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Enhancing Water Security in Zanzibar:
The Potential of Rainwater Harvesting

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List of abbreviations

AHP	Analytic Hierarchy Approach
DEM	Digital Elevation Model
FAO	Food and Agriculture Organization
GIS	Geographic Information System
HWSD	Harmonized World Soil Database
ISRIC	International Soil Reference and Information Centre
LGA	Local government authority
MCA	Multicriteria analysis
MoWEM	Ministry of Water, Energy and Minerals
NGO	Non-government organization
RS	Remote sensing
RWH	Rainwater harvesting
SADC	Southern African Development Community
SIDS	Small Island Developing States
UNDP	United Nations Development Programme
USGS	United States Geological Survey
ZAWA	Zanzibar Water Authority

Abstract

This research study assessed the perceptions, current status and potential of rainwater harvesting (RWH) in Zanzibar to serve as an alternative source of freshwater supplies for domestic and commercial use. The study applied a descriptive research design using both quantitative and qualitative data collection methods, including document reviews, key informant interviews and a household survey. The survey covered a sample of 536 households in 35 shehias across all 7 districts of Unguja Island and included visits to traditional RWH systems and discussion with users to understand the functionality and challenges of these systems while exploring the potential for adoption of modern RWH systems. The study further utilized Geographic Information System (GIS) and Remote Sensing (RS) to assess the suitability of potential sites for installation of RWH infrastructure for harnessing the vast amounts of surface runoff during rainfall events in Zanzibar.

Despite almost universal awareness of rainwater harvesting among the surveyed households (95 percent) and high levels of rainwater usage during rainy seasons (76 percent), only 46 percent of households have installed RWH systems. Traditional methods of RWH are the most common (64 percent of households) but only 65 percent of respondents described them as effective. Harvested rainwater is primarily used for domestic purposes (83 percent of households); only 7 percent of respondents use rainwater for agricultural activities. This limited use of rainwater for agriculture is primarily a result of inadequate skills, resources and technology to harness and use surface RWH, which is costly and requires trained expertise. This is further evidenced by the finding that 98 percent of the respondents who harvest rainwater use rooftop RWH, while only 2 percent make use of surface RWH. A small proportion of respondents also mentioned cultural barriers to rainwater usage. For example, 4% of respondents shared the perception that rainwater could cause ailments to women.

Analysis of the GIS and remote sensing data identified potential suitable sites for surface RWH in northern Magharibi A and Kati districts. The areas have high rainfall and higher soil water retention capabilities, hence, minimal impediments to the development of RWH infrastructure. However, the study highlighted key barriers to the wider adoption of communal RWH, including lack of technical knowledge, rapid urbanization and high population density. The latter poses a challenge by limiting the space for installing or constructing storage facilities, especially in populous urban areas in Stone Town.

Based on the findings, the study recommends development of national guidelines for RWH, establishing a dedicated inter-ministerial RWH coordination platform to harmonize efforts across ministries and improving public awareness and capacity building through structured educational campaigns and training programmes.

1 Introduction

Water insecurity is especially acute in Small Island Developing States (SIDS), where small land mass areas, fragile ecosystems and high vulnerability to climate change present significant challenges. Globally, 71 percent of SIDS are at risk of water shortages, rising to 91 percent in the lowest lying countries (UNESCO 2019). Among the most pressing concerns in these nations are the depletion of freshwater aquifers and saltwater intrusion, posing significant threats to sustainable water management. Zanzibar, a semi-autonomous region of the United Republic of Tanzania, is no exception to these phenomena.

Comprising two major islands, Unguja and Pemba, and 53 islets located off the eastern coast of Africa, Zanzibar exemplifies many of the critical water management challenges faced by small island states. The archipelago experiences a tropical climate with two distinct rainy seasons; the long rains (Masika) from March to May, and the short rains (Vuli) from October to December (Kai et al. 2020). Annual rainfall volumes vary significantly between the two islands with Unguja receiving approximately 1,600Mm3/annum and Pemba receiving a higher volume of 1,900Mm3/annum. The islands depend on four major water sources: groundwater, rainwater, underground water and seawater. Groundwater serves as the primary freshwater supply, but its availability is increasingly threatened by impacts of climate change and anthropogenic activities. In the 2022 National Census, Zanzibar's population was estimated to be 1,889,773 people and is growing at more than 3 percent annually (Ministry of Finance and Planning (URT) et al. 2022). The rapidly growing tourism sector, which accounts for over 27 percent of GDP (UNDP 2020), has continued to exert immense pressure on the limited water resources. In addition, urbanization has led to increased surface imperviousness, reducing aquifer recharge from rainfall leading to reduced storage.

Infrastructure constraints present another critical challenge, as the islands lack adequate water storage and distribution systems. According to the Zanzibar Water Authority (ZAWA) Five-Year Rolling Strategic Plan (FYRSP)(2020–2025), approximately 84 percent of households have piped connections to water supply services. However, the level of service delivery is often deemed unsatisfactory. This is attributed to administrative and management issues, including unregulated water allocations, which have led to uncontrolled drilling of private boreholes. These practices have further stressed Zanzibar's already limited groundwater resources. Despite these challenges, rainwater harvesting (RWH) has not been given the priority it deserves as a means for mitigating water scarcity in Zanzibar. Various rainwater harvesting techniques have been extensively utilized in other island nations, such as those in the Pacific and Caribbean (Table 1), whereby rainwater harvesting has been the main source of fresh water supply in both rural and urban areas.

Table 1. Percentage of population using rainwater as a drinking water source in the Pacific Islands

Country/Territory	Urban	Rural
Cook Islands	6	79
Fiji	1	25
Marshal Islands	71	98
Papua New Guinea	22	15
Palau	20	63
Solomon Islands	29	28
Tokelau	-	100
Tonga	68	84
Tuvalu	100	100
Vanuatu	14	44

Source: Foster et al. 2021

The United Nations Environment Programme (UNEP) has supported development of guidelines for rainwater harvesting in Pacific islands. Compiled by the South Pacific Applied Geoscience Commission (SOPAC) in collaboration with the Tonga Community Development Trust, these guidelines were published under SOPAC in 2004. Okovido et al. (2018) demonstrated the potential of RWH in Abuja- Nigeria while, in Zanzibar, the study by Malesu (2007) assessed the potential for rainwater harvesting by calculating the indicative volume of rainwater that could be generated. The Zanzibar analysis also highlighted the technologies that could be adopted, how the water could be utilized, and ways to address the challenges related to saltwater intrusion.

Building upon the work by Malesu (2007), this study explores the potential of rainwater harvesting in Zanzibar in light of recent trends in the enabling environment, climate change and rapid urbanization. It examines the existing policies and legal frameworks for supporting RWH technologies, the current status and future potential of rainwater harvesting for meeting freshwater needs as well as identifying appropriate RWH systems and sites for installation. The research aligns with the aspiration of the Zanzibar Development Vision 2050 (RGoZ 2020) to achieve upper middle-income status by 2050, which will require substantially increased water resources. Such a development trajectory is anticipated to enhance the accessibility and affordability of water supply and sanitation services and ensure the sustainability of water resources. Similarly, the Zanzibar Water Investment Programme (ZanWIP) 2022-2027, which is the framework for investments in the water sector, highlights the need for exploration and investment in RWH systems (RGoZ 2022a). It notes that the status of rainwater harvesting is hampered by, among other issues, a lack of awareness among stakeholders. Therefore, this study strived to increase the body of knowledge on RHW systems in Zanzibar and proposed actions for effective implementation and adoption of rainwater harvesting in the archipelago.

2 | Research Problem

Given its limited surface freshwater resources, Zanzibar finds itself at a critical crossroads where the sustainability of its freshwater supply and sanitation services is under threat. The archipelago is heavily dependent on groundwater, which is increasingly vulnerable due to overexploitation, pollution and impacts of climate change. This necessitates the urgent exploration of alternative freshwater sources as well as adoption of sustainable water resources management practices.

The studies by Kihila (2014), Mwamila et al. (2016), and Siphambe et al. (2024) highlight the effectiveness of RWH as an alternative source of freshwater for addressing water scarcity, enhancing groundwater recharge and improving water quality to meet the water needs of a growing population and expanding economy. The importance of RWH in Zanzibar cannot be understated because it offers a low-energy and cost-effective method to capture and store freshwater, thus reducing the reliance on limited and vulnerable groundwater reserves. It serves as an adaptive measure to climate change, providing a buffer against the impacts of altered precipitation patterns, sea-level rise and depletion of groundwater aquifers. However, the adoption and optimization of RWH in Zanzibar requires a comprehensive understanding of current RWH practices, potential capacity and the identification of suitable locations for possible infrastructure development.

This study leverages the existing body of research knowledge and guidelines at global and regional levels to assess RWH systems as part of sustainable water management in Zanzibar. It examines the current status and future potential of RWH as an alternative source of freshwater supplies for domestic and commercial use by:

i. Emphasizing the potential of RWH systems for complementing groundwater resources and lessening the dependence on overexploited aquifers;

ii. Evaluating the adequacy of RWH infrastructure, design, implementation and maintenance practices;

iii. Identifying the gaps and challenges in the adoption and optimization of RWH systems; and

iv. Recommending practical strategies and policy interventions to enhance the efficiency and scalability of RWH systems in Zanzibar.

3 | Research Objectives

The main objective of the study was to assess the potential for rainwater harvesting (RWH) in Zanzibar while considering the existing trends in enabling environment, climate change and urbanization. The specific objectives of the study are to:

1. Undertake a situation analysis of existing RWH systems by examining their capacity, efficiency, sustainability and cost-effectiveness;

2. Assess the existing legal and institutional landscape by identifying gaps and opportunities in policies and institutional structures that support the implementation of RWH systems in Zanzibar;

3. Explore potential sites and sustainability approaches for developing rainwater harvesting systems; and

4. Assess community perceptions on RWH systems by exploring cultural attitudes, traditional knowledge, and barriers to their adoption.

4 | Scope of Study

The study focused on Unguja Island due to the critical issues affecting the management of groundwater resources on the island, primarily from anthropogenic activities. Pemba Island is relatively pristine compared to Unguja. The analysis covered both urban and rural areas of Unguja because urban areas are characterized by groundwater overextraction and infrastructure challenges, while rural areas employ diverse traditional RWH methods. The research encompassed:

