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Enhancing Rainwater Harvesting for Water, Food, and Health Security in Kenya

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Kenya Institute for Public Policy
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Abstract

Adoption of rainwater harvesting technologies has been low at household and community levels in Kenya. Besides, rainwater harvesting and storage is one of the strategies earmarked towards water security. The study provides evidence that rainwater harvesting promotes water and food security but fails to support the likely incidental effect on waterborne health risks. It reveals that adoption of rainwater harvesting technology increases with household wealth, time taken to collect water, amount of rainfall, age of household head, female gender as head of household, and post-secondary education. However, rainwater harvesting decreases with water demand, household size, rented dwellings, urban areas, employed heads of household, and number of roundtrips. Further, distance to water sources and marital status were not significant. The study recommends mandatory requirement of rainwater harvesting systems in all rental housing plans, investment in rainwater harvesting research, development, and innovations to establish appropriate domestic rainwater harvesting technologies that can serve large-sized and poor households for their high demand for water and limited ability to buy. Further, the selection criteria for potential adopters may consider household characteristics, rainwater technology characteristics, and water water-specific characteristics representing climatic and ecological factors.

Abbreviations and Acronyms

EF	Expected Frequency
KNBS	Kenya National Bureau of Statistics
NWHSA	National Water Harvesting and Storage Authority
RWHS	Rain Water Harvesting System
RWHT	Rain Water Harvesting Technology
WHO	World Health Organization

Table of Contents

List of Tables

1. Introduction

Harvesting and storage of rainwater is one of the interventions identified in Kenya as a means of enhancing water availability for various water uses, including domestic, agricultural, and industry (Government of Kenya, 2007; 2016). Rainwater harvesting technology entails three key processes: capturing, conveyance, and storage. At the household level, rainwater harvesting from rooftops is the most common technology while the use of dams and water pans are common technologies for shared water points among community initiatives. However, not the entire population has proactively adopted advanced rainwater harvesting technologies, thus not enjoying the benefits of rainwater harvesting. Increased harvesting of rainwater enhances the attainment of water security through the ease of access to improved and adequate water for all. The level of adoption of rainwater technologies has been low at both household and community levels, with less than one (1) per cent of Kenyans identifying rainwater as a primary source of drinking water (KNBS, 2013), which translates to less than 10 per cent of the households. This poses a critical policy question as to why rainwater harvesting technology has only been adopted by a small number of the population.

The National government and County governments have put in place strategies to enhance rainwater harvesting through the projects identified in the Medium-Term Plans and County Integrated Development Plans, which include the construction of dams and water pans as major infrastructure for harvesting rainwater. However, the rate of completion of the projects is low, which impedes the achievement of the planned water harvesting capacity of 16m^3 per capita by 2030 (Government of Kenya, 2007). Kenya's Vision 2030 articulates that water storage capacity can be enhanced through increased investment in the storage infrastructure and the development of innovative community-based methods and technologies. The Vision also provides for capturing and storing run-off water from tin roofs in rural areas and intensifying catchment methods for ground run-off water. The plan was to develop two major multipurpose dams with a storage capacity of 2.4 billion m^3 and 22 medium-sized dams with a storage capacity of 22 billion m^3 for the supply of water for domestic, irrigation, and livestock.

The Water Act 2016 (Government of Kenya, 2016) established a National Water Harvesting and Storage Authority (NWHSA) for the purpose of enhancing water harvesting and storage through the development of a water harvesting policy and enforcement of water harvesting strategies. The Authority mainly focuses on harnessing rainwater, especially for medium and large activities among other projects. However, the policy framework should also be supportive of rainwater harvesting at household and small-scale levels. In its strategic plan for 2022-2027 (NWHSA, 2021), the NWHSA acknowledges that the average annual rainfall in Kenya is 630mm, varying from less than 200mm in Northern Kenya to over 1,800mm on the slopes of Mt Kenya and that Kenya has low water endowment at 647m^3 per capita, which is below the global benchmark of 1,000m^3 per capita. It further indicates that the country targets to establish a storage capacity of

16m^3 per capita by 2030, up from 5.3m^3 per capita in 2010, which translates to increasing the capacity from 124 million cubic metres to 4.5 billion cubic meters, given the projected increase in population by 2030. However, all these initiatives concentrate on government interventions to store water, with little effort being made to promote household rainwater harvesting.

The country has also developed regulations on water harvesting where the government is expected to establish incentives to enhance rainwater harvesting by the public (Government of Kenya, 2019). The regulations seek to facilitate the provision of technical and capacity building support on rainwater harvesting techniques to the public and private institutions at national and county levels, and enforce a requirement that buildings shall have their roofs adequately guttered for rainwater harvesting or establish ground catchment for rainwater harvesting. The policy also allows for a person to directly capture and store precipitation on a parcel of land owned or leased by the person with a maximum capacity of not more than 10,000 litres.

Water security is essential in improving the socio-economic status of households and communities. Therefore, the population should use the available sources of water effectively and efficiently. One such source is rainwater, which is least tapped in Kenya with less than one (1) per cent of the population and less than 10 per cent of households identifying it as the main source of water for drinking. This respectively disaggregates to only 0.8 per cent and 0.5 per cent of the population in rural and urban areas using rainwater as their main source (KNBS, 2013). To improve water security in the country, the population needs to enhance rainwater harvesting, especially in semi-arid regions. Rainwater harvesting can offer short-term and long-term solutions to water security depending on the size of the rainwater harvesting system, precipitation, and frequency of rain.

Kenya's Vision 2030 (Government of Kenya, 2007) recognizes that water insecurity is a major challenge that emanates from low water resource availability and is aggravated by inadequate water harvesting. It also indicates that there are differentials across the country in the availability of water during rainy and dry seasons. The Vision considers rainwater harvesting as a panacea to improving agriculture productivity, which is constrained by over-dependence on rain-fed agriculture, and identifies effective water harvesting and storage facilities as a strategy towards water security.

The central problem is that the low adoption of rainwater harvesting technology reduces the availability of water, which increases levels of water deprivation. Access to safe water was estimated at 59 per cent in Kenya by 2019, leaving over 40 per cent of the population exposed to water-related challenges, including waterborne diseases, long distance walking in search for water, deprivation of education to girl-child charged with the responsibility of fetching water, high water prices, among others. In addition, limited harvesting of rainwater increases run-offs and floods, which have devastating consequences such as death, traffic congestion, and destruction of property. Floods clog the drainage system, destroy roads, and pose health risks. They also threaten biodiversity. Similarly, the high surface run-off leads to soil erosion, thereby threatening agriculture productivity and food security, besides reducing the groundwater recharge. Harvesting of rainwater can minimize these problems by encouraging each household to collect, capture, and store rainwater from the roofs and by digging small water pans per compound to increase water availability and reduce the effect of floods and environmental degradation. At the community level, water dams or pans using land surfaces to capture rainwater can also enhance water availability and play a role in the minimization of conflicts emanating from water disputes. Kenya experiences two seasons of rain annually and proper harvesting and storage of rainwater has the potential to mitigate the effects of dry season, which is associated with crop failure and death of livestock.

