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Water Availability and Household Adaptive Mechanisms of Smallholder Farmers in Refugee Settlement Camps: Insights from Nakivale, Uganda

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ABSTRACT

Smallholder farmers in refugee settlements demonstrate resilience to climate change through localized adaptation, yet inadequate water infrastructure, economic limitations, and weak institutional support constrain their efforts. Despite this, limited empirical research has examined how displaced farmers cope with water scarcity, as most studies focus on host communities and overlook refugee contexts. This study, therefore, assesses water resource availability and adaptive mechanisms among smallholder farmers in Nakivale Refugee Settlement, Uganda one of the largest and most climate-stressed

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settlements in East Africa. A cross-sectional design was used, involving 384 randomly selected households and 12 purposively selected key informants. Data were collected through household questionnaires and interviews, and analyzed using descriptive statistics, chi-square tests, and thematic analysis. Results showed heavy reliance on precarious water sources, with most farmers depending on rainfall and purchased water, followed by river water, boreholes, wells, and taps. Major challenges included poor water quality, long distances to water sources, seasonal drying of water points, insufficient supply, conflicts over water access, and climate-induced variability. To cope with scarcity, households adopted mechanisms such as rainwater harvesting, storing water, seeking alternative sources, reducing cultivated land, and planting drought-resistant crops. However, adoption of water-saving technologies remains low due to financial barriers and limited training. Community collaboration in water management is also minimal, indicating weak collective action. The study underscores the need for targeted policies and interventions to strengthen resilience in refugee settlements, including expansion of reliable water infrastructure, promotion of affordable water-saving technologies, enhanced community-based water governance, and integration of these efforts into broader climate adaptation and humanitarian programming.

***Keywords**: Water Scarcity, Adaptive Mechanisms, Smallholder Farmers, Nakivale, Uganda.*

INTRODUCTION

Water scarcity is one of the most pressing global challenges of the 21st century, with its effects felt most severely in arid and semi-arid regions and among already vulnerable populations (United Nations, 2023). The problem is multidimensional, driven by climate change, rapid population growth, and unsustainable water management practices. Worldwide, water shortages persist due to mismatches between water demand and supply, influenced by physical, economic, and institutional factors (Msongaleli et al., 2023). Physical scarcity arises when natural water sources including rainfall, rivers, and aquifers, cannot meet household, agricultural, and industrial demand. Arid regions with annual renewable water availability below 1,000 m³ per capita are particularly affected (Bakiika et al., 2023). Economic water scarcity, in contrast, occurs when water is available but inaccessible because of financial, infrastructural, or governance limitations, such as inadequate investment or inequitable distribution systems (Pastori & Sindico, 2020).

Water scarcity manifests differently across regions. In the Aral Sea Basin, unsustainable irrigation triggered ecological collapse (Pastori & Sindico 2020). Prolonged droughts in the Southwestern United States led to strict water conservation measures (Denis & Che, 2021). Australia's Millennium Drought (late 1990s to 2009) exposed vulnerabilities in water supply and prompted extensive investments in water infrastructure and management (Rey et al., 2019). These experiences illustrate the sensitivity of agriculture and food systems to climatic variability (Rey et al., 2019).

In Africa, water challenges have intensified due to climate change and rising population pressure. Madagascar has faced prolonged droughts that triggered severe food insecurity and displacement (Hanadé Houmma et al., 2022), while shrinking water resources in the Lake Chad Basin have fueled resource-based conflicts (Hanadé Houmma *et al*, 2022). Across East Africa, fluctuating climatic patterns have undermined water access and agricultural production. Somalia continues to experience recurrent droughts and humanitarian crises (Malkawi & Kapiel, 2024). Tanzania's major cities, including Dar es Salaam, struggle with water stress linked to rapid urbanization and climate variability (Smit & Wandel, 2006). Kenya's pastoralist communities have endured repeated livestock losses due to persistent droughts (Yator, 2024). Uganda also faces a dual challenge of droughts and floods, disrupting farming systems and water security (Price, 2020). These impacts vary regionally. Karamoja faces chronic drought and dependence on relief (Price, 2020) Kampala experiences infrastructure overload and sanitation risks, while Western Uganda suffers climate-induced flooding (UBOS, 2024).