1. Examination of the knowledge and use of different RWH systems at household level;

2. Assessment of in-situ RWH systems and mapping of potential sites using modelling and GIS based approach; and

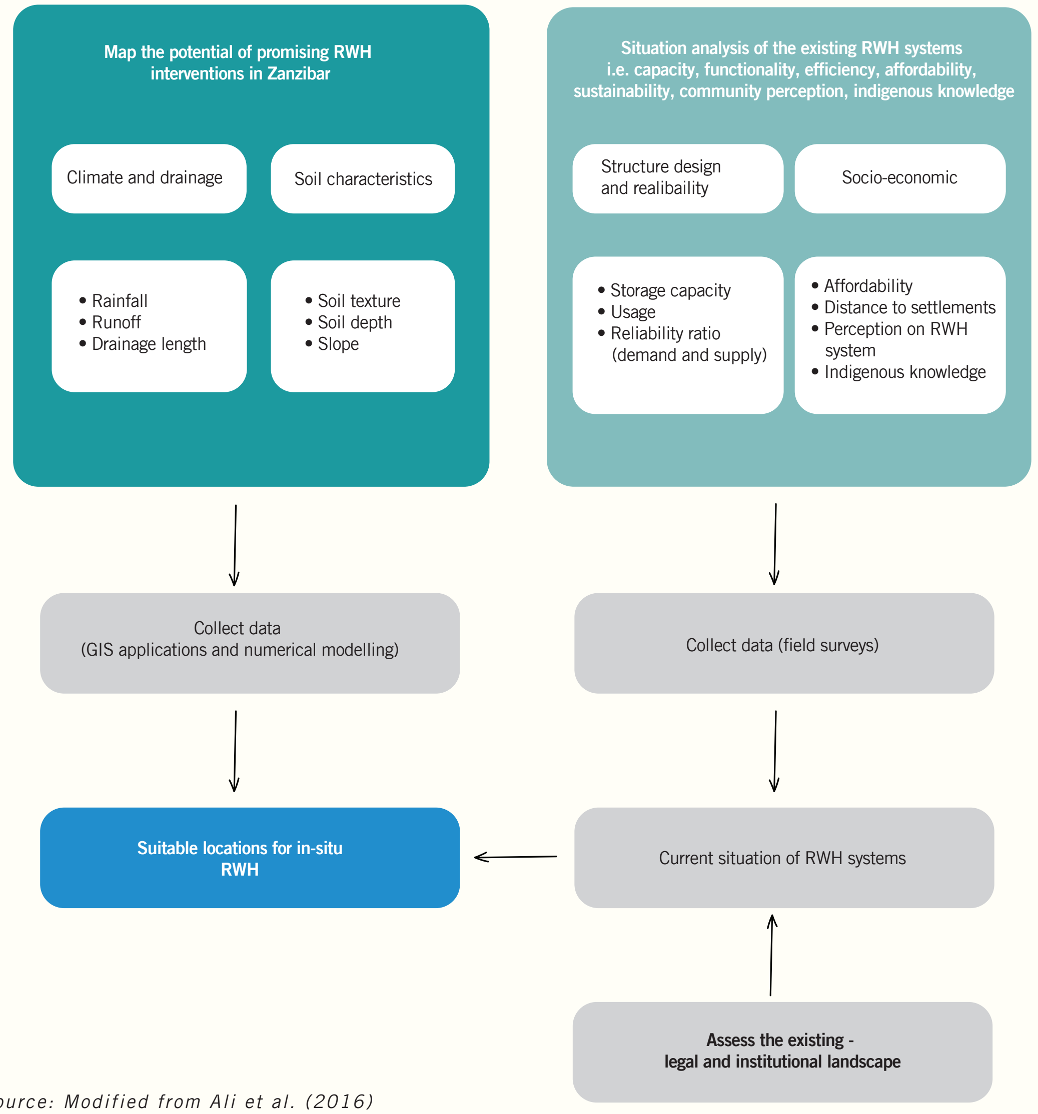
3. Stakeholder consultation covering all water and related sectors with special consideration given to large water users and those with limited access to groundwater.

5 | Conceptual Framework

The study was informed by the conceptual framework for assessing and evaluating rainwater harvesting potential, as described and modified from Ali et al. (2016) (Figure 1). This framework is centred on adopting GIS applications and numerical modelling to determine surface runoff RWH potential and suitability analysis based on hydro-climatic and drainage information, such as rainfall and runoff. The framework underscores that RWH is a function of social, economic and cultural factors, hence, the study conducted a survey of households to explore the various social, economic, cultural and behavioral variables for utilizing and adopting RWH systems. The research framework included, among other things, the analysis of the structural design, efficiency and reliability of existing RWH systems to determine their cost-benefit to households as well as an assessment of the present status of RWH systems in Zanzibar and the potential for adopting RWH as an alternative source of domestic water supply.

Given the fact that RWH is also guided and influenced by various national policies and legal frameworks, the study also examined existing legal and regulatory frameworks to ascertain gaps and opportunities for the adoption and development of RWH systems specifically for domestic water supply in Zanzibar.

Figure 1: Conceptual framework of the study



Source: Modified from Ali et al. (2016)

6 Methodology

1.1 Background information

The study entailed undertaking a literature review, examining the institutional and policy framework for RWH in Zanzibar, engaging stakeholders through key informant interviews and a household survey, and evaluating and mapping potential sites for the installation of surface RWH infrastructure. Stakeholder engagement and field visits were undertaken in November and December 2024. Based on the findings, the study provides regulatory and operational recommendations for enhancing the implementation and adoption of RWH systems as an alternative water source in Zanzibar. The methods used by the study are explained in detail in the sections below.

6.1Assessment of legal and regulatory frameworks

The study conducted an analysis of the legal and regulatory frameworks supporting RWH systems in Zanzibar. This involved a systematic review of relevant policies and legal documents to identify gaps and opportunities for advancing RWH systems in Zanzibar. Key documents were reviewed, followed by stakeholder consultations as described below.

6.1.1 Key informant interviews

Key informant interviews, using structured and semi-structured interview guides, were conducted with selected groups of stakeholders from sectors related to water management. These stakeholders included representatives from government ministries, departments and agencies (MDAs), development partners, the private sector, academic institutions and non-governmental organizations (NGOs). The list of stakeholders engaged is presented in Appendix 1. The purpose of these interviews was to gather diverse perspectives and insights on the challenges, opportunities and strategies for improving water management in Zanzibar.

6.1.2 Household survey

The household survey was designed to collect the information required to fulfil two of the study objectives, i.e., establish the state of RWH systems in Zanzibar in terms of their capacity, functionality, efficiency, affordability and sustainability, and assess community perceptions, traditional knowledge on RWH systems as well as barriers to their adoption. This included, among other things, validating the identified potential sites for in-situ RWH. The survey questions and tools were developed online using Kobo Toolbox and are available through this link.

6.1.3 Sampling approach

The interviews and household survey were conducted in all 7 districts of Unguja Island. Estimation of sample size for each district followed a systematic approach as described by Cochran's sample size formula in Equation 1.

$$n = \frac{z^2 \cdot p \cdot (1-p)}{E^2} \quad \text{......... Equation 1}$$

Where:
P represents population size, **n** represents sample size, **Z** represents Z-score, and **E** represents the margin of error.

This study targeted household heads or their representatives, aged 18 years and above. The confidence level was set at 95 percent, which statistically corresponds to a Z-Score of 1.96 percent. A five percent margin of error was selected, implying that the results are expected to be within five percent of the value with the indicated level of confidence above. On this note, the minimum sample size was set at 385 individuals, with each individual representing a single household. The actual sample size for each district was calculated by multiplying the proportional population of each district by the total required sample size, which was adjusted to a range of 400 and 540 individuals (Appendix 2). The total sample size for each district was used to determine the required number of shehias, which were then selected purposively to minimize bias. Proximity and population size were the main factors used to select individual shehias. Shehias with populations above 5,000 people were selected equally with those with populations less than 5,000 people. Similarly, the selection of shehias considered the distance from one shehia to another to reduce biases associated with similarities in behaviours and livelihoods between settlements in close proximity. In total, 536 households in 35 shehias across all 7 districts of Unguja Island participated in the household survey.

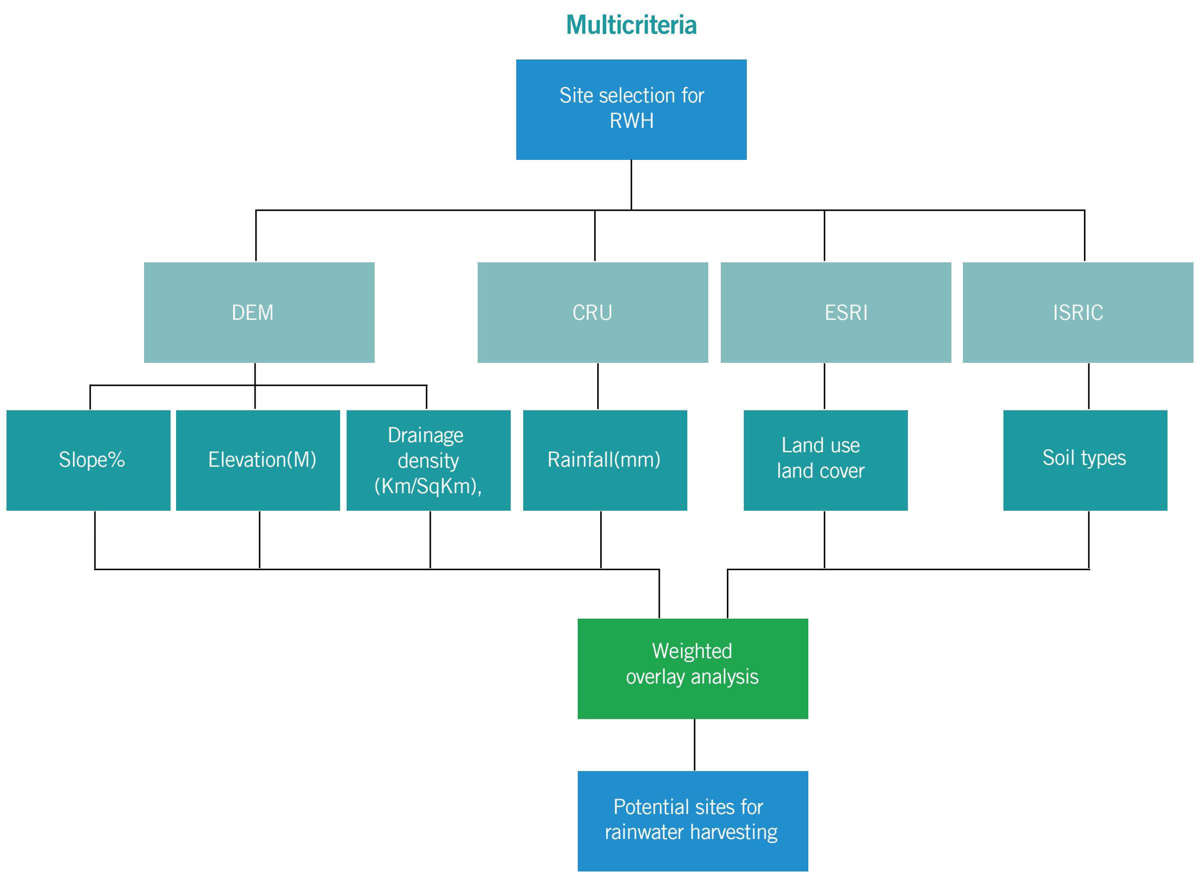
6.2 Identification of potential sites for promising RWH sites

The study adopted numerical modeling approaches to map the potential sites for in-situ RWH and the associated suitable locations. Given that the availability of rainwater is influenced by multiple environmental and hydrological parameters, the research integrated various factors to enhance the accuracy of site selection by adopting multi-criteria analysis (MCA) coupled with an Analytic Hierarchy Process (AHP) to develop suitable locations based on multiple parameters.

6.2.1 Multicriteria analysis and Analytic Hierarchy Process

Multicriteria analysis is a widely used decision-making approach for evaluating multiple conflicting criteria or parameters in complex scenarios. MCA is often used where selection of the best option among alternatives is complex and involves various quantitative and qualitative factors (Taherdoost and Madanchian 2023). Understanding the RWH system requires complex understanding of the interaction of multiple parameters. This study identified suitable sites for RWH based on various criteria outlined by the Food and Agriculture Organization (FAO) and utilized AHP to support decision-making in selecting the best potential sites. These criteria include slope, elevation, drainage density, rainfall, land use and land cover, and soil types as indicated in Figure 2. These six criteria, which were considered as the main parameters, had other sub-parameters which were used accordingly. For example, rainfall was chosen for climate, drainage density for hydrology, slope for topography, land use/land cover for agronomy, and soil characteristics for soils (Aziz et al. 2023). Six thematic maps, each representing individual selected parameters, were preprocessed using GIS and remote sensing approaches to ensure their compatibility in extent, spatial resolution and spatial references.