There have been limited initiatives to research on rainwater harvesting by households in Kenya. Besides, such studies have limitations with respect to focus, coverage, and scope. For instance, Jack et al. (2016) focused on access to credit for rainwater harvesting. Kimani et al. (2015) and Ahmed et al. (2013) limited their analysis to Makueni County and Yatta District, respectively. Further, Kimani et al. (2015) focused on rainwater technologies used as opposed to factors affecting the adoption, while Ahmed et al. (2013) focused on technologies and factors affecting adoption but from farmers' perspective. This leaves research gaps in terms of countrywide coverage and the utilization of rainwater by all households. There is also no research that has investigated linkages with water security, food security, and health risks. It is significant to respond to the question of why the adoption of rainwater harvesting technology is low in the country from a countrywide perspective, and by creating a case for the relevance of rainwater from a policy perspective. Specifically, this study seeks to explore the factors that explain the adoption of rainwater harvesting technology among households and communities in Kenya, and the gains that accrue from the adoption by assessing the relationship between rainwater harvesting and water security, together with the effects on food and health outcomes in Kenya. The findings of the study will inform the policy framework to create a conducive environment and promote water harvesting and storage strategies, especially to be successful among households and communities.

2. Literature Review

2.1 Theoretical Literature

2.1.1 Rainwater Harvesting Theory

The theory builds on rainwater harvesting technology, which involves the collection of raindrops into a storage facility through a channel of conveyance (Liaw and Chiang, 2014). At the domestic level, the amount of rainwater collected depends on several factors that can be categorized as building characteristics, economic, climatic, and ecological factors (Liaw and Chiang, 2014). The authors relate building characteristics with roof area, run-off coefficient, and storage capacity, while investment cost on rainwater systems, rainwater demand, and water collection efficiency represent economic factors, the level of precipitation and downstream impact represent climatic and ecosystem factors. This can be expounded to rainwater harvesting at the community level where these set of factors can be modified where precipitation and topography can represent climatic conditions, but surface area characteristics can substitute buildings characteristics to define the run-off rate, while investment in storage capacity can represent economic factors. Ecological factors come in as a moral factor where the decision on the amount of rainwater to be collected upstream would be considered as a deprivation and cost of access of water for the downstream users, and the groundwater recharge.

The size and design of the capturing surface, conveyance infrastructure, and storage capacity determine the amount of water to be harvested. The common collection technologies are rooftops and land surfaces, where large surface areas capture more rainwater. The common conveyance technology is gutters or trenches, where the surface area and gradient determine the flow rate of rainwater. The types of storage technologies include water containers, tanks, pans, and dams, all of which can vary in terms of structural design and volumetric capacity. Rainwater harvesting systems also consider economic and environmental dimensions, where economic perspectives determine the scale of the designs to respond to the affordability question while environmental factors determine the structure of the design to cater for water collection efficiency and management of its quality. Therefore, besides the engineering design, there are other factors that determine rainwater harvesting decisions and potential, including the socio-economic characteristics of a household or community and the climatic factors such as precipitation and temperature and ecological factors such as soil type and topography.

2.1.2 Consumer Theory

Rainwater harvesting is one of the choices that households may have based on the various sources of water at their disposal. Through the concept of utility maximization, consumer theory can help in understanding how individuals make such choices based on the level of satisfaction or value they would derive from the consumption of the choices they make. Consumer theory structures a framework on which a rational consumer makes consumption decisions, defined by certain prices and the consumer's income or wealth, by posing a consumer problem of seeking to maximize utility subject to a budget constraint (Levin and Milgrom, 2004). Such decisions are largely based on the consumer's preferences for the good or service and the prevailing market dynamics, including quantity, quality, and prices.

Rainwater harvesting enhances water availability for households, communities, and businesses, and this defines the utility variety and bundles through its use for domestic or agricultural purposes as well as for industrial use including hydropower and construction. Water choices can vary in terms of quantity and quality, which determine both the preference, use, and cost. Therefore, it is expected that households with higher income levels will have higher affinity and thus higher demand for rainwater systems and that these households should also show inverse preferences for rainwater systems with respect to changes in prices. However, there are other factors other than price and income which determine the quantity of a good a household will be willing to buy. The optimal demand function for a good or service will, therefore, fundamentally rely on the prevailing price and income of the household. Besides the direct cost that defines the price of water, there are pseudo costs and opportunity costs arising from the distance travelled to obtain water and trade-offs for water collection time, which may include time to be spent for social or economic activity. Therefore, this theory presents critical indicators to investigate if they have any influence on rainwater harvesting.

2.2. Empirical Literature

2.2.1 Factors affecting rainwater harvesting

Several factors have been empirically investigated on their influence on the adoption of rainwater harvesting technology or the willingness to pay for its acquisition. Some of these factors include distance to water sources, quality of water, household economy, the age of water carrier, and opportunity costs and direct costs as indicated by Lanka Rainwater Harvesting Forum (1999). Other factors are water demand, age and education of the household head, the experience of water shortage or crisis, awareness of water technology, farm size, household size, and household income (Kimani et al., 2015; Jeyakrishnan and Umashankar, 2015; Ahmed et al., 2013 and Baiyegunhi, 2015). Other studies (Baiyegunhi, 2015; Zingiro, Okello and Guthiga, 2014; and Kimani et al., 2015), also investigated the effect of membership to associations or groups and land ownership on rainwater harvesting, while others investigated the role of gender in rainwater harvesting (Baiyegunhi 2015; Kimani et al., 2015; Zingiro, Okello and Guthiga, 2014; Mume, 2014; and Amoah and Adzobu, 2013).

It is expected that education increases the capacity to adopt technology through increased awareness and income. This was confirmed in various studies where the level of education was found to be significant and positively influencing the adoption of rainwater harvesting systems - RWHS (Ahmed et al., 2013, Baiyegunhi, 2015;

Kimani et al., 2015; Jeyakrishnan, 2015 and Mume, 2014). Amoah and Adzobu (2013) found that higher willingness to pay for RWHS would be associated with respondents who were educated and employed in Ghana. However, some studies for example Pasakhala (2013) for Nepal and Zingiro, Okello and Guthiga (2014) for Kenya did not find education as a significant factor in explaining the adoption of RWHS, which could have been attributed to the fact that education has the potential to make households use alternative water sources such as piped water and groundwater. This is because education increases the ability to afford such technologies; however, the same studies show that income has a positive effect on rainwater harvesting. In addition, the question of preference and availability of water options comes into play as Pasakhala (2013) results show the significance of education in purchasing water and using groundwater in Nepal.

