M = 2.98$ ,  $SD = 1.001$ ). Land size ranked fourth ( $M = 4.42$ ,  $SD = 1.081$ ), while extension services ranked fifth ( $M = 4.73$ ,  $SD = 0.947$ ). Climate variability ranked sixth ( $M = 5.29$ ,  $SD = 1.227$ ), whereas cultural beliefs had the highest mean rank ( $M = 6.69$ ,  $SD = 0.997$ ), indicating that respondents perceived them as the least influential factor.

The response distribution supports the mean rankings. Knowledge and skills were ranked first by 64.2% of respondents, installation cost second by 49.7%, and availability of materials third by 62.4%. Land size was ranked fourth by 55.3%, extension services fifth by 59.7%, and climate variability sixth by 56.3%. Cultural beliefs were ranked seventh by 86.6% of respondents. Overall, respondents perceived technical, economic and physical factors as more influential than environmental and socio-cultural factors. The findings suggest that the practical capacity of households to understand, finance, access and implement water harvesting technologies may be important in shaping adoption decisions in the study area. The factors are therefore discussed under technical, economic and physical; institutional; environmental; and socio-cultural dimensions.

#### 4.1.1 Technical, Economic and Physical Factors Influencing Adoption of Water Harvesting Technologies in Bungoma North Sub-County, Kenya

Knowledge and skills emerged as the most influential factor ( $M = 1.79$ ,  $SD = 1.498$ ). This finding indicates that respondents considered technical capacity important in adopting water harvesting technologies. Knowledge is required to select appropriate systems and understand their installation, operation and maintenance. Limited technical capacity may therefore make adoption more difficult, even where households recognize the benefits of water harvesting. This finding is consistent with the innovation-decision process described by Rogers (2003), in which knowledge is an initial stage in the adoption of an innovation. It also corresponds with Irungu et al. (2024), who found that socioeconomic, socio-demographic and institutional factors were associated with the adoption of different rainwater harvesting practices among smallholder farmers in Murang'a County. The finding therefore supports the need for practical farmer training and technical guidance alongside the provision of WHT infrastructure.

Installation cost ranked second ( $M = 2.09$ ,  $SD = 1.005$ ), indicating that respondents perceived affordability as an important consideration in adoption. Water harvesting technologies require different levels of investment depending on the technology, materials, size and installation requirements. For households with limited financial resources, these initial and associated costs may constrain adoption. A male FGD participant explained:

*"Many people rely on rainfall because the cost of installing tanks and farm ponds is high and yet they are either unemployed or have low incomes to even sustain their immediate needs in their households."* (Male FGD participant, Mbakalo Ward, April 8, 2026).

The qualitative evidence illustrates how household financial constraints may affect investment in WHTs. This finding is consistent with evidence from Kenya showing that socioeconomic and implementation conditions are relevant to the adoption and expansion of rainwater harvesting practices (Irungu et al., 2024; Mutschinski & Coles, 2023). Mose (2024) found that household wealth was positively associated with rainwater harvesting adoption in Kenya and highlighted the need for investment and technologies appropriate for households with limited purchasing capacity. The findings therefore point to the potential value of affordable technologies and financing or cost-sharing mechanisms in reducing barriers to adoption.

Availability of materials ranked third ( $M = 2.98$ ,  $SD = 1.001$ ). This suggests that access to the physical inputs required for installation and maintenance was also considered important by respondents. Materials such as tanks, gutters, pipes, cement and liners may involve acquisition and transportation costs, particularly where they are not readily available locally. Limited access can consequently make installation and maintenance more difficult. The finding is consistent with the broader evidence from Lutta et al., (2020), which showed that household and institutional conditions were associated with WHT adoption among agro-pastoralists in southeastern Kenya. The present findings suggest that improving access to appropriate WHT materials could complement financial and technical interventions.

Land size ranked fourth ( $M = 4.42$ ,  $SD = 1.081$ ), indicating a moderate perceived influence. The amount of land available may affect the suitability of particular technologies. Ponds and water pans generally require more physical space, whereas rooftop collection systems can be implemented within smaller household compounds. Recha et al., (2015) found that arable land size was associated with the number of rainwater harvesting and conservation techniques practiced by farmers in Tharaka Sub-County, Kenya. The present finding therefore supports consideration of household landholding characteristics when promoting different WHT options.

#### **4.1.2 Institutional Factors Influencing Adoption of Water Harvesting Technologies in Bungoma North Sub-County, Kenya**

Extension services ranked fifth ( $M = 4.73$ ,  $SD = 0.947$ ), indicating that respondents perceived them as less influential than knowledge and skills, installation costs, materials and land size, although they remained relevant. Extension services can provide information and technical guidance on technology selection, installation, operation and maintenance. A female FGD participant stated:

*"Extension services are available and only on demand because at first the extension officers would walk around in homes but now if you need them you have to look for them and the ward representatives come from far."* (Female FGD participant, Milima Ward, April 6, 2026).