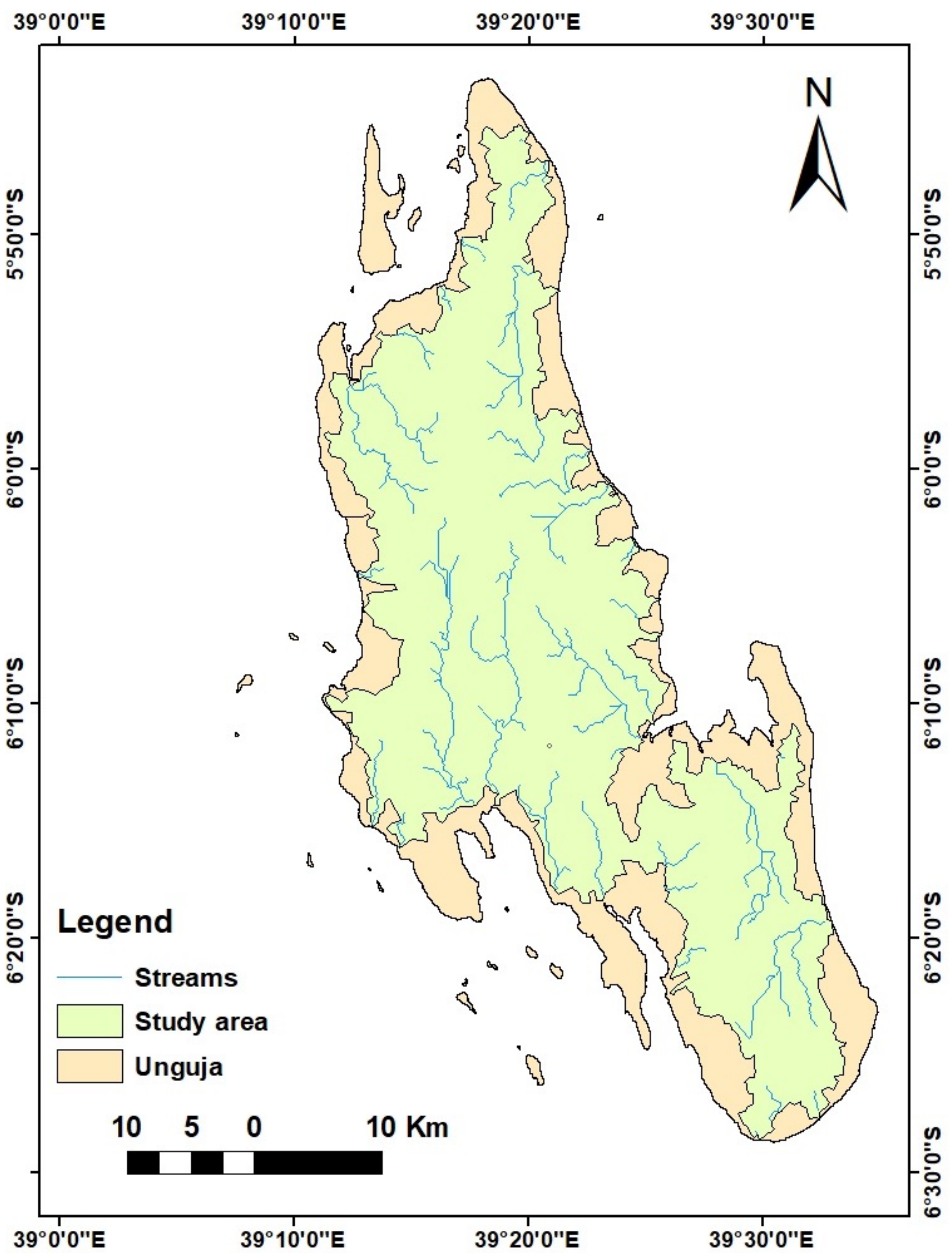
Figure 2. Methodological framework for implementing multicriteria model



6.2.2 Delineation of watersheds

Delineation of watersheds was done using ArcMap. Notably, the Digital Elevation Model (DEM) of Unguja Island (the study area) was obtained from United States Geological Survey (USGS) with a spatial resolution of 30 metres. The DEM, which was pre-processed by filling sinks and correcting inconsistencies, was used to create a flow direction raster map, which shows the direction of water flows across the study area. This was followed by creation of a flow accumulation raster map, which was generated to identify areas where water converges and to demarcate drainage networks. The flow direction and flow accumulation maps were used to define watershed boundaries. Figure 3 presents delineated watersheds of the study area. The study aimed to identify at least two watersheds with the longest flow paths with a clear network of streams and the associated sub-catchment for further analysis of RWH suitability. This is because many parts of Unguja Island are characterized by flat terrain, which makes it challenging to compute all individual sub-catchments and, ultimately, the entire basin.

Figure 3: The credibility of governance frameworks



6.2.3 Thematic map processing

Rainfall
It is widely accepted that the potential sites for RWH must first receive sufficient rainfall for the initiative to be viable. A rainfall thematic map was created based on data from six stations and thereafter interpolated using an Inverse Distance Weighted (IDW) method to generate the spatially distributed mean annual precipitation map for the area.

Slope
Slope is an important parameter which influences the speed and amount of runoff, and amount of sediment generated and transported. It has been established that the acceptable slope for suitable sites for RWH should be less than 5 percent. Areas with slopes large than 5 percent are considered susceptible to erosion which means that extensive earthwork is needed for constructing RWH structures (Jourgholami et al. 2021). The slope map for the study area was created using the Digital Elevation Model with a spatial resolution of 30 metres.

Soil texture
Soil texture influences both the rate of infiltration and surface runoff. The textural class of the soil is ascertained by the proportions of sand, silt and clay. Soil texture leads to different soil infiltration rates and hence different influence on runoff amount. The suitable soil for RWH is clay soil since it has higher water retention capacity and low permeability (Gören and Tekin 2024). The soil thematic map for the study area was generated using the FAO Harmonized World Soil Database (HWSD) with a shape file created from the International Soil Reference and Information Centre (ISRIC).

Land use/Land cover
Land cover plays a crucial role in influencing runoff whenever it rains within a specific area. Dense vegetation is related to higher rates of infiltration, which generate lower runoff. This means that the preferred land covers for RWH are bare, cultivated and/or grassland, which often have lower rates of infiltration (Regüés et al. 2017). Land use/ land cover data for the study area were extracted from ISRIC.

Drainage density
Drainage density is defined as the ratio of total watercourse length to the surface area of the basin (Adiat et al. 2012; Mogaji et al. 2015). This parameter plays a crucial role in RWH whereby high drainage density influences rapid surface runoff. This means that areas with high drainage density are well-suited for RWH because of multiple channels draining water. In this study, drainage patterns were delineated from Digital Elevation Model (DEM) with 30m resolution. The delineated stream pattern was used to generate the drainage density maps using "Line Density" tool in ArcGIS spatial analyst as illustrated in Equation 1.

$$Dd = \sum_{n=1}^{i=n} Di/A \text{ .... Equation 1}$$

where zDi represents the cumulative length of all streams within the grid i (measured in kilometres), while A denotes the area of the grid (measured in square kilometres).

Elevation
The suitability of RWH sites depends on elevation, notably, areas with low elevation tend to be more suitable and cost-effective than high elevation areas. Low elevation areas tend to have high water accumulation coupled with low water movement compared to high elevation sites, which might require extensive earthworks in designing RWH systems (Niemans 2024).

6.3 Delineation of potential sites for surface RWH

The identification of suitable sites for surface rainwater harvesting requires a systematic analytical approach in mapping them. The Analytic Hierarchy Process and Multicriteria Analysis helped to evaluate the different factors that influence site selection for RWH in Unguja. The following are the practical MCA steps for locating appropriate RWH sites as applied in this study.

Step 1: Select criteria to be used for site identification
The first step in MCA was to select relevant parameters that influence the selection of potential rainwater harvesting sites.

The parameters that were used to assess the suitability of RWH sites are outlined below:

- **Rainfall characteristics** of the study area, noting that higher rainfall areas are commonly preferred and found to be more suitable.
- **Slope characteristics** help in identification of areas that would not be susceptible to erosion but facilitate ease of runoff collection. Normally, gentle slopes (gradient from 1.5 to 5 percent) are more suitable.
- **Soil type:** This determines the amount of stored water that can infiltrate through the soil matrix or seepage potential of the RWH structure. Clay, sandy clay and/or clay loam soils with moderate infiltration rates are commonly regarded as more suitable.
- **Land use land cover characteristics**: Bare land and/or agricultural land are prioritized.
- **Site drainage density**: The higher the drainage density, the more suitable for rainwater harvesting.
- **Site elevation or topographical features:** Ideal sites for RWH are usually those with minimal elevation.

Step 2: Applying an expert decision-making process from multiple criteria for ranking or prioritizing the criteria (by assigning weights)

Using the Analytic Hierarchy Process, each of the above parameters were given a weight according to its relative value and importance using the structured AHP technique. AHP facilitates making decisions by comparing two options at a time, (referred to as pairwise comparison) in priority setting. This is commonly supplemented with experts' judgment.
Pairwise comparison entails comparing a parameter against the others in terms of importance using a scale (e.g., 1 to 9, where 1 signifies least importance and 9 extreme importance). The second step entails constructing a comparison matrix where the pairwise comparisons are structured in a matrix, followed by calculating weights, in which case the weight of each parameter is determined by computing the matrix's eigenvalues. Finally, the consistency ratio (CR) is computed to make sure that expert decisions make sense. If CR is greater than 0.1, then values assigned to the parameters must be changed.

Step 3: Use of a GIS-based Multicriteria Analysis in evaluating weighted spatial data
GIS tools were used to integrate and evaluate spatial data after weights were assigned to each parameter as follows:

- **Data normalization:** To enable comparison, the values of all the parameters were normalized on a similar scale between 0 and 1.
- **Weighted overlay analysis:** To produce a suitability map, the GIS layers that correspond to each parameter were multiplied by the weights that were determined or established through the AHP process and then added together.
- **Reclassification:** Different categories or classes of suitability, i.e., extremely suitable, highly suitable, moderately suitable, low suitability and less suitable were developed.

6.3.1 Data integration and analysis.
The study adopted a GIS-based weighted overlay process to determine suitable sites for rainwater harvesting. This entailed several processes as follows:

i. The thematic layers which were in vector format (.shp file extension) were converted into raster files (.tif) by using a rasterization function. This was followed by resampling to develop thematic layers with similar spatial resolution.

ii. Reclassification was conducted on the resampled layers which entailed transformation and grouping of large distribution of values in each layer into specific groups. This means, all layers were reclassified into the same group for easy comparative analysis.

iii. The weighed overlay process was conducted by overlaying the reclassified layers and the associated weighted values to produce the raster layer, which represents suitability of the potential sites for RWH.

The values of the produced raster layer were then reclassified into five major groups including 1 for less suitable, 2 for low suitability, 3 for moderate suitability, 4 for high suitability, and 5 for extreme suitability.

6.4 Verification of identified potential sites for RWH

The identified potential sites for RWH were subjected to field verification to validate their viability. This was carried out through fieldwork, which included both field visits to existing in-situ RWH systems as well as the stakeholder interviews and household survey.

7 Findings and Discussion

7.1 Demographic characteristics

As described in the methodology and detailed in Appendix 2, the household survey was conducted in all 7 districts of Unguja Island. In total, 536 households across 35 shehias were visited and interviewed. As illustrated in Figures 4 and 5, the majority of respondents were female (79 percent) and 42 percent of participants were aged between 36 and 50 years. The high proportion of female respondents primarily reflects that activities related to securing water supplies at household level are largely performed by women, who are often found at home compared to men. It is much easier to acquire reliable information on water usage including RWH from female members of the household than men, who are less engaged in domestic chores.