Income is critical in explaining the adoption of rainwater technology, since it boosts the willingness and ability to pay. There seems to exist a common finding that the adoption of RWHS is significant and positively correlated with the income of households, as supported by the studies by Ahmed et al. (2013), Baiyegunhi (2015), Kimani et al. (2015), Jeyakrishnan (2015), Mume (2014), Pasakhala (2013), and Zingiro et al. (2014). This provides a case for investment in lending to households to acquire the RWHS as one way of boosting their incomes, whereas low-income households can increase the uptake of RWHS by taking microfinance loans. This is because low-income households may be associated with non-adoption. However, this needs assessment of the household willingness to take and pay for RWHS loans, though Amoah and Adzobu (2013) found this to be insignificant in explaining the willingness of a household to pay for the adoption of rainwater harvesting technology in Ghana. In addition, Jack et al. (2016) found that though a large proportion (42%) of farmers were willing to borrow money to purchase a water tank, a small proportion (6%) had borrowed loans for rainwater tanks because of the structure of the loans which did not collateralize the loan with the tank and the down deposit, which was relatively high.

The age of the household head has mixed results. Whereas Pasakhala et al. (2013) and Mume(2014) found it to be positively related with the adoption of RWHS in Nepal and Ethiopia, respectively, Baiyegunhi (2015) and Kimani et al. (2015), on the other hand, found it to be negatively correlated in South Africa and Kenya, respectively. Further, Jeyakrishnan (2015) found it to be insignificant in the case of Sri Lanka. The effect of the age of the household head is therefore indeterminate, which can be explained by the fact that age can be overrun by variations of other factors such as education and income.

Water demand would necessitate the uptake of rainwater. The level of water consumption is also dependent on the household size, thus most likely to influence the adoption of rainwater harvesting technology. Adoption of RWHT is significantly and positively explained by household size in various studies (Pasakhala, 2013; Jeyakrishnan, 2015; and Zingiro, Okello and Guthiga, 2014). However, Kimani et al. (2015) found contradicting results where household size is significant but negatively related with the adoption of RWHT. Other studies such as Baiyegunhi (2015) and Mume (2014) did not find the variable household size to be significant in explaining RWHT. Further, Amoah and Adzobu (2013) found that households with a higher proportion of minors had a higher willingness to pay for the adoption of rainwater harvesting technology. Such inconsistencies in correlating household size with the adoption of RWHT may be a pointer to the effect of poverty since large-sized households are more likely to be poor due to high dependency levels.

Economic activities that depend on water, for example agriculture are expected to encourage rainwater harvesting and this can be assessed through farm size, adoption of irrigation, or rearing of livestock. Farm size similarly had mixed results in explaining the adoption of RWHS. Households with bigger farms were found to have a higher affinity to adopt RWHT in the studies by Jeyakrishnan (2015), Kimani et al. (2015) and Mume (2014). On the other hand, Ahmed et al. (2013) indicated that there was an inverse relationship, while Pasakhala (2013) and Zingiro (2012) did not find farm size to be significant. Livestock is expected to boost the need for adopting a variety of water sources, since the consumption of water is higher. The incentive to take loans for rainwater harvesting technology was higher for dairy farmers than for non-dairy farmers (Jack et al., 2016).

Households travelling long distances to fetch water may have an incentive to adopt rainwater harvesting due to the burdens such as time loss and associated opportunity costs. Such an indicator may correlate with the time taken to collect water and the number of roundtrips taken per day. Though Kimani et al., (2015) showed that distance from a water source is significant and positively correlated with the adoption of RWHS, Ahmed et al. (2013) and Baiyegunhi (2015) found no significant relationship.

Female gender is often associated with water issues, but with respect to the adoption of RWHS, mixed results emerged. Households headed by males were higher adopters of RWHS (Baiyegunhi, 2015). On the contrary, Kimani et al. (2015) found households headed by females to be higher adopters. Interestingly, in the studies by Zingiro, Okello and Guthiga (2014) and Mume (2014), gender was insignificant. Further, Amoah and Adzobu (2013) did not find gender variables to be significant in explaining the willingness to pay for rainwater harvesting technology. The female gender is likely to make rainwater harvesting decisions more consciously than the male counterpart because of their experiences in collecting water.

There are generally consistent results across surveys in associating the uptake of rainwater harvesting with the social orientation or interaction of the household head. If any member of a given household belongs to a specific social group, such a household has a higher chance of adopting RWHS than those without any member in any social grouping. This has been supported by Baiyegunhi (2015), Kimani et al. (2015) and Zingiro, Okello and Guthiga (2014). Nevertheless, Jack et al. (2016) demonstrate that group lending mechanisms may require a balance between individual liability and group liability since a loan structure of a 25:75 ratio of individual liability to group collateralization, respectively, on the amount of money borrowed had a higher rate of repayment than a 0:100 ratio.

2.2.2 Effects of rainwater harvesting on water, food and health

Bitterman (2016) asserts that water security describes the multidimensional linkages between human well-being and water access and availability. The study provides a framework for assessing water security from the rainwater harvesting dimension, which includes planted area, the volume of water collected using groundwater wells, hydrology using precipitation and evaporation and groundwater recharge, income levels through crop prices and incomes, agricultural productivity or yield, tank functionality in terms of capacity, structural stability and diversity in use, social equity through the number of farmers irrigated, health and nutrition, among others. Akiyemi, Afolabi and Aluko (2022) found that 52 per cent of households in Nigeria had a higher water insecurity intensity score by crossing the 50th percentile mark during the dry season compared to 12 per cent of households during raining season.

Rainwater harvesting has the potential of increasing agricultural productivity and households can use the yield to address food insecurity and raise income to reduce poverty levels. Rain-fed agriculture is critical in addressing declining food productivity and access. Wubetu (2020) presents that food security can take different perspectives, including physical availability, economic access, food utilization, and stability of food markets, where physical availability relates to quantities that have been produced or imported and which are physically reachable, while economic access means the ability to afford the food, as utilization relates with quality of the food with respect to nutrient value, and stability of the food market represents predictability of the three components. This provides a ground for one to use the income to approximate food security from the economic perspective, especially when the data on food availability is not readily available. Mume (2014) used income, expenditure, and consumption to approximate food security levels in the absence of data on food consumption by associating the observed behaviour with the minimum subsistence requirement and found rainwater harvesting having a positive effect on the income and food expenditure or consumption of households in water stress areas of Eastern Haraghe in Ethiopia (Mume, 2014). In addition, Makau et al. (2014) found that farmers in Kitui West in Kenya depended on rainwater harvesting to undertake farming and that 60 per cent of the households depended on their farms for food while 40 per cent purchased their foods from the market, with 96.8 per cent indicating that drought is the key factor causing food shortage and 61.4 per cent believing that rainwater harvesting would be a game changer.