In response to rising water insecurity, different countries have adopted diverse adaptation mechanisms. Singapore has invested in desalination and water recycling to secure long-term water access (Manungufala, 2021). Australia's Murray Darling Basin Plan seeks to balance environmental sustainability and economic water use (Pastori & Sindico, 2020). Globally, digital tools such as remote sensing and data analytics increasingly support water monitoring and planning (UBOS, 2024). Localized nature-based solutions — such as community rain gardens help reduce stormwater runoff and improve groundwater recharge (Manungufala, 2021).

Across Africa, adaptation strategies have prioritized strengthening water infrastructure, sustainable resource management, and building community resilience. Rwanda has expanded rainwater harvesting and small-scale irrigation to enhance rural water access (Pastori & Sindico, 2020). Ethiopia's Grand Renaissance Dam aims to improve storage and hydropower generation, though it has sparked geopolitical debate (OPM, 2019). Community-centred models, such as participatory irrigation associations, have improved equitable resource distribution(Zhang et al., 2021).

In East Africa, resilience efforts include investing in infrastructure, promoting drought-resistant crops, and diversifying livelihoods. Kenya's Northern Rangelands Trust supports collaborative natural resource management among pastoralists (Malkawi & Kapiel, 2024). while in Ethiopia, mobile platforms disseminate real-time water information to strengthen early warning systems (Naidoo, 2022).

In Uganda, resilience strategies focus on water infrastructure development, sustainable agriculture, and community-based management, though inequalities in access remain (Siregar, 2022). Integrating indigenous knowledge with modern technologies has also enhanced adaptive capacity (Choden et al., 2020). Despite these advancements, refugee settlements — often located in ecologically fragile areas experience heightened water scarcity due to their high population density, limited infrastructure, and exclusion from formal governance systems (Calderón-Villarreal et al., 2022).

In Nakivale Refugee Settlement, Western Uganda, water scarcity has especially affected smallholder farmers, who depend on water for domestic use and agricultural production. According to (UBOS, 2023) 60% of households spend over four hours daily collecting water, and 30% rely on unsafe sources, increasing exposure to waterborne diseases (UNHCR, 2021). Agricultural output has been heavily disrupted, with yield reductions of more than 50% due to unpredictable and insufficient water supply, heightening food insecurity among households largely dependent on rain-fed farming (Malkawi & Kapiel, 2024). Low income further limits adaptation: nearly 60% of smallholders earn less than $0.50 per day (Daoust & Selby, 2023), constraining access to irrigation, filtration technologies, or improved seeds.

Competition for scarce water resources has led to social tension and displacement within the settlement, with projections suggesting that up to 20% of Nakivale's population could migrate by 2030 due to water stress (Pastori & Sindico, 2020). Already, 15% of households report monthly conflicts over water access (UNHCR, 2021). Institutional responses remain limited, with only about 15% of households participating in water management programs. The absence of refugee-specific water policies deepens inequities in resource allocation, and existing governance frameworks do not sufficiently address the interconnected effects of physical scarcity, poverty, and institutional neglect. As a result, smallholder farmers experience a compounded vulnerability, especially given their dependence on rain-fed agriculture and limited access to alternative water sources. Persistent scarcity undermines livelihoods, economic stability, and social cohesion (Pastori & Sindico, 2020)

Although households develop coping strategies, their effectiveness depends on access to knowledge, financial resources, and institutional support (Smit & Wandel, 2006). Yet empirical research examining the relationship between water availability and household-level adaptation in refugee contexts remains limited. Consequently, policies often fall short of addressing the unique challenges facing displaced farmers. To address this gap, study in Nakivale Refugee Settlement focuses on two core questions:

1. What are the perceived causes of water scarcity for agriculture among smallholder farmers in Nakivale Refugee Settlement?
2. What adaptive mechanisms do households adopt to cope with water scarcity?
3. Theoretical perspectives of water resource availability and household adaptive mechanisms

This study employs the Sustainable Livelihoods Framework (SLF) as its theoretical framework to analyze the relationship between water resource availability and households' adaptive mechanisms to water scarcity among smallholder farmers. Within this framework, water resource availability is conceptualized as a critical component of natural capital, influencing the capacity of households to engage in productive agricultural activities and sustain their livelihoods (Choden et al., 2020).