Figure 4. Gender distribution of respondents

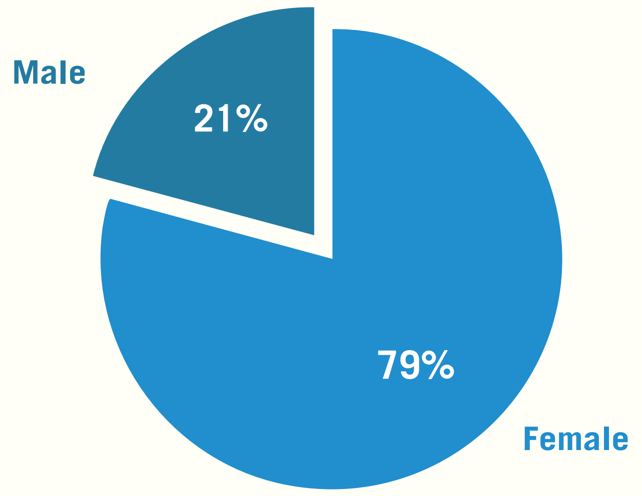
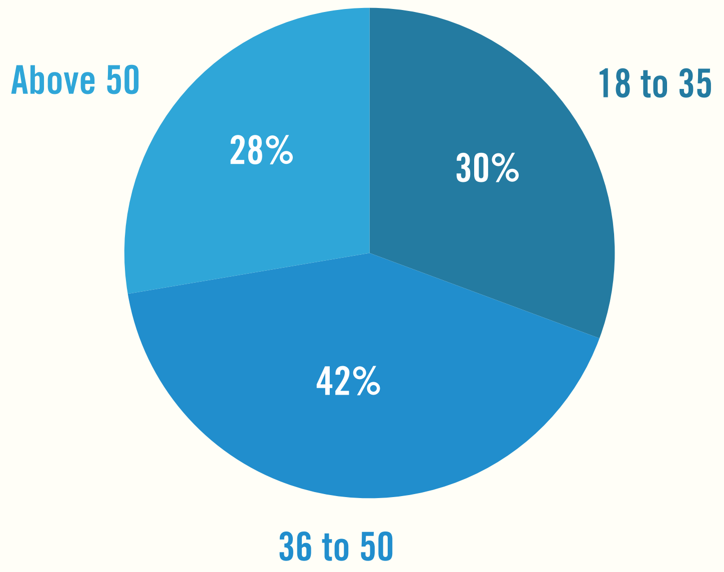


Figure 5. Age distribution of respondents (in years)



7.2 Current state of RWH systems in the study area

Figure 6 indicates that many households in Unguja (76 percent) use rainwater as a source of freshwater, i.e., 3 out of 4 households reported harvesting rainwater during rainy seasons. Results further show that community wells served as a source of water for many households in Unguja (73 percent), followed by water from ZAWA (57 percent). However, the latter is often associated with unreliable service. Other sources reported included private wells (7 percent), while a small proportion (5 percent) depend on other sources, such as purchasing water from local vendors, which is then delivered by carts.

Figure 6. Household usage of water sources in Unguja

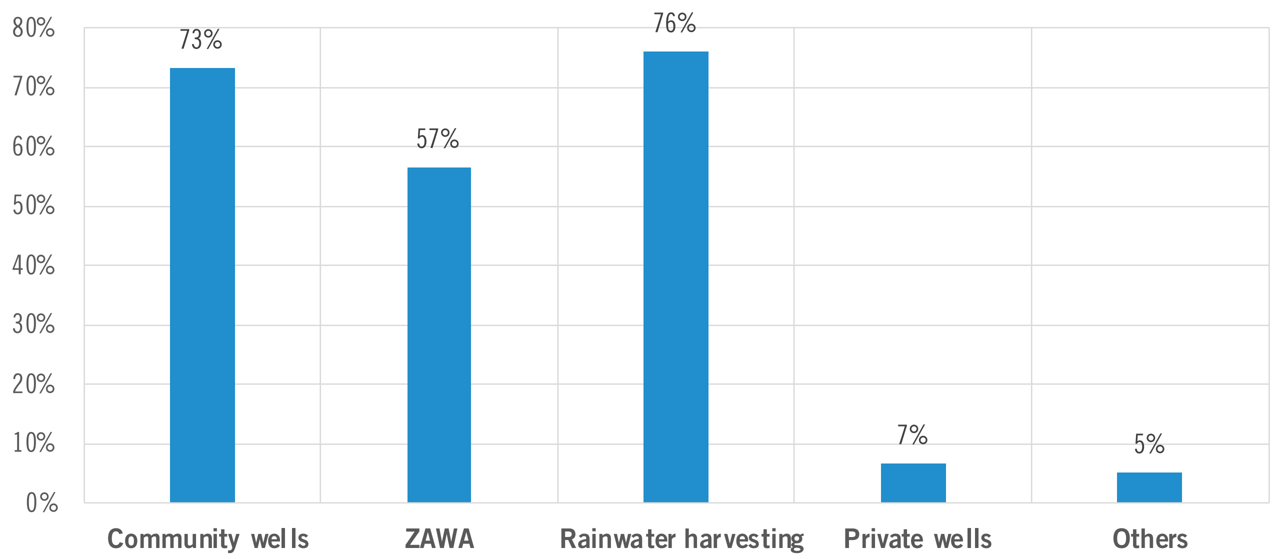
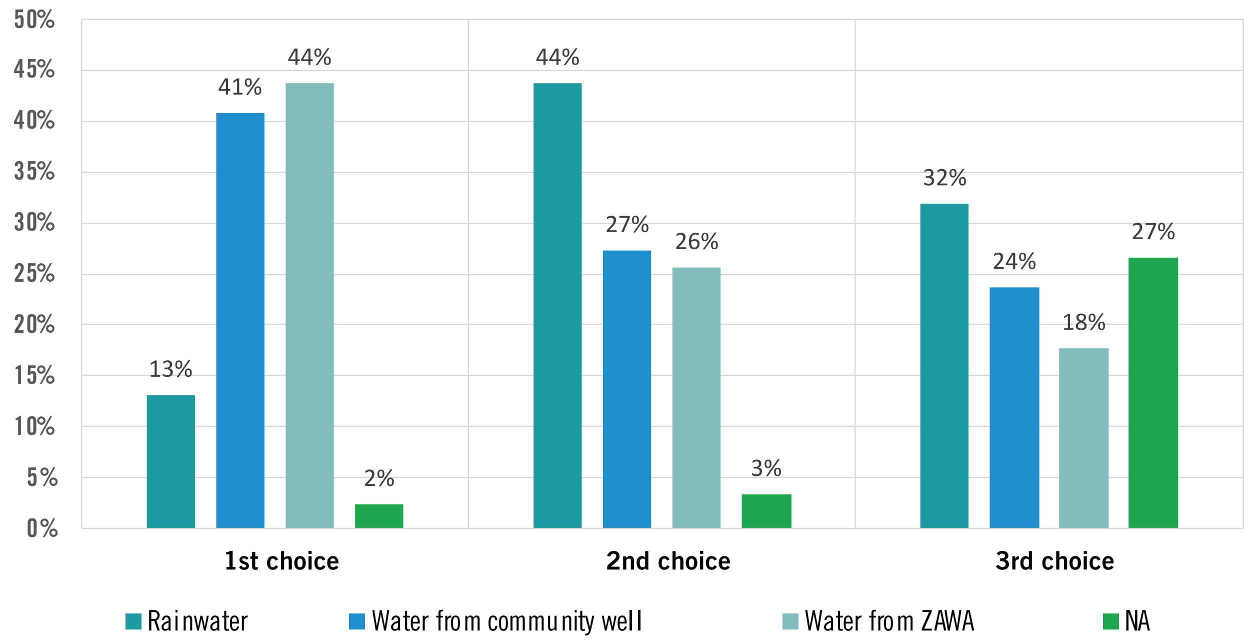


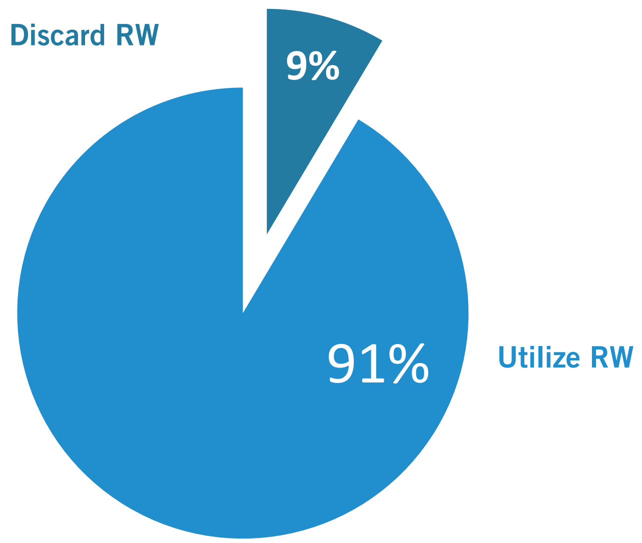
Figure 7 presents the results on household preferences for water sources in Unguja, which have been categorized into respondents' first, second and third choices. The findings indicate that the most preferred water sources are ZAWA (44 percent) and community wells (41 percent). These sources are therefore regarded as the primary options for most households. A small proportion of respondents (2 percent) either do not have a defined first choice of water source or rely on other alternatives – and in most cases, these households lacked a reliable water supply. Despite many households making use of rainwater during the rainy season, only 13 percent of households selected rainwater as their first choice of water supply, likely due to its seasonal availability. For many households (44 percent), rainwater becomes a more significant choice when other primary sources are not available, indicating its significance as an alternative water source, especially during the rainy season. It is important to note that community wells (27 percent) and ZAWA (26 percent) are also considered as viable alternatives when the preferred source is inaccessible. A quarter of households (27 percent) had no defined third choice, which indicates exclusive reliance on their primary and or secondary water sources and underscores the limited accessibility to multiple water sources for these households.

Figure 7. Community water source preferences in Unguja



Although many households (91 percent) use rainwater as an alternative source of water to cater for their daily needs, only 9 percent of respondents reported no perceived benefits of rainwater and often discard harvested rainwater (Figure 8). This may be attributed to cultural and traditional barriers or the poor quality of infrastructure used for collecting rainwater, which often leads to contamination before the water is used. One of the main cultural barriers that was mentioned (4 percent of respondents) was the perception that rainwater could cause ailments to females. Another barrier for not using rainwater especially in town areas, but not associated with cultural norms, is the dirt on most roofs which mainly emanates from bird droppings, especially crows, and stray cats. In Stone Town, for example, respondents mentioned that stray cats frequently inhabit the roofs of buildings and they are very difficult to eradicate.

Figure 8. Rainwater usage as a source of drinking water supply in households



Generally, awareness of households on harvesting rainwater is high, as presented in Figure 9, which indicates that over 95 percent of respondents knew about RWH. However, despite this widespread awareness, the adoption of RWH remains limited. Figure 10 reveals that only 46 percent of respondents have established rainwater harvesting systems, while a majority of households (52 percent) do not have such systems in place. This implies that knowledge alone is not enough to enhance or drive implementation, indicating the existence of barriers, such as cost, lack of proper infrastructure, or cultural and belief systems, that may hinder households from adopting or investing in RWH systems.