The qualitative evidence suggests that the presence of extension services does not necessarily guarantee regular or convenient access. This finding is consistent with Irungu et al. (2024), who identified institutional conditions as relevant to the adoption of rainwater harvesting practices among smallholder farmers in Kenya. Lutta et al., (2020) similarly examined the role of institutional and household conditions in WHT adoption. The findings suggest that extension services can complement household knowledge by providing practical technical support and facilitating access to relevant information.

#### **4.1.3 Environmental Factors Influencing Adoption of Water Harvesting Technologies in Bungoma North Sub-County, Kenya**

Climate variability ranked sixth ( $M = 5.29$ ,  $SD = 1.227$ ), indicating that respondents perceived it as less influential than the other five factors ranked above it. This ranking does not imply that climate variability is unimportant. Rather, it suggests that respondents did not perceive it as the primary factor determining their adoption decisions. Rainfall variability and seasonal dry periods can increase the need for water storage and management, but the ability to respond may depend on household resources, technical knowledge, land and access to support. Mutschinski and Coles (2023) examined rainwater harvesting as an approach to strengthening climate resilience among smallholders in Kenya, highlighting the relevance of water availability and climate-related pressures. Meshesha et al., (2022) similarly found that farmers' perceptions of climate-related conditions were associated with decisions to adopt climate-smart agricultural innovations in Ethiopia. The relatively low ranking of climate variability in the present study therefore suggests that

perceived climate pressure may create a need for adaptation, while household capacity and enabling conditions may influence whether that need results in adoption.

#### **4.1.4 Socio-cultural Factors Influencing Adoption of Water Harvesting Technologies in Bungoma North Sub-County, Kenya**

Cultural beliefs had the highest mean rank ( $M = 6.69$ ,  $SD = 0.997$ ), with 86.6% of respondents ranking them seventh. This indicates that respondents perceived cultural beliefs as the least influential of the seven factors assessed in Bungoma North Sub-County. The finding suggests that cultural considerations were not perceived as a major constraint to WHT adoption in the study area. However, this result should be interpreted within the local context and should not be generalized to other communities. The role of social systems in innovation adoption is recognized in Diffusion of Innovations Theory, where adoption occurs within social settings that influence how innovations are perceived and communicated (Rogers, 2003). Recha et al., (2015) also demonstrated that adoption of rainwater harvesting and conservation practices varies according to socioeconomic and contextual conditions. The difference between the present finding and evidence from other Kenyan settings may therefore reflect differences in environmental conditions, livelihood systems, technologies, community practices and institutional contexts.

Overall, respondents perceived technical, economic, physical and institutional factors as more influential in WHT adoption than environmental and socio-cultural factors. Knowledge and skills, installation costs, availability of materials, land size and extension services were ranked ahead of climate variability and cultural beliefs. The findings suggest that improving household capacity to understand, finance, access and implement appropriate water harvesting technologies may provide important conditions for wider adoption. Such measures could also support the use of harvested water for agricultural and household purposes, contributing to broader household food-security and climate-resilience objectives.

### **V. CONCLUSION & RECOMMENDATIONS**

#### **5.1 Conclusion**

The study concludes that the perceived influence of factors on the adoption of water harvesting technologies varied among smallholder farming households in Bungoma North Sub-County. Knowledge and skills were ranked as the most influential factor, followed by installation cost, availability of materials, land size, extension services, climate variability, and cultural beliefs, respectively. The findings therefore indicate that technical capacity and economic and physical conditions were perceived as more influential to adoption than environmental and socio-cultural factors. Addressing gaps in knowledge and skills, affordability, access to appropriate materials, land-related suitability, and extension support could create more favorable conditions for the adoption and effective use of water harvesting technologies. This may improve the availability of harvested water for household and agricultural uses and support household food-security objectives.

#### **5.2 Recommendations**

The study recommends practical farmer training, affordable financing and cost-sharing mechanisms, improved access to WHT materials, and strengthened extension support to promote adoption among smallholder farming households in Bungoma North Sub-County. The training should equip farmers with practical skills in the selection, installation, and maintenance of appropriate technologies. The County Government of Bungoma, NGOs, and other development partners should support affordable financing and improve the availability of essential materials. Extension officers should provide continuous technical guidance and follow-up support, while farmers should be encouraged to select technologies suitable for their land sizes and available resources. These measures could promote sustained adoption of WHTs and contribute to improved household food security.

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