Bitterman et al. (2016) relate water security with social equity where health and nutrition are a key indicator. Whereas rainwater harvesting may be associated with water security and by extension good health, Khayan et al. (2019) found that air contamination causes rainwater to become acidic and cloudy and adds heavy metals such as lead into rainwater, which increases health risks. The World Health Organization holds that rainwater is of higher quality source than surface water. It however recommends appropriate disinfection or treatment where there is a risk of contamination, and this can be achieved by ensuring safe storage and handling, and using chlorination, boiling, solar disinfection or any other suitable household water treatment option (WHO, 2020a and 2020b). This provides a bidirectional nexus between rainwater and health, since though it is regarded as being safe, air pollution and mismanagement may increase the risk of contamination, thus leading to health risks. It is, therefore, important to assess the status of rainwater harvesting with health risks in Kenya.

2.3 Overview of Literature

Consumer and rainwater harvesting theories lay a solid foundation for understanding household behaviour with respect to water demand and the adoption of technologies for collecting rainwater. For instance, consumer theory provides a reliable link through which rainwater can be viewed as a commodity in the market accessible at a price and depending on household income. Rainwater harvesting theoretical arguments extend the space of factors that determine the consumption of rainwater, including other household characteristics, ecological factors, and other market dynamics such as the existence of alternative water sources. Mixed results are witnessed among the factors thought to be influencing rainwater harvesting decisions, with significant factors being the age, education level, gender, income level, and group membership of the household head and farm size, household size, and distance to water sources or the existence of alternative water sources. This calls for continued investigation of these factors with a view to ascertaining the causes of the inconsistencies. Some of the usual suspicion is on the quality of data, structure of the variables, model specification, and interactive nature of the various factors.

3. Methodology

3.1 Theoretical Framework

The study modified a model by Baiyegunhi (2015) presented in equation 3.1, which links the adoption of rainwater harvesting systems (RWHS) with socio-economic factors. In equation 3.1, U_{ij} represents the utility obtained by a household (*i*) for making choice (*j*) on the adoption of RWHS, X_{ij} are socio-economic factors, while *i* (*1…n*) and *j [0,1]* represent the range of households and the choices on the adoption, respectively.

$$U_{ij} = X_{ij}\, a_j + \varepsilon_j \quad \text{......} 3.1$$

To derive the demand function for RWHS, the study integrated the price of RWHS and the income levels of households by assuming that a household seeks to maximize the utility of water *(U)* by consuming different sources of water. For simplicity, it is assumed that the two sources of water are rainwater (R) and surface water (S). Therefore, the utility space for water that a household seeks to maximize can be presented as *U (R, S)*. Following the utility optimization process, households seek to maximize *U (R, S)* by making rational decisions over water sources *R* and *S* while observing a budget constraint *(Y)* and facing respective prices *(Pr, Ps)* the consumption functions of *R* and *S* are derived as expressed in equation 3.2. The optimization process observes *Max*_U (R,S) as the objective function subjected to $Y = P_r R + P_s S$ as budget constraint.

$$R = f(Y, Pr), \text{ and } S = g(Y, Ps) \quad \text{......} 3.2$$

An extension of equation 3.2 leads to theoretical model in equation 3.3, which the study used. The extended model has foundational factors, which are income and price, which can also be a vector depending on the dimensions of the proxies on incomes and prices. The extension factors include vectors of household characteristics (H) and water-specific characteristics (W) representing climatic and ecological factors, that the literature has shown to be influencing rainwater harvesting.

$$R = f(Y, P, H, W) \quad \text{......} 3.3$$

3.2 Analytical Framework

The study focused on factors that influence the adoption of rainwater harvesting systems (RWHS) at the household level. Following the literature and the modified equation 3.3, the study estimated equation 3.4.

$$RWHS = \beta 0 + \beta 1 Wall + \beta 2 Dwell + \beta 3 Roof + \beta 4\ Employ + \beta 5\ Distance + \beta 6\ Time + \beta 7 Rounds + \beta 8 Climate + \beta 9 Use + \beta 10 Size + \beta 11 Age + \beta 12 Gender + \beta 13\ Education + \beta 14\ Marital + \beta 15\ Area + \varepsilon \dots\dots 3.4$$

Where:

RWHS – represents an incidence of rainwater as a source of water for the household;

- Y (income) – which is proxied by wealth in the form of permanence of the dwelling represented by types of walling (Wall), roofing (Roof), and dwell ownership (Dwell) and employment status (Employ);
- P (price) – which is proxied by distance covered (Distance), time taken (Time), and number of roundtrips made for water collection (Rounds);
- W (water characteristics) – which is proxied by climatic conditions (Climate) and water demand (Use);
- H (household characteristic) – which is proxied by household size (Size), age of the household head (Age), gender variable represented by the household head (Gender), highest education of the household head (Education), marital status (Marital), and area of residence (Area).

Given that RWHS is a binary variable, the study used probability model as an estimation technique. It adopted a probit model as presented in equation 3.5. A Probit is adopted for its simplicity in the interpretation of results. Equation 3.5 presents P(RWHS=1|Z) as the probability that a household has a rainwater harvesting system, given some set of variables (Z) as specified in equations 3.3 and 3.4. The response function for $RWHS^*$ in equation 3.5 assumes that:

$$\text{RWHS} = \begin{cases} 1 & RWHS^* > 0 \\ 0 & Otherwise \end{cases} \quad thus\ \ RWHS = \begin{cases} 1 & Z'\beta > -\varepsilon \\ 0 & Z'\beta = 0 \end{cases} \quad \text{and } \varepsilon \sim N(0,\delta^2).$$

$$RWHS^* = Z\beta + \varepsilon \dots\dots 3.5$$

In addition, following Pasakhala (2015), the study adopted proportions analysis using relative frequency and chi-square test, given that the data under consideration was categorical. The chi-square test is adequate in exploring the relationship between two categorical variables, with a null hypothesis that the variables are independent of each other. The incidence of rainwater harvesting on water security and associated welfare effects in food and health were analyzed, using relative frequency between the categories in equation 3.6 and the chi^2 (X^2) estimated in equation 3.7, using the observed frequency (OF) and expected frequency (EF). Pearson's Chi-squared test statistic was used to confirm the significance of the results.