Figure 9. Respondents' awareness of rainwater harvesting

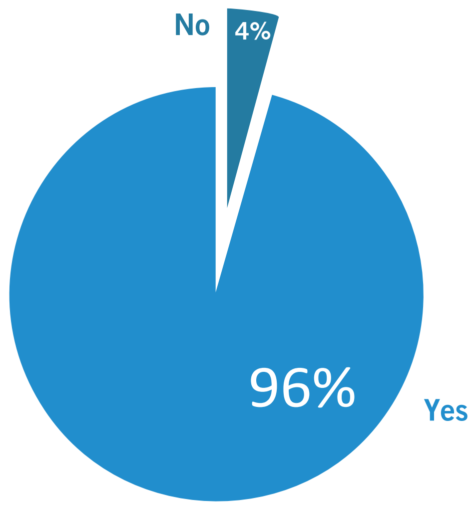
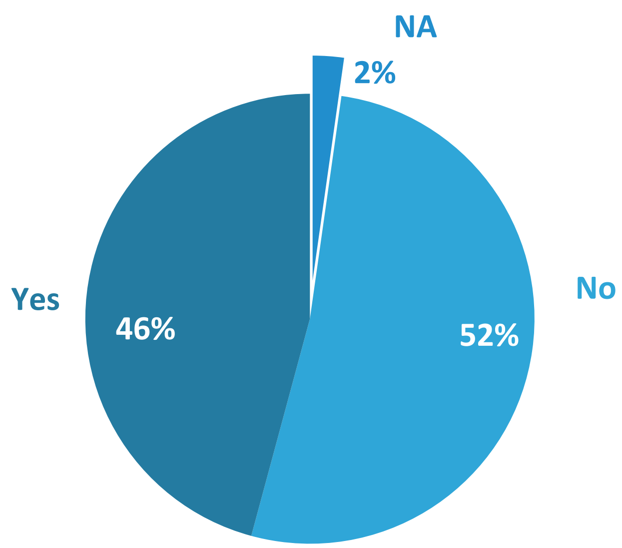
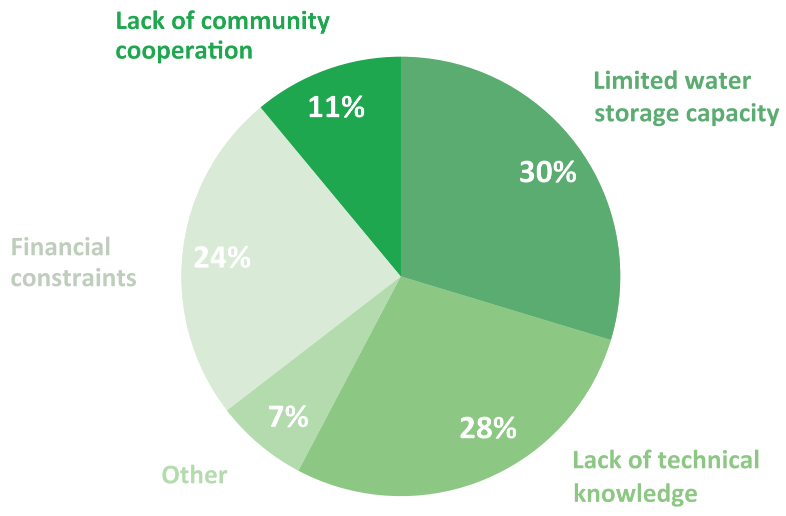


Figure 10. Proportion of households with RWH systems



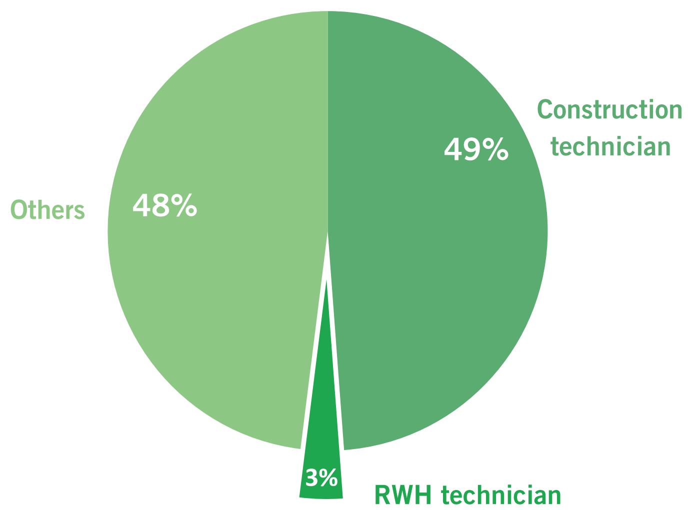
Many households in Unguja lack the necessary expertise to effectively design, install and maintain RWH systems. As shown in Figure 11, over 28 percent of respondents reported limited technical knowledge, while 30 percent highlighted insufficient water storage capacity. This implies that even where RWH systems are in place, they may not be equipped with adequate storage capacity to meet long-term needs. Additionally, 24 percent of respondents cited financial constraints, indicating that even with improved technical knowledge, affordability remains a significant barrier. This underscores the need for subsidies, grants or financing options to enhance the accessibility and sustainability of RWH systems.

FIGURE 11. BARRIERS TO ADOPTION OF RAINWATER HARVESTING



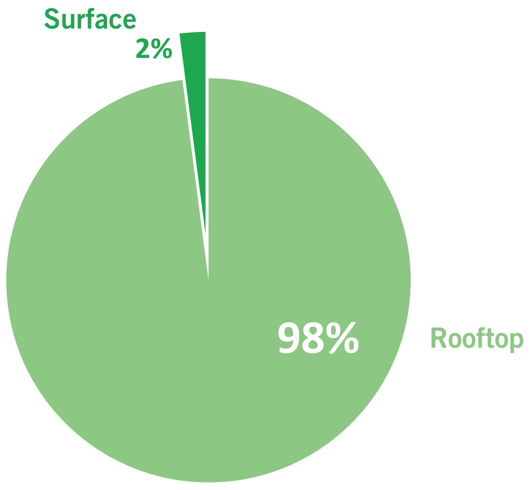
When households who reported having a RWH system (46% of the total sample) were asked who they had engaged to construct their RWH systems, only 3 percent of respondents reported they had hired technicians specialized in building RWH systems (Figure 12). Almost half of these households (49 percent) reported that they had engaged general construction technicians, while 48 percent said they had relied on contractors from other fields. These results highlight a shortage of professional technicians specifically trained in RWH construction and indicate a significant need for specialized training programs to build capacity in this field.

FIGURE 12. TYPES OF TECHNICIANS INVOLVED IN CONSTRUCTING RAINWATER HARVESTING SYSTEMS



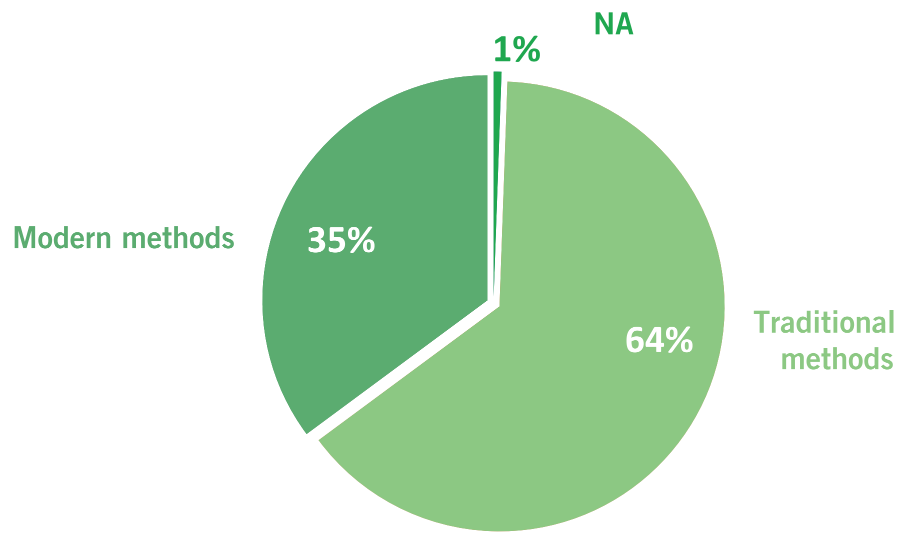
As illustrated in Figure 13, rooftop rainwater harvesting (RWH) is the predominant practice used by households in Unguja. Almost all respondents (98 percent) reported harvesting rainwater from their rooftops, whereas only 2 percent relied on RWH from surface runoff. The limited adoption of surface runoff systems may be attributed to land use changes, urbanization, technical expertise gaps and financial constraints, which impact the feasibility of this type of system. The preference for rooftop RWH is likely driven by its cost-effectiveness, ease of implementation and the minimal infrastructure required, making it the most viable option for many households.

FIGURE 13. EXISTING TYPES OF RWH SYSTEMS



Over 64 percent of respondents (344 households) used traditional rainwater harvesting methods, while 35 percent (188 households) have adopted modern methods as illustrated in Figure 14. In this study, traditional methods generally refer to indigenous practices such as the use of Mikingo (gutters and downpipes fashioned from recycled corrugated iron sheets) and storage in Mahodhi (iron drums or in-ground concrete tanks constructed with local materials). By contrast, modern methods include the use of factory-manufactured gutters, plastic tanks, and purpose-built ferro-cement tanks, which represent more standardized and durable technologies. A more detailed description of indigenous knowledge and practices is provided in Section 7.3, which further elaborates on the traditional systems used in Zanzibar.

FIGURE 14. TYPES OF RWH SYSTEMS



More than 65 percent of respondents considered that traditional RWH systems to be "moderately" or "very" effective, but approximately one in three respondents (30%) reported that they were not effective (Figure 15). These results indicate that, despite the widespread use of traditional RWH systems, the perceptions of their effectiveness vary. Nevertheless, a majority of households perceived that traditional RWH are the most effective methods despite the associated bottlenecks, such as maintenance needs and temporary storage capacity.

Figure 15. Respondents' perceptions on the effectiveness of traditional RWH systems

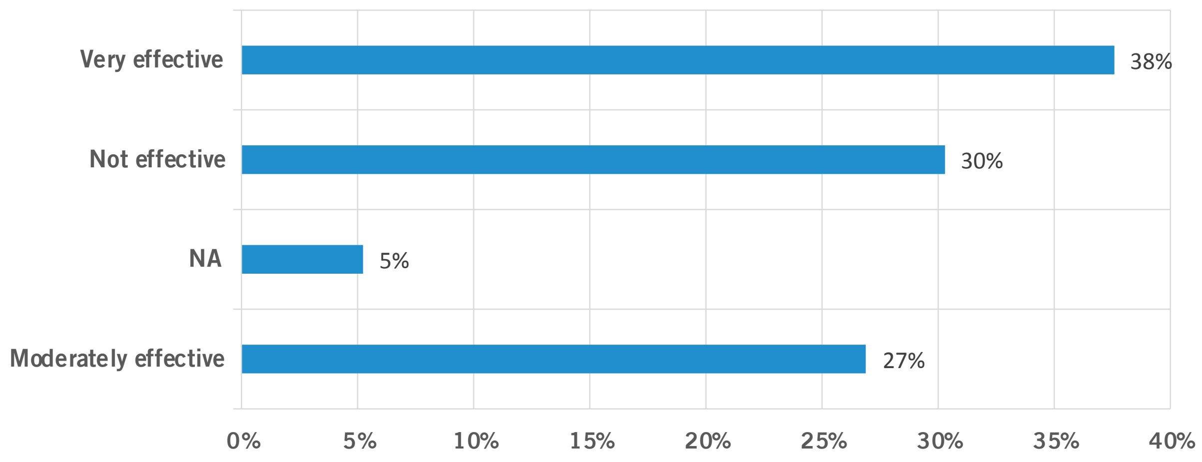
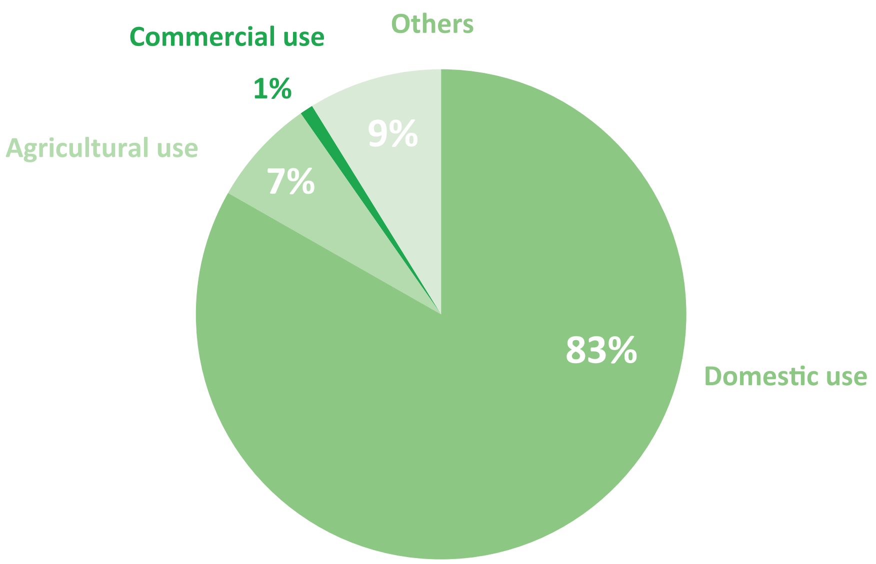


Figure 16 shows that majority of respondents indicated that the primary use for rainwater is for domestic use (83 percent), which highlights a strong reliance on rainwater to cater for household needs such as drinking, cooking and cleaning. Use of rainwater for agriculture is significantly lower; only 7 percent of respondents (or 40 households) reported this use. This shows that rainwater harvesting has a minor role in small-scale farming activities. This correlates with the finding that the vast majority of respondents relied on rooftop RWH than surface runoff, which is widely considered to be the most effective for agricultural purposes. Additionally, 1 percent of respondents indicated relying on rainwater for commercial uses, such as car washing.