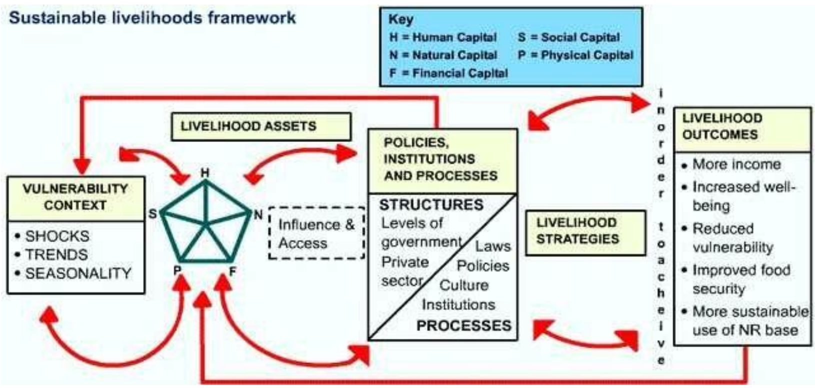

Figure 1: Sustainable Livelihoods Framework (SLF) (DFID (1999)

Household adaptive mechanisms are assessed by examining how smallholder farmers utilize their livelihood assets, including physical capital (water storage and irrigation infrastructure), human capital (knowledge and skills in water conservation), financial capital (resources to invest in water-saving technologies), and social capital (community-based water management practices) to manage water scarcity (Fletcher et al., 2015). Policies, institutions, and processes are integrated into the framework to analyze how water governance structures, humanitarian support systems, and local regulations either facilitate or constrain farmers' capacity to access and use water resources efficiently (Denis & Che, 2021; Mukasa et al., 2020).

Adaptive mechanisms such as rainwater harvesting, the use of water-efficient technologies, and crop diversification are explored within the SLF as livelihood strategies adopted by households to cope with water scarcity while maintaining agricultural productivity and household food security (Chepkoech et al., 2020; Matewos, 2020).

The framework further assesses livelihood outcomes including income stability, food security, and reduced vulnerability; as critical indicators of resilience under water-stressed conditions (UNHCR, 2021). By adopting the SLF, this theoretical framework systematically examines how water resource availability interacts with household adaptive mechanisms to determine resilience to water scarcity. It provides a structured approach to identify leverage points for policy and community-based interventions aimed at enhancing sustainable water management and adaptive mechanisms among smallholder farmers in Uganda and similar contexts.

METHODOLOGY

Description of the study area

The study was conducted in Nakivale Refugee Settlement, located in Isingiro District, Southwestern Uganda. The settlement lies approximately 35 kilometers south of Mbarara City and is one of the oldest and largest refugee settlements in Africa. Geographically, Nakivale is situated at coordinates approximately 0.8500° S latitude and 30.8500° E longitude. The settlement covers a vast area subdivided into several zones, each hosting refugees from different countries including Somalia, the Democratic Republic of Congo, Burundi, Rwanda, and Ethiopia (OPM, 2019).

Nakivale experiences a tropical savannah climate, characterized by two rainy seasons (March–May and September–December) and two dry seasons. Average annual rainfall ranges between 600 mm and 1,000 mm, while temperatures vary from 18°C to 30°C. The climatic conditions influence agricultural activities, which remain the backbone of livelihoods within the settlement (UNHCR, 2021).

The living conditions of refugees in Nakivale vary depending on access to services, resources, and humanitarian support. The cost of living has progressively increased due to high demand for basic goods, limited employment opportunities, and fluctuating market prices. Households often face challenges related to access to food, water, health services, and shelter. Although basic social services are available, they are sometimes overstretched due to the high population size(UBOS, 2023).