$$Relative\ proprotional\ frequency\ = \frac{Frequency\ of\ the\ case}{Total\ frequency\ within\ the\ category} \quad \ldots\ldots\ldots\ldots 3.6$$

$$X^2 = \frac{(OF-EF)^2}{EF} \quad \ldots\ldots\ldots\ldots 3.7$$

$$EF = \frac{(total\ of\ target\ category\ in\ variable\ 1 \cdot total\ of\ target\ category\ in\ variable\ 2)}{Population} \quad \ldots\ldots\ldots\ldots 3.8$$

For instance, in the case of technology adoption, it may be hypothesized that being a male or female household head does not influence decision making on the adoption of rainwater technology. The respective EF is specified in equation 3.8 (a-c).

$$EF(adopers\ being\ water\ secure) = \frac{(total\ of\ adapters\ \cdot\ total\ of\ water\ secure)}{Population} \quad \ldots\ldots\ldots\ldots 3.8a$$

$$EF(adopers\ being\ food\ secure) = \frac{(total\ of\ adapters\ \cdot\ total\ of\ food\ secure)}{Population} \quad \ldots\ldots\ldots\ldots 3.8b$$

$$EF(adopers\ being\ health\ secure) = \frac{(total\ of\ adapters\ \cdot\ total\ of\ health\ secure)}{Population} \quad \ldots\ldots\ldots\ldots 3.8c$$

It is assumed that water security is a pre-condition for food security and health security. To aid food security, water not only supports agriculture but is also used for cooking. The incidence of waterborne diseases is dependent on water security, yet water security is also partially tied to the adoption of rainwater harvesting.

3.3 Data Sources and Description

The study used the Kenya Integrated Household Budget Survey of 2015/16, which was conducted by the Kenya National Bureau of Statistics. The initial dataset had 23,880 households but upon data cleaning, the total sample size used in the analysis was 21,738 households. The key indicators that informed this study are described in Table 3.1 and are traced to the literature. Random sampling was adopted during the survey using a clustered approach and countrywide coverage. This, therefore, presented comprehensive and reliable data for analysis of household dynamics in Kenya.

Table 3.1: Description of data

Variable	**Description**	**Hypothesis (adoption of RWHS)**
R (Rainwater)	Rainwater harvesting adopters (1) and non-adopters (0)	NA (dependent)
Y (Income)	Income or wealth of household head (1-rich, 2-poor)	Rich adopts more
Wall	1-house with permanent wall; 2-non-permanent wall	Permanent adopts
Roof	Type of roofing; (1- iron sheet, 2-not)	Iron sheets adopt more
Dwell	Ownership of dwelling; (1-owned, 2-rented)	Rented adopts less
Employ	Status of employment; (1-employed, 2-not employed)	Employed adopts more
P (Price)	Price of water or proxy distance and time to water source	Positive
Distance	Distance in metres to a main water source	Positive
Time	Time taken in minutes to a main water source	Positive
Rounds	Number of roundtrips made to collect water	Positive
W (Water)	Availability of water	Availability adopts more
Climate	Amount of rainfall; 1-Low, 2-High	High adopts more
Use	Amount of water used in litres per capita per day	Positive
H (Households)	Characteristics of households	Varies
Size	Number of household members	Positive
Age	Number of years the household head has	Positive
Gender	Gender of the household head (1-male, 0-female)	Females adopt more
Education	Household head education (1-primary, 2-secondary, 3-post-secondary	Higher adopts more
Marital	Marital status of household head; (1-married, 2-not married)	Married adopts more

Variable	**Description**	**Hypothesis (adoption of RWHS)**
Area	Area of residence (1-rural, 2-urban, 3-peri-urban)	Rural adopts more
E (Effects)	Welfare effects on water, food, and health	Adopters are secure
Water-secure	Access 1-< 15 litres per person per day, otherwise -2	Adopters are secure
Health-secure	Waterborne diseases 1- waterborne, 2 - no waterborne	Adopters are secure
Food-secure	Meals periodicity; 1-missed meal, 2- never missed meal	Adopters are secure

3.4 Descriptive Statistics

The level of adoption of rainwater harvesting methods such as the construction of water pans and installation of own domestic rainwater harvesting system is one of the strong measures towards mitigation of the effects of drought and floods. In terms of the adoption of rainwater technology or the application of rainwater harvesting, rainwater adopters were 13 per cent compared to 87 per cent who were non-adopters. On average, the household size was four (4) members of the household, consuming an average amount of water estimated at 23 litres per person per day. This is below the survival level of 40 litres per day, which is recommended by WHO for drinking, cooking, personal washing, and washing clothes (WHO, 2011). Household size determines the water demand, but water collection decisions can be influenced by factors such as the gender, education, and age of the household head. Most of the households were headed by males (66%), yet the female gender is the most associated with the decision making on water in a household. In terms of the highest level of education attained 15 per cent had post-secondary education, 30 per cent had secondary education while the majority (55%) had either primary or pre-primary or no formal education. The large proportion of household heads with primary education and below can be regarded as being inhibitive to rainwater harvesting since education is expected to be a catalyst in decision making to adopt rainwater harvesting technologies, besides its likely effect on income. The income levels for household heads varied with 20 per cent being rich and 80 per cent being poor, which is indicative of the low ability to pay for the acquisition of rainwater harvesting systems. The average age of the household heads was 45 years and the youngest was 12 years old, and age had a standard deviation of 16 years apart.

Table 3.2: Descriptive statistics of data

a. Continuous variables							
Variable	**Description**	**Obs**		**Mean**	**Std. Dev.**	**Min**	**Max**
Distance	Distance to a main water source (metres)	19,828		1	8	0	600
Time	Time taken to main water source (minutes)	19,862		22	35	0	720
Rounds	Number of roundtrips to collect water	19,839		2	2	0	40
Use	Litres of water used per household member per day	21,616		23	31	0	1,481
Age	Number of years a household head has	21,738		45	16	12	100
Size	Number of household members	21,738		4	3	1	28

b. Categorical variables							
Variable	**Description**	**Frequency**	**%**	**Variable**	**Description**	**Frequency**	**%**
Rainwater	No	18,939	87.12	Climate	Low rainfall	5,974	27.48
	Yes	2,799	12.88		High rainfall	15,764	72.52
Income	Rich	4,319	19.90	Dwell	Own	14,903	68.68
	Poor	17,380	80.10		Rent	6,797	31.32

a. **Categorical variables**

Variable	Description	Frequency	%	Variable	Description	Frequency	%
Gender	Male	14,356	66.04	Employed	No	8,602	43.89
	Female	7382	33.96		Yes	10,999	56.11
Water Security	No; <15 l/c/d	9,369	43.10	Marital	Married	19,878	91.44
	Yes;>= 15 l/c/d	12,369	56.90		Not Married	1,860	8.56
Area	Rural	13,075	60.15	Education	Primary	9,553	55.26
	Urban	5,980	27.51		Secondary	5,150	29.79
	Peri-urban	2,683	12.34		Post-secondary	2,584	14.95