Figure 16. Uses of rainwater



The study further evaluated the level of adoption of rainwater harvesting (RWH) practices in the community. Unlike the earlier analysis, which reported the proportion of households that already have RWH systems in place (46% of households), this question enquired on the broader community's likelihood or willingness to adopt RWH in the future, regardless of whether they currently own a system. Figure 17 shows that 74 percent of households (398 respondents) are very likely to adopt RWH, while 18 percent (95 respondents) are somewhat likely. Only 2 percent of respondents considered that adoption of RWH was unlikely. Reflecting on the factors that influence adoption of RWH (Figure 18), it is noted that "environmental and land use changes" was the factor most commonly cited by respondents. In this study, environmental changes were mainly understood to refer to climate variability, shifting weather patterns and catchment conditions, which together influence the feasibility of RWH. Other leading factors cited by respondents for adoption of RWH included population growth (41 percent of respondents) and the introduction of modern technologies that have improved or replaced traditional RWH methods (44 percent of respondents). Policy changes were perceived to have had the least impact, even though regulations can significantly support or hinder adoption of RWH.

Figure 17. Likelihood of community adoption of RWH

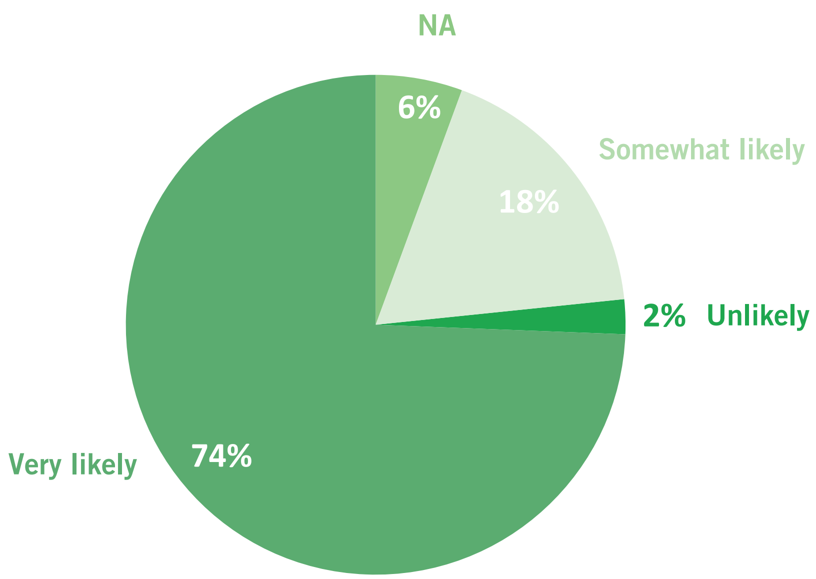
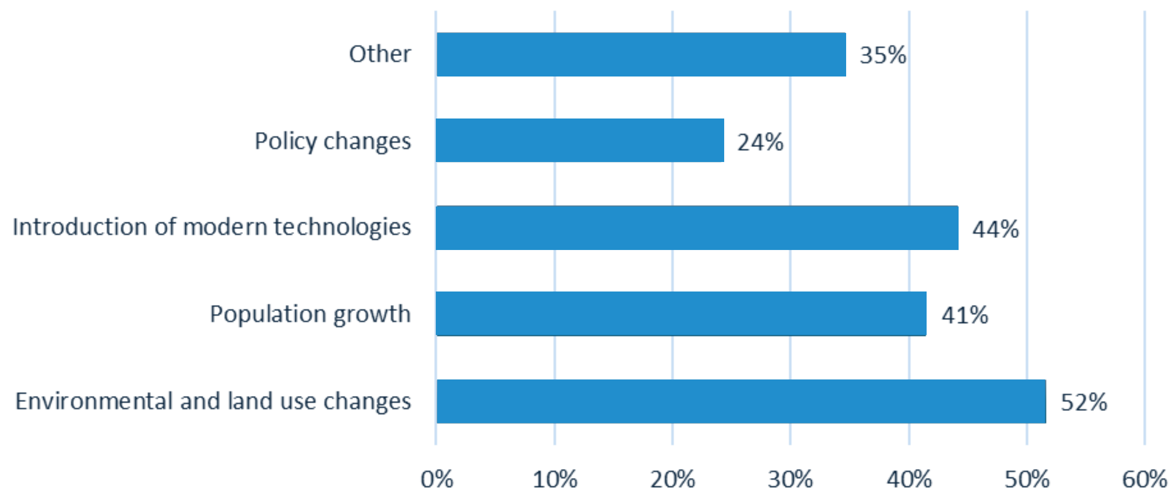
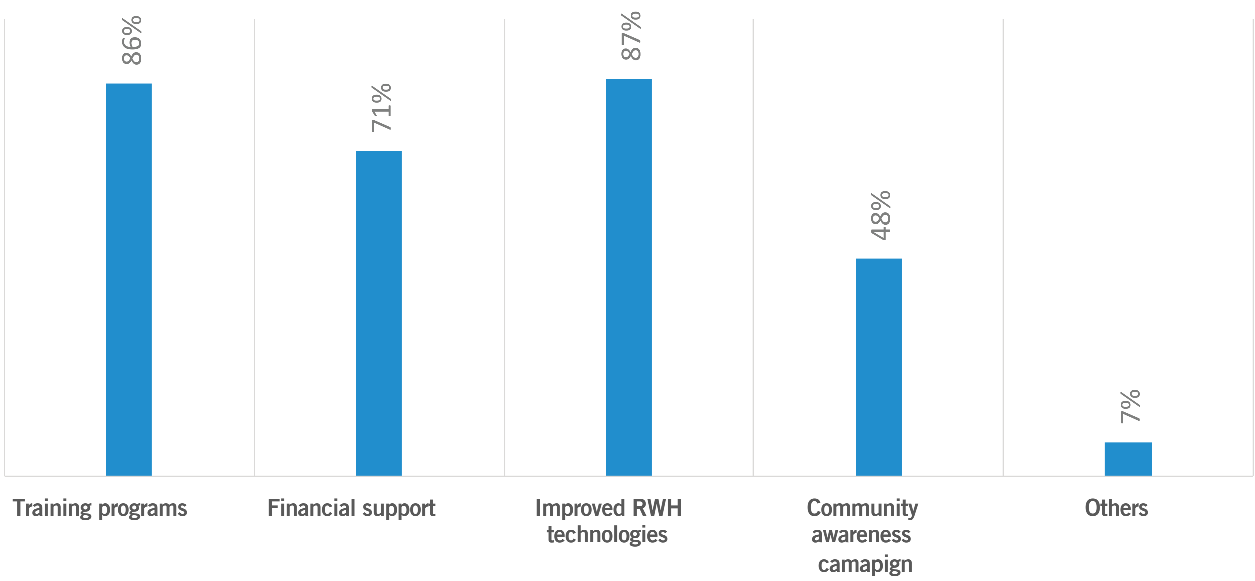


Figure 18. Factors affecting adoption of RWH



The study further sought to understand community perceptions on what would be required to scale up the adoption of RWH. As illustrated in Figure 19, a large majority of respondents highlighted the need for improved RWH technologies (87 percent) and for training programmes (86 percent) to improve adoption of RWH. This strongly implies the need and relevance of capacity-building and technical improvements in facilitating adoption. Additionally, 71 percent of respondents cited financial support as another crucial factor, which indicates that cost of installing and maintaining RWH is a significant barrier to adoption. Around half of the respondents (48 percent) also mentioned the need for community awareness campaigns through education and outreach programmes to enhance general knowledge on RWH and influence decisions towards adoption.

Figure 19. Opportunities for increasing adoption of RWH technologies



7.3 Community perceptions and indigenous knowledge

7.3.1 Indigenous RWH techniques

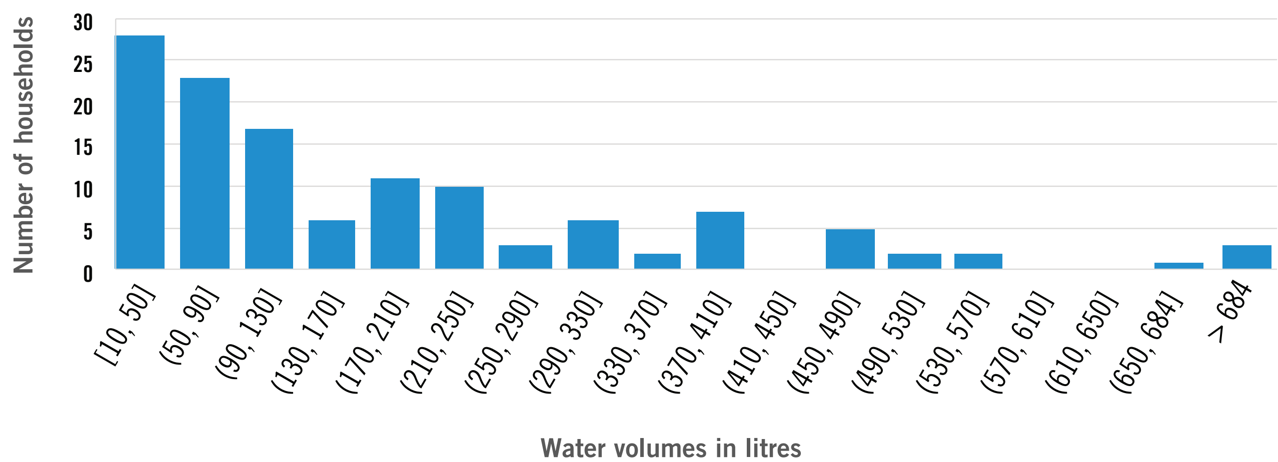
At present, and with reference to Figure 14, the techniques used by households for rainwater harvesting in Zanzibar are predominantly indigenous methods, where gutters and storage facilities/tanks commonly known in Kiswahili as Mikingo and Hodhi (pl. Mahodhi) are used to collect and store rainwater from rooftops (see Plate 1). In practice, Mikingo refers to the system of gutters, channels, and downpipes that guide rainwater from rooftops into storage containers. These are typically fabricated from recycled corrugated iron sheets, locally adapted for this purpose. The term Hodhi (plural Mahodhi) refers to the storage facilities, which vary in form and material: some are above-ground iron drums, others are in-ground or semi-underground concrete tanks, while in certain cases brick structures are incorporated as protective or supporting elements around the storage units. These techniques are relatively expensive and associated with collection of larger volumes of rainwater than other available storage facilities.