The economic livelihood of refugees in Nakivale relies mainly on small-scale farming, petty trade, casual labor, fishing, and humanitarian aid. Many households cultivate small plots of land provided by the Office of the Prime Minister (OPM), growing crops such as maize, beans, cassava, sweet potatoes, and vegetables. Other residents run small businesses including shops, tailoring, motorbike transport (boda boda), and food vending. However, income levels remain low, making households vulnerable to shocks such as drought, food price increases, and reduced humanitarian assistance(OPM, 2019).

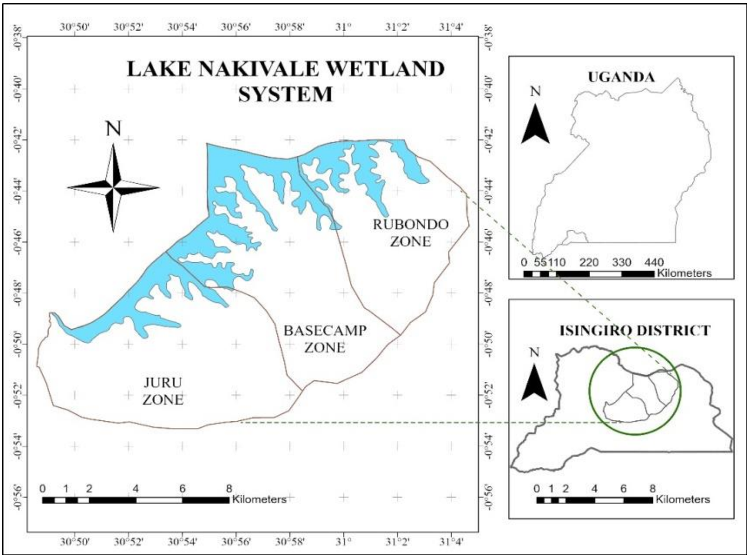

Figure 2: Map of the study area

Research design

The study employed a cross-sectional research design, allowing data collection at a single point in time to examine the relationship between water availability and adaptive mechanisms among smallholder farmers (Weyant, 2022). This design was appropriate due to the need to gather quantitative and qualitative information from a large population within limited time and resources. The design also enabled the comparison of household experiences, perceptions, and adaptive responses to water scarcity across different zones of the settlement.

Data collection (methods and tools)

Both quantitative and qualitative approaches were used to strengthen reliability and validity. A household survey served as the primary quantitative data source. A sample of 384 households was randomly selected based on population proportion across the settlement zones. A structured questionnaire was administered to collect data on demographic characteristics, water sources, water challenges, agricultural activities, and coping strategies.

For qualitative data, Key Informant Interviews (KIIs) were conducted with 12 purposively selected participants, including camp leaders, water officials, agricultural extension workers, and humanitarian actors supporting water and agricultural programs. An interview guide was used to explore deeper insights on institutional responses, water governance, and community-based adaptation.

Pilot testing of the tools was carried out to ensure clarity, consistency, and cultural sensitivity. Ethical considerations such as voluntary participation, confidentiality, and informed consent were strictly observed throughout the data collection process.

Data analysis

Data were entered, cleaned and coded in Microsoft excel, and later analyzed using R software version 4.5.0 (R Core Team, 2025). Descriptive statistics (frequencies, percentages, and means) were used to summarize household characteristics, primary water sources, and the prevalence of various adaptive strategies. To test relationships between variables, chi-square tests were employed to determine the association between water resource availability and the adoption of adaptive mechanisms among households.

RESULTS AND DISCUSSION

This section presents a detailed analysis of the quantitative and qualitative findings on water source usage, access challenges, and adaptive mechanisms among smallholder farmers in Nakivale Refugee Settlement. The interpretation is framed within the Sustainable Livelihoods Framework (SLF) and situated within the broader context of existing literature on water scarcity and adaptation in refugee and fragile contexts.

Demographic characteristics of the respondents

The demographic characteristics of the 384 surveyed households provide a crucial context for understanding their vulnerability and adaptive capacity to water scarcity. The community is predominantly of working age, with 86.5% of respondents aged between 18 and 50 years. This suggests the presence of a significant labor force capable of implementing labor-intensive adaptations, such as building rainwater harvesting structures or traveling long distances for water. However, this potential is critically undermined by other socio-economic constraints.