4. Findings and Analysis

4.1 Determinants of Uptake of Rainwater Harvesting Technology

The results show that decisions to adopt rainwater harvesting technology are dependent on household wealth, time taken to collect water from the main source, number of roundtrips taken in collecting water, climatic conditions based on the amount of rainfall expected, water demand in terms of average water demand per household member, the characteristics of the household head such as sex, age, education level, and employment status, as well as ownership of dwelling, and area of residence (Table 4.1). However, distance to water sources and marital status were not significant as well as middle level education.

Table 4.1: Probability of rainwater harvesting by households, probit model

Independent variables	Dependent variable: Rainwater harvesting (1-yes, 0-no)							
	dy/dx (average)	Std. error	Z-score	P>z	dy/dx (at-mean)	Std. error	Z-score	P>z
Wall (permanent) #	0.0746	0.007	10.85	0.0000	0.0762	0.007	10.26	0.0000
Roof (iron sheet) #	0.1918	0.015	13.18	0.0000	0.1226	0.005	22.91	0.0000
Dwell (rented) #	-0.0909	0.010	-9.44	0.0000	-0.0815	0.008	-10.2	0.0000
Employed (not)#	0.0311	0.006	4.96	0.0000	0.0300	0.006	4.99	0.0000
Distance	0.0002	0.000	0.52	0.6050	0.0002	0.000	0.52	0.6050
Time	0.0003	0.000	3.09	0.0020	0.0003	0.000	3.09	0.0020
Rounds	-0.0178	0.002	-7.12	0.0000	-0.0172	0.002	-7.14	0.0000

Climate (high rainfall) #	0.0325	0.008	4.16	0.0000	0.0299	0.007	4.39	0.0000
Water use	-0.0006	0.000	-3.66	0.0000	-0.0005	0.000	-3.66	0.0000
Size of HH	-0.0068	0.001	-4.85	0.0000	-0.0066	0.001	-4.85	0.0000
Age of HHH	0.0011	0.000	5.00	0.0000	0.0011	0.000	4.98	0.0000
Sex (female)#	0.0275	0.006	4.34	0.0000	0.0275	0.007	4.20	0.0000
Education (sec)#	0.0024	0.007	0.35	0.7260	0.0023	0.007	0.35	0.7270
Education (post-sec) #	0.0412	0.010	4.26	0.0000	0.0432	0.011	3.95	0.0000
Marital (not married) #	-0.0165	0.012	-1.33	0.1840	-0.0154	0.011	-1.38	0.1680
Area (urban)#	-0.1029	0.010	-10.16	0.0000	-0.0880	0.008	-11.7	0.0000
Area (peri-urban) #	0.0347	0.008	4.38	0.0000	0.0359	0.009	4.12	0.0000

Model fitness: Marginal effects after probit; Y = Pr (rwhs) (predict) = 0.1304

Prediction power: Correctly classified = 84.31%; No. of Obs. = 14,584

(#) dy/dx is for discrete change of dummy variable from 0 to 1

Wealth or income has a positive relationship with the uptake of rainwater harvesting. A household headed by a rich person is seven (7) per cent more likely to adopt rainwater harvesting than one headed by a poor person, other factors held constant. This is the case since rainwater harvesting requires some basic installations such as having adequate roofing and collection conveyance and adequate storage for rainwater collection, all of which have cost implications, which poor households may not afford. Policies seeking to reduce the cost of rainwater harvesting systems may have a positive effect on the uptake of rainwater harvesting technologies especially among the middle class and the poor households. This will enhance the ability to pay by reducing the relative cost to be incurred.

The design of rooftops of main buildings for households is key in promoting rainwater harvesting. Households with proper roofing, for example using iron sheets, have a higher potential and likelihood of harvesting rainwater since the catchment is already fitted. Households whose roofs are fitted with iron sheets are 19.2 per cent more likely to harvest rainwater than those without iron sheets. However, in some areas, iron sheets may not be used to roof buildings due to climatic or environmental conditions, which may require setting up of a separate structure with iron sheets for capturing rainwater. Other surfaces such as concrete or levelled ground can be used to capture and convey rainwater to a storage, which can be a tank or a water pan.

Unemployed heads of households are three (3) per cent more likely to harvest rainwater than employed households. This is likely the case since most of the employed persons live in rented houses where they work, and this result is corroborated by the marginal effects of ownership dwelling. Therefore, ownership of the dwelling is critical in making decisions for rainwater harvesting since the household head has full control of the homestead. A household living in a rented dwelling is nine (9) per cent less likely to be harvesting rainwater compared to a household in its dwelling. This supports policies that promote homestead ownership since it is more likely to increase rainwater harvesting as opposed to rentals.

The time taken to collect water from the main water source increases the desire for rainwater harvesting, unlike the number of trips taken and the distance between the household and the water source. An increase by one minute in time taken to collect water from the main water source is more likely to increase the chance of a household adopting rainwater harvesting technology by about 0.03 per cent. Therefore, a household which takes one hour longer than another to collect water from a water source is more likely to adopt rainwater harvesting by approximately two (2) per cent. The number of rounds or times a household member takes to collect adequate water for the household has an inverse response mechanism with the desire to collect rainwater, but the distance covered to collect water was not significant. Household members making more rounds to collect water are less likely to belong to the rainwater harvesting groups. An additional round makes a household two (2) per cent less likely to belong to rainwater harvesting households. Making more roundtrips implies that the distance of the water source may be nearer to the household, which supports the observation of a positive correlation between rainwater harvesting and time. This shows that rainwater harvesting is a viable alternative for households seeking to reduce time spent in collecting water, and those households collecting water from long distances.

Households in areas with high rainfall are three (3) per cent more likely to be harvesting rainwater than those in low rainfall areas. Rainwater harvesting depends on the quality of precipitation, such that the cost-benefit analysis would approve rainwater harvesting projects collecting adequate amounts of water to meet the prevailing water demand. However, it would be more beneficial for areas with minimal rainfall to harvest the little rain available because of the scarcity. This points to inadequacy in technologies that can promote rainwater harvesting in low rainfall areas.