Plate 1. Traditional rooftop RWH using mikingo and mahodhi

[redacted]

Figure 20 presents data on the estimated amount of water collected per rain event by households in the study area. Most households collect between 10 litres to 130 litres of water per rain event, depending on the intensity of the rainfall.

Figure 20. Average amount of rainwater in litres collected per rain event



Additionally, many residents lack access to ZAWA water, and they rely on purchasing water from vendors who deliver by vehicle or cart. The cost per 20-litre bucket ranges between 300 to 500 Tanzanian shillings, which is expensive for a typical household. Additionally, many wells in the northern part of Unguja are salty, making the water unsuitable for domestic use. This has influenced some communities to construct relatively large concrete tanks designed to store enough water for prolonged use. Water stored in these tanks is drawn from both wells and rainwater, allowing for the natural dilution and softening of salty water from wells by harvested rainwater. Communities perceived that rainwater can help reduce or dilute the salt content in water obtained from wells.

7.3.2 Domestic RWH storage and handling facilities

The study observed that many households effectively harvested rainwater for domestic use and stored this water to last throughout the dry season. As described earlier, the majority of households use rainwater for bathing, washing clothes and cooking, particularly boiling foods like beans. Respondents reported that rainwater had a softening effect when cooking beans. Additionally, many households noted that rainwater was softer than water from wells, as it tends to produce more suds/foam when used for washing, which has the direct benefit of reducing the amount of soap used for household washing and cleaning. Respondents cited this as one of the major reasons for the adoption of RWH as an alternative source of water in Zanzibar. Most households also practice indigenous methods to maintain the quality of harvested rainwater. For example, one respondent reported using metallic lids to cover containers storing rainwater to prevent mosquito breeding, and to ensure that the water remains safe and usable for an extended period of time. Similarly, respondents from Nungwi indicated that they store rainwater in a dark room for several months to prevent any contamination and possible chemical reaction (Plate 2).

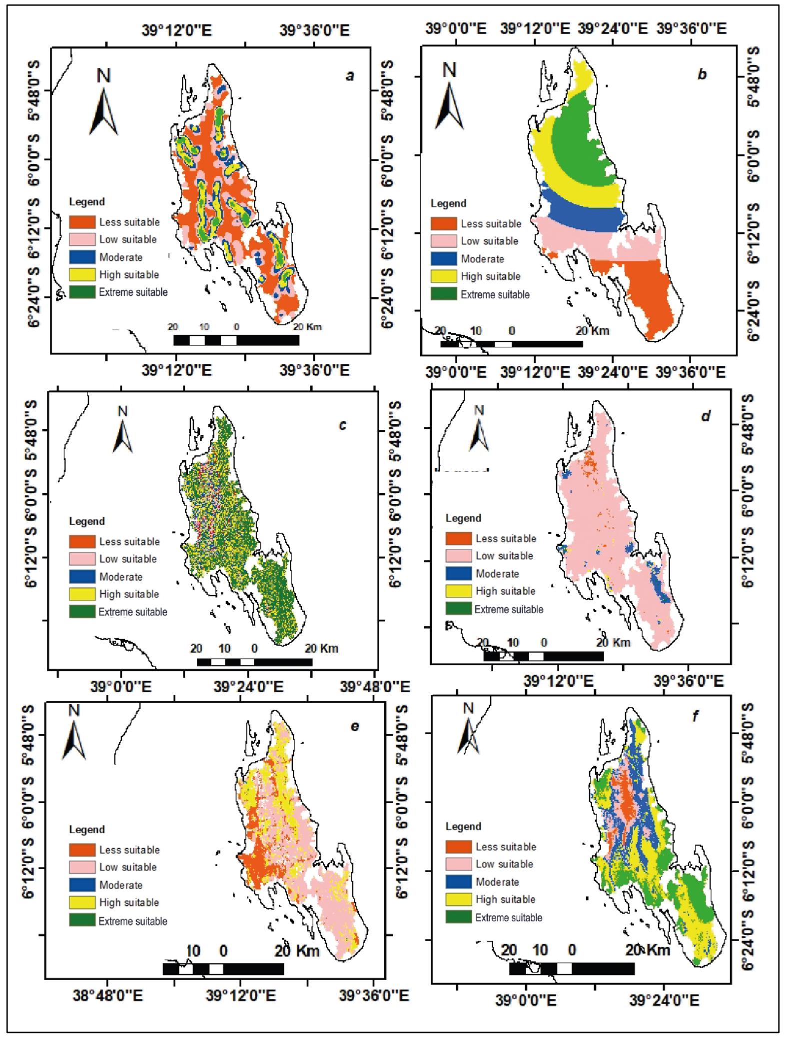
Plate 2. Indigenous approaches for storing and preserving the quality of rainwater

Source: Photographs taken by the research team

7.4 Potential sites for surface RWH

Identification of potential sites for in-situ RWH in Unguja entailed analysis of multiple supporting parameters that influence their suitability. As described in the methodology, these parameters include slope, soil texture, drainage density, annual average rainfall, land use and land cover, elevation and stream order. Each of these parameters influence the selection of RWH sites as illustrated in Figure 21 where data for the different parameters were used to assess suitable sites. The results, as presented in Figures 22 and 23, indicate a positive outcome, as it was noted that no sites in Zanzibar were entirely unsuitable for RWH. The study found that 20 percent of the selected catchments within the study area have low suitability for RWH, implying challenges related to insufficient rainfall, poor drainage, flat terrain and a high concentration of settlements and artificial modification of landscapes, which make these areas less ideal for efficient rainwater collection. A further 60 percent of the selected catchments were moderately suitable for implementing RWH. These sites are largely located in the southeastern part of Magharibi B district and the western part of Kati district. Areas with high RWH potential (19 percent) are mainly located in the northern part of Magharibi A and Kati district. These areas are considered high-potential sites due to the availability of high rainfall, good water retention capacity, and minimal barriers to infrastructure development, such as settlements.
In addition to the spatial analysis, these potential sites were verified through field visits. Community members and local stakeholders living in these locations generally confirmed the suitability of areas identified as "highly suitable", noting that these areas are sites for many other water-related projects due to their reliable rainfall and relatively open landscapes.

Figure 21. Maps showing input data to the model



Note: From top left to bottom right, the maps depict: a) Drainage density; b) Rainfall; c) Slope; d) Soil texture; e) Land use/Land cover; f) Elevation

FIGURE 22. POTENTIAL SITES FOR IN-SITU RWH

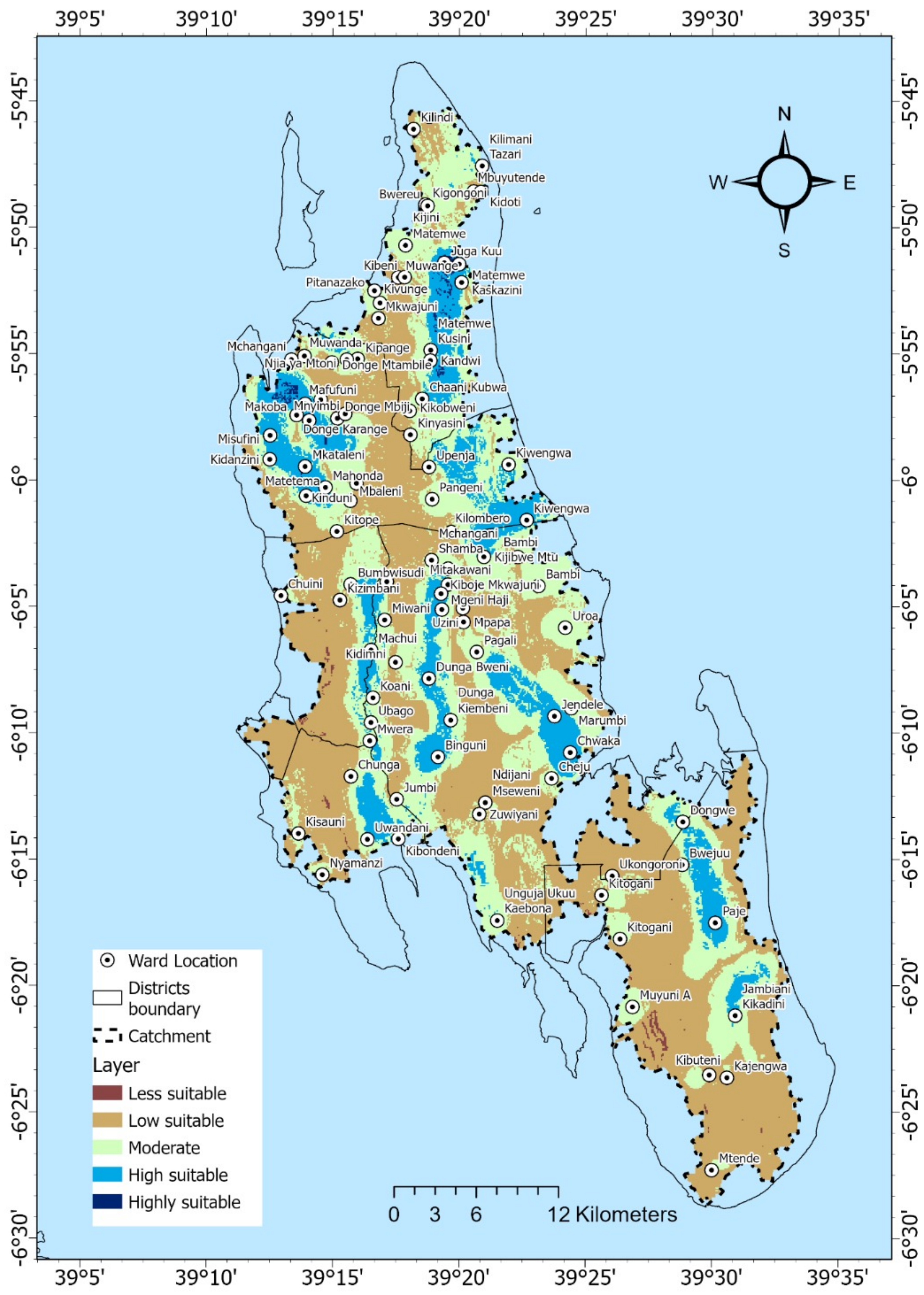
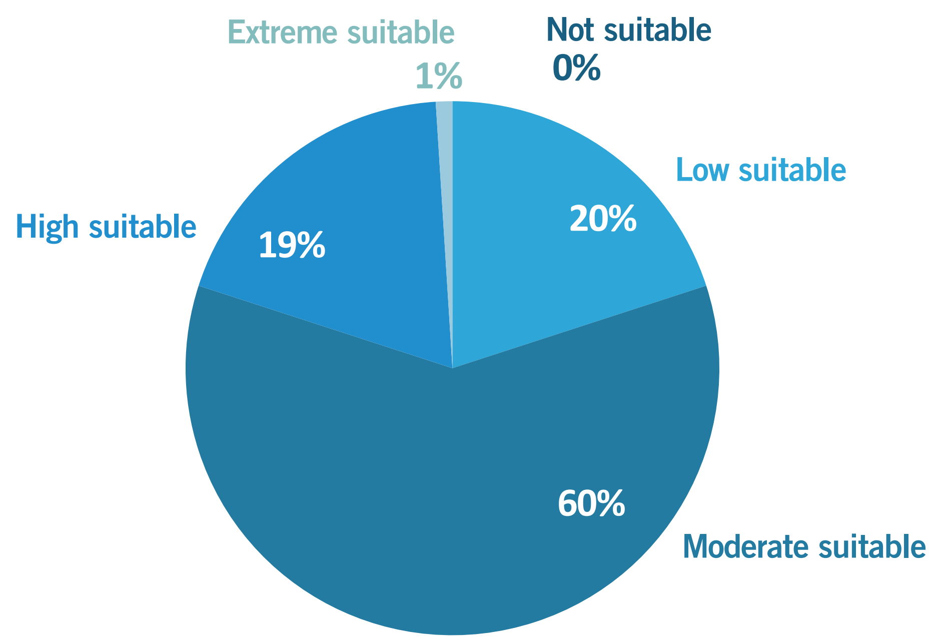