Table 1: Demographic characteristics of the respondents

Characteristic	Category	Frequency (n=384)	Proportion (%)
Age	Under 18	23	6.0
	18 – 35	159	41.4
	36 – 50	173	45.1
	Over 50	29	7.6
Gender	Male	190	49.5
	Female	194	50.5
Education level	No education	184	47.9
	Primary	141	36.7
	Secondary	51	13.3
	Tertiary	8	2.1
Household size	1 - 3 members	123	32.0
	4 - 6 members	175	45.6
	Above 6 members	86	22.4
Land size	0.1 - 0.5 acre	182	47.4
	0.6 - 1.0 acre	152	39.6
	Above 1 acre	50	13.0
Time of settlement in area	Below 1 year	54	14.1
	1 - 5 years	205	53.4
	Above 5 years	125	32.6

Household income	Mean (SD)	220,000	(166,000)
	Median [Min, Max]	150,000	[30000, 700000]

The age distribution shows that the majority of the population (86.5%) is within the working-age bracket of 18-50 years. This suggests a significant labor force potential for implementing labor-intensive adaptations, such as building rainwater harvesting structures or walking long distances for water. However, as noted by Eriksen et al. (2021), a young and active demographic in a resource-scarce setting can also intensify pressure on limited natural resources if not coupled with sustainable livelihood opportunities.

The near-equal gender split (49.5% male, 50.5% female) is representative of the settlement's population. This variable is crucial as gender roles profoundly influence water access and management. The data corroborates global findings that women and girls are primarily responsible for water collection, a task that becomes more burdensome and time-consuming in conditions of scarcity (Graham et al., 2016). The time spent fetching water directly impacts women's ability to engage in income-generating activities or education, thereby constraining the development of human capital.

The education level is a stark indicator of human capital constraints. With 47.9% of respondents having no formal education and only 15.4% having secondary education or above, the capacity to comprehend, evaluate, and adopt new, technically complex water-saving technologies is severely limited. This finding aligns with Wutich *et al*. (2020), who demonstrated that low educational attainment is a significant barrier to the adoption of climate-resilient agricultural practices. The lack of literacy and numeracy skills can hinder farmers' ability to access training materials, calculate irrigation schedules, or engage with formal financial institutions for loans, perpetuating a cycle of low adaptive capacity.

Household size shows that 68% of households have 4 or more members. While larger households may have more labor available for tasks like farming and water collection, they also have greater aggregate water demands for both domestic and agricultural use (Kemeze, 2021).

This creates a double-edged sword: more labor to cope with scarcity, but also higher consumption that exacerbates the scarcity itself.

Land size is a key component of physical capital. The data reveals that 87% of households farm on 1 acre of land or less, with nearly half (47.4%) on plots between 0.1 and 0.5 acres. Such micro-plots, common in refugee settlements due to land allocation policies, limit the potential for agricultural diversification and the economic viability of investing in irrigation infrastructure. As shown by Zaitchik *et al*. (2019), the small scale of landholding often makes the per-unit cost of technologies like drip irrigation prohibitively high, pushing farmers towards lower-cost but less effective coping strategies.

The time of settlement indicates that most respondents (86%) have been in the settlement for over a year, with 32.6% for over five years. This suggests a population with settled livelihoods and local ecological knowledge, which is a form of human capital. However, as posited by Hunter et al. (2020), long-term residence without secure land tenure can lead to environmental degradation as farmers are unable to make long-term investments in soil and water conservation, fearing displacement.

Finally, household income reveals a community in poverty. With a median monthly income of 150,000 UGX (approximately 40 USD), households operate with extremely limited financial capital. The substantial standard deviation (166,000 UGX) indicates high income inequality, but even the upper range of reported incomes (700,000 UGX) is modest. This level of poverty directly constrains the ability to purchase water, invest in water storage, or acquire efficient irrigation equipment, thus forcing households into difficult trade-offs between immediate consumption and long-term resilience (Sovacool *et al*, 2021