A higher amount of water demanded is a disincentive to rainwater harvesting. An additional litre in the requirement of water per capita makes the household 0.07 per cent less likely to be a rainwater harvesting household. Whereas it was expected that households with high water demand would be more likely to adopt rainwater harvesting technologies, the converse hints to the likelihood of available technologies being limited to supporting large-scale water harvesting. The disincentive to collect rainwater may be constrained by storage capacity or catchment surface area, whose capacity cannot sustain large water demands. This is supported by the finding on household size, where smaller households demonstrated a relatively higher affinity for the uptake of their domestic rainwater systems than large households. The uptake of rainwater systems among small-sized households was proportionately higher than large-sized households, with an additional member of the household making the household 0.7 per cent less likely to be a rainwater harvesting household. The overall trend shows that rainwater harvesting decreases with household size. This may lead to a conclusion that the rainwater harvesting technology adopted may not be of adequate scale to offer adequate water for use for large families.

The female gender is more associated with the uptake of rainwater harvesting technology. The female-headed households are more likely to be rainwater harvesting households since a female-headed household is 2.8 per cent more likely to be a household with rainwater harvesting than a male-headed household. This is supported by the observation that water has a gender dimension, where the society assumes that the role of water collection is a preserve of the women and girls. Thus, the female gender is more likely to prefer decisions that increase water availability, including rainwater harvesting.

An additional year in age makes a household 0.1 per cent more likely to be a rainwater harvesting household. Young generations may not invest in water collection because of their lifestyle and wealth level. Older generations are likely to be living in their homes, rather than rented buildings and thus have control over the rainwater harvesting decisions.

Households with household heads having post-secondary education are 4.3 per cent more likely to be harvesting rainwater than those with primary education, though secondary education was not significantly different from primary education. Education can increase awareness of the benefits of rainwater harvesting and increase the potential to earn a high income to generate wealth, which is associated with high adoption of rainwater harvesting. There is a need for public awareness campaigns to support rainwater harvesting, and this may increase adoption by the population with primary and secondary education.

A larger proportion of rural households have higher rainwater harvesting uptake than the proportion of households in urban areas. For instance, households in urban areas are 10 per cent less likely to harvest rainwater than rural households while peri-urban households are 3.5 per cent more likely to harvest rainwater compared to those in rural areas. The rural population has higher rainwater harvesting systems than the urban areas in both their own rainwater systems and water pans. Urban dwellers largely rely on piped or vended water. Peri-urban dwellers tend to buy land and build their homesteads, thus have higher chances of installing rainwater harvesting systems. In addition, this difference may be attributable to the type of ownership of the houses, where the ownership in the rural areas has absolute discretion to establish rainwater harvesting systems, unlike in urban areas where most of the households are living in rented houses with limited rights of modification.

If the adoption of rainwater harvesting at the domestic and community level can be improved, this can enhance water security and associated welfare effects such as good health, food security, and reduced water conflicts. At the community level, water pans and dams are suitable means and this requires efforts of the community, civil society, and governments to cooperate in the construction and management of such projects. Home-based rainwater harvesting relies on water collection potential mainly using roof catchment, and it needs promotion through awareness campaigns, financial support, and fiscal incentives such as reduction in taxes and other levies on the materials and other inputs. The common resource requirements for the successful installation of water pans are land, materials, technical know-how, and finances.

4.2 Associating Rainwater Harvesting with Security in Water, Food and Health

The analysis of the degree of association of rainwater harvesting with socio-economic objectives is based on the incidence of rainwater harvesting in promoting water security, food security, and health security. This is achieved by exploring the relative frequency within the categories of adopters and non-adopters. The incidence is the difference between the relative frequencies, which demonstrates the likelihood of making lives better when rainwater harvesting is undertaken by the household.

4.2.1 Water security

Water-secure households are those accessing more than the basic water requirement of 15 litres per person per day. The incidence of rainwater harvesting in promoting water security is three (3) percentage points above households not harvesting rainwater (Table 4.2). Adopters of their rainwater harvesting systems have more relative proportion of households with water security (59.7%) than a relative proportion of water secure population among non-adopters (56.5%), and above the average incidence of water security (56.9%), as shown in Table 4.2. This means that rainwater improves the availability of water and is corroborated with a higher proportion of rainwater non-adopters falling into the water insecurity trap of less than 15 litres per person per day. This reflects that the infrastructure required for rainwater harvesting is critical in enhancing water security, and this should be promoted for both domestic and community rainwater harvesting systems.

Table 4.2: Relative incidence of rainwater harvesting in water security

Occurrence of water secure		**Rainwater harvesting**		
No		**Yes**	**Total**	
No	freq	8,241	1,128	9,369
	%	43.51	40.30	43.10
Yes	freq	10,698	1,671	12,369
	%	**56.49**	**59.70**	**56.90**
Incidence		59.70 – 56.49 **= 3.21**		59.70 – 56.90 **= 2.81**
Test statistics (Model stability and significance)		Pearson chi2(1) = 10.2671; Prob = 0.00		
	likelihood-ratio $\text{chi}^2(1)$ = 10.31; Prob = 0.001			

The study indicated that there is a likelihood of rainwater harvesting having a positive impact on the level of water security in general. This supports efforts to enhance the policy environment for rainwater harvesting as a mitigation measure against water insecurity and related socio-economic consequences. Water security is promoted as a global agenda under Sustainable Development Goal No. 6, and it is expected to have welfare effects, especially on food and health.

4.2.2 Food security

Food security is often measured using the incidence of a household member missing a meal in a given period because it was not available. Adopters of rainwater harvesting have higher food security status relative to non-adopters. The incidence of rainwater harvesting in promoting food security is two (2) percentage points above households not harvesting rainwater (Table 4.3). Among the adopters of rainwater harvesting, the incidence of food security is higher with approximately 61.6 per cent, which is a marginal two (2) percentage points higher than the proportionate frequency in non-adopters who are food secure (59.1%). This incidence is also above the overall average incidence of food secure, which was estimated at 59.5 per cent. Therefore, rainwater harvesting enhances food security, but the marginal difference demonstrates that the rainwater may not necessarily support agriculture through irrigation. This supports efforts to promote rainwater harvesting at the household and community level, especially for both small and large-scale irrigation, since this analysis is at the household level.