FIGURE 23. SUITABILITY OF POTENTIAL SITES FOR RWH



7.5 Existing policy, legal and institutional landscape for RWH

7.5.1 The policy landscape

Zanzibar's policy framework demonstrates a growing recognition of rainwater harvesting as a critical tool for addressing water scarcity and enhancing climate resilience. The newly launched 2025 Zanzibar Water and Sanitation Policy (RGoZ 2025) explicitly highlights the significant loss of surface runoff (36 percent in Unguja; 52 percent in Pemba) and advocates for RWH to support social and economic activities. It also calls for cross-sectoral collaboration between water and other sectors to regulate water use and prevent groundwater depletion. Similarly, the Environmental Policy (2013) identifies RWH as a key strategy for climate adaptation, explicitly mentioning rainwater harvesting technologies under its implementation strategies. The Agricultural Policy (2002) takes a slightly different approach, focusing on private sector driven innovations for water harvesting and storage, though it also acknowledges the challenges of rainwater loss due to unused surface. Strategic national frameworks such as the Zanzibar Development Vision 2050 and the Zanzibar Development Plan (ZADEP) 2021-2026 further highlight RWH as a priority (RGoZ 2020, 2022b). The Development Vision has included RWH under its aspiration on diversifying water sources, linking to climate resilience and institutional strengthening. The Development Plan goes a step further, outlining specific actions on developing rainwater harvesting infrastructure as part of its strategic interventions. However, despite these positive strides, the policy landscape remains largely aspirational. Policies lack actionable details, such as timelines, budgets or technical standards, and hence portray RWH as a theoretical solution rather than a practical one. For example, while ZADEP mentions RWH infrastructure, it does not specify how such projects will be funded or implemented.

A notable gap in the policy landscape is the Zanzibar Investment Policy (2007), which does not mention RWH. This omission represents a missed opportunity to align investment priorities with sustainable water management goals. Without financial incentives or targeted investments, RWH initiatives are unlikely to gain traction, particularly in rural areas and low-income communities where the need is greatest.

7.5.2 Institutional setup for management of RWH

The institutional framework for RWH in Zanzibar is characterized by fragmentation and overlapping mandates. Multiple institutions are involved in water management, but their roles are not clearly defined, leading to inefficiencies and gaps in implementation. The Ministry of Water, Energy and Minerals is the principal body responsible for water resources management while providing clean and safe water supplies in Zanzibar, including through RWH. The Ministry of Agriculture is also tasked with integrating RWH into irrigation schemes and agricultural practices. Local government authorities (LGAs) also play a role, particularly in the context of the Development Vision 2050, which emphasizes institutional strengthening at the local level.

However, this multi-institutional approach suffers from a lack of coordination. For instance, the ministries responsible for water and agriculture are both mandated to promote RWH, but no formal mechanisms are in place to harmonize their efforts. This overlap creates confusion and dilutes accountability, as neither ministry takes full ownership of RWH implementation. Enforcement is another critical issue. Although the Environmental Policy includes a strategy to enforce water-related laws, no dedicated institution or framework has been established to monitor compliance or penalize non-adoption of RWH. This lack of enforcement undermines the effectiveness of existing policies and leaves RWH initiatives reliant on voluntary participation, which is often insufficient to drive widespread adoption.

7.5.3 Gaps in legal and institutional frameworks

Despite RWH being mentioned in most policies, the strategies outlined for RWH are often not clear or specific. For example, the Water Policy highlights the need for RWH but does not provide technical guidelines or standards for implementation. Similarly, ZADEP calls for RWH infrastructure development but does specify how such projects will be funded or executed. The absence of responsible mandates and actionable targets further weakens the policy framework, leaving RWH as a low-priority initiative.

In addition, no specific laws or regulations govern RWH systems, such as permits for installation or water quality standards for both roof and surface RWH. This regulatory vacuum leaves households and institutions without clear guidance on safe and efficient RWH practices. Moreover, frameworks like the Development Vision 2050 lack the legal authority for enforcement, rendering their RWH related aspirations largely symbolic.

The overlapping mandates of the ministries responsible for water, agriculture and other sectors create confusion and inefficiency, with no institution taking full responsibility for promoting RWH. The absence of a centralized authority to oversee RWH integration across sectors further exacerbates this issue. LGAs are also underutilized, as their roles in implementing RWH initiatives are not clearly defined or supported.

The lack of technical guidelines for designing, installing and maintaining RWH systems is a major barrier to adoption. While the Agricultural Policy encourages private sector innovation, it provides no public sector technical support, leaving farmers and communities without an accessible pool of technical knowledge. Financial incentives are also absent, with no subsidies, grants or fiscal mechanisms to encourage RWH adoption. This reliance on private sector solutions is a risk to low-income households and communities that can afford traditional RWH systems but cannot afford modern technologies.

Public awareness of RWH's benefits and implementation methods also remains limited. Although the Environmental Policy mentions "public awareness on sustainable water use", the study found no evidence of structured education campaigns or community-led initiatives to promote RWH. Without grassroots engagement, households are unlikely to adopt RWH practices, even if the technical and financial barriers are addressed.

8 Conclusion

This study provides a comprehensive analysis of the state of rainwater harvesting in Unguja Island. The results underscore that despite a high level of awareness on RWH in Zanzibar, implementation and adoption of RWH is relatively low. The study identified several factors affecting the adoption of RWH as an alternative source of water. These included financial constraints, inadequate technical expertise, insufficient storage capacity and cultural perceptions on RWH. Affordability of RWH was viewed through two lenses. First, affordability was linked to storage capacity, as many households seemed to lack the financial capacity to install long-term and large water storage tanks, leaving the majority to rely on temporary storage, such as buckets. Second, affordability was linked to the types of RWH, with rooftop harvesting being the predominant method in Zanzibar. Many households indicated that traditional rooftop RWH is affordable, and the majority integrate it with indigenous knowledge, such as reuse of iron sheets to build RWH collection tools. Many households also indicated that traditional RWH is effective despite storage limitations.

The study found that the issue of affordability becomes a concern when modern RWH or surface RWH methods are considered. Respondents also identified limited technical capacity at both institutional and household level as a barrier inhibiting efficient implementation of RWH. The lack of standardized national guidelines for RWH system design, installation and maintenance leaves both institutions and households without the necessary technical guidance on adoption of sustainable RWH practices. In addition, the absence of financial incentives—such as subsidies, grants or public-private partnerships—limits access to RWH technologies, particularly for low-income communities, such that many households resort to traditional RWH practices. The study concludes that streamlining RWH within national frameworks, strengthening the technical capacity of local technicians in operation and maintenance of RWH systems, and integrating indigenous knowledge and beliefs into RWH programmes will be essential to enhance community acceptability, ownership and adoption of rainwater harvesting.

The study noted that existing policies and regulations in Zanzibar, including the Water and Sanitation Policy (2025), Environmental Policy (2013) and Agricultural Policy (2002) have provisions related to RWH as a mechanism to mitigate water insecurity. However, significant gaps remain in implementation, technical guidance, financial support and institutional coordination. This institutional fragmentation impedes efficient implementation of RWH. The study also identified overlapping mandates between the Ministry of Water, Ministry of Agriculture and other stakeholder institutions, which exacerbates the existing inefficiencies and undermines accountability. Despite being well-positioned to facilitate community-based RWH initiatives, local government authorities remain underutilized due to unclear roles and limited technical capacity. This study concludes that the lack of a centralized, mandated body overseeing RWH integration hinders efficient implementation and exacerbates cross-sectoral and multi-stakeholder coordination in expanding RWH to enhance water security in Zanzibar.

9 Policy implications and recommendations

Based on the findings, the study identifies the following strategic interventions to enhance the implementation and adoption of RWH as an alternative water source in Zanzibar:

1. Develop a national guideline that establishes technical standards for RWH, including system design at both household and community levels. This includes, among other things, reviewing policies related to construction to prioritize the establishment of RWH systems in public buildings. While the present study primarily focused on household RWH systems, policy reviews highlighted the importance of extending RWH infrastructure to public buildings such as schools, health facilities and administrative centres. These institutions often serve as water access points for surrounding communities, particularly during dry seasons. Incorporating public buildings into RWH policy and construction standards would therefore complement household-level adoption and enhance community-wide water security.

2. Establish a dedicated inter-ministerial RWH coordination platform to harmonize efforts across ministries

3. Enhance accessibility and affordability of modern RWH technologies, particularly for low-income households. Potential mechanisms could include targeted subsidies or tax incentives for RWH equipment, and establishment of public-private partnerships for RWH initiatives

4. Improve public awareness and capacity building through structured education campaigns to enhance public knowledge of RWH benefits and best practices. This will include strengthening local technical capacity in the operation and maintenance of RWH systems to ensure their long-term functionality and sustainability.

5. Incorporate provisions related to RWH in the Zanzibar Investment Policy (2007) to prioritize investments in RWH initiatives for sustainable development. This will require the establishment of clear funding strategies and implementation guidelines for key stakeholder institutions, especially the ministries responsible for water and agriculture.

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Annexes

Appendix 1. List of stakeholder institutions participating in key informant interviews

Stakeholder	
Government ministries, departments and agencies	Ministry of Water, Energy and Minerals
	First Vice President's Office (FVPO)
	Zanzibar Environment Management Authority (ZEMA)
	Ministry of Tourism and Heritage
	Ministry of Agriculture, Irrigation, Natural Resources and Livestock
	Ministry of Health
	Ministry of Education
	Zanzibar Water Supply Authority (ZAWA)
Academic institutions	State University of Zanzibar (SUZA)
Development partners	UNICEF
	UNDP
	Food and Agricultural Organization (FAO)
Private sector	Industries – Drop of Zanzibar and Lulu Water
	Hotels - Golden Tulip Airport Hotel

Appendix 2. Sample size estimation for household survey

Districts	Population	Estimation	Minimum sample size	Recommended sample size	No. of shehia	Selected shehia	Final number of households
Kaskazini A	157,369	12%	47	67	4	• Kiungani • Fukuchani • Mkwajuni • Gamba	67
Kaskazini B	99,921	7%	30	50	4	• Mkataleni • Kinduni • Mahonda • Kwagubwe	50
Kati	132,717	10%	39	59	4	• Tindini • Bambi • Binguni • Mchangani	59
Kusini	63,156	5%	19	39	3	• Bwejuu • Paje • Jambiani • Muungoni	39
Magharibi A	329,645	24%	98	118	7	• Kijichi • Mtoni kidatu • Mbuzini • Mwera • Kizimbani • Kianga • Bububu	118
Magharibi B	344,517	26%	102	122	8	• Fumba • Kijitoupele • Mikarafuni • Pangawe • Bweleo • Kiembesamaki • Chukwani • Mwanakwerekwe	118
Mjini	219,007	16%	65	85	5	• Kilimani • Kwamtipura • Mkunazini • Mwembemakumbi • Mlandege	85
Total	**1,346,332**	**100%**	**400**	**540**	**35**		

At 95% confidence level (Z = 1.96) and a margin of error of 5% (E = 0.05), and maximum variability (p = 0.5)

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