Table 4.3: Relative incidence of rainwater harvesting in food security

Occurrence of food secure		**Rainwater harvesting**			**Water security**		
No		Yes	**Total**	**No**	**Yes**	**Total**	
No	freq	7,722	1,075	8,797	3,247	5,550	8,797
	%	40.86	38.43	40.55	34.67	45.01	40.55
Yes	freq	11,176	1,722	12,898	6,118	6,780	12,898
	%	**59.14**	**61.57**	**59.45**	**65.33**	**54.99**	**59.45**
Incidence		61.57 - 59.14 = **2.43**		61.57 - 59.45 = **2.12**	54.99 – 65.33 = **- 10.34**		54.99 – 65.33 **= - 4.46**
Test statistics (Model stability and significance)		Pearson chi^2(1) = 5.955 Pr = 0.015			Pearson chi^2(1) = 236.079 Pr = 0.000		
	likelihood-ratio chi^2(1) = 5.98; Pr=0.014			Likelihood-ratio chi^2(1) = 237.49; Pr=0.000			

Further, it is observed that water security in general as opposed to rainwater harvesting is a necessary condition but not a sufficient condition for food security in Kenya. This is because the relative incidence of water security in food security is negative, whereby the incidence of food security among households who were water insecure had a higher relative frequency (65.3%) compared to the relative frequency among water-secure households (55%), as shown in Table 4.3. The converse is expected to be the ideal situation. These observations recognize that water sources are diverse and not all such sources can be targeted for food security. It also shows that other factors that may affect food security include income levels, market dynamics, and infrastructure.

4.2.3 Health security

Some of the direct waterborne health risks that households face and most likely to be attributable to water insecurity are diarrhoea, stomachache, vomiting, and typhoid. However, it was observed that the incidence of waterborne diseases is relatively more dependent on overall water security than rainwater harvesting. There is no statistical difference in the proportion of households among rainwater harvesters experiencing incidences of waterborne diseases compared to the proportion of non-harvesters (Table 4.4). This showed that the proportional difference in relative frequencies is similar for waterborne diseases regardless of adoption or non-adoption of rainwater harvesting technology.

Table 4.4: Incidence of rainwater harvesting in health security

Occurrence of waterborne disease **No**		**Rainwater harvesting**			**Water secure**		
		Yes	**Total**	**No**	**Yes**	**Total**	
No	freq	18,489	2,729	21,218	9,171	12,047	21,218
	%	**97.62**	**97.50**	**97.61**	**97.89**	**97.40**	**97.61**
Yes	freq	450	70	520	198	322	520
	%	2.38	2.50	2.39	2.11	2.60	2.39
Incidence		97.50 – 97.62 **= - 0.12**		97.50 – 97.61 **= - 0.11**	97.40 - 97.89 **= - 0.49**		97.40 – 97.61 **= - 0.21**
Test statistics (Model stability and significance)		Pearson chi^2(1) = 0.1628 Pr = 0.687			Pearson chi^2(1) = 5.4803 Pr = 0.019		
	likelihood-ratio chi^2(1) = 0.1608 Pr = 0.688			likelihood-ratio chi^2(1) = 5.5410 Pr = 0.019			

Nevertheless, some level of significance may be experienced in cases of waterborne diseases based on overall water security status as opposed to just rainwater harvesting. For instance, cases of waterborne diseases were less proportionate for water-secure households (97.40%) than water-insecure households (97.89%). This shows that the likelihood of a household with water security having waterborne diseases was higher than that of a household with water insecurity. This result contradicts the expected welfare effect of water security on health. However, it stresses the point that water security in terms of quantity accessed is just a necessary condition but not a sufficient condition in the prevention of waterborne diseases. This is because incidences of waterborne diseases primarily depend on the quality of water as opposed to the quantity of water, and further vary with changes in hygiene norms and behaviour among household members, whose difference can account for the dissociation of water security and rainwater harvesting from incidence of waterborne diseases. Therefore, this has laid evidence for holistic campaigns for the prevention of waterborne diseases by integrating water availability and quality, together with public awareness creation on self and community hygiene.

5. Conclusion and Recommendations

5.1 Conclusion

Harvesting and storage of rainwater has the potential to enhance water availability for domestic, agricultural, and industrial uses. Water security is significant in the realization of Kenya's Vision 2030, which recognizes that water insecurity is a major challenge that can have socio-economic ramifications. Further, water security is a global commitment under the sixth goal among the Sustainable Development Goals. This emphasizes the need to maximize efforts to exploit all water sources, including rainwater harvesting. It is important to understand the factors that can promote rainwater harvesting and the likely effect on socio-economic agenda.

The results show that adoption of rainwater harvesting technology increases with household wealth, time taken to collect water, amount of rainfall, age of household head, female gender as head of household, and post-secondary education. However, rainwater harvesting decreases with water demand, household size, rented dwellings, urban areas, employed heads of household, and number of roundtrips. Further, distance to water sources and marital status were not significant.

The analysis also showed that rainwater harvesting promotes water security, since households adopting rainwater harvesting showed relatively higher access to an adequate amount of water, as benchmarked on the basic water requirement of 15 litres per person per day. It was also evident that rainwater harvesting enhances food security, besides water security emerging as a necessary but not a sufficient condition for food security. However, there was a marginal difference in the incidence of waterborne health risks between adopters and non-adopters of rainwater harvesting. Households with rainwater harvesting systems were marginally less prone to waterborne diseases than non-adopters. However, water security showed unexpected results, where water-insecure households had a relatively lower incidence of waterborne health risk, compared to water-secure households. This has underlined the need to control other factors such as quality of water and hygiene education and practices among households, if the argument attributing water security to control water-related health risks is to be sustained.

5.2 Recommendations

To enhance rainwater harvesting among households in Kenya, based on the findings of this study, it is recommended that:

(i) Policies promoting rainwater harvesting to include appropriate rainwater harvesting systems in the design of rental housing plans and ensure they are installed before a certificate of occupation is awarded. This will improve rainwater harvesting in the urban areas and among employed people, which showed a negative effect on the adoption of rainwater harvesting.

(ii) Investment in rainwater harvesting research, development, and innovations, will be necessary in establishing appropriate rainwater harvesting technologies that encourage affordable designs to serve large size households that have a high water demand. This is because large households and higher water demand had lower adoption of rainwater harvesting, and this was partially attributable to the amount of water required, which also requires higher water collection surfaces, appropriate conveyance, and adequate storage facilities that can meet mid-term to long-term water demand interests. Installing such systems may be expensive and therefore not affordable to poor households.

(iii) Stakeholders promoting rainwater harvesting may find it useful to develop selection criteria for beneficiaries of rainwater harvesting projects by including rainfall potential, income of households, female gender, age of household heads, and time taken by households to collect water and post-secondary education as basic parameters for successful launch and campaign for rainwater water harvesting. This is because these factors promote faster adoption and can act as ambassadors of the significance of rainwater harvesting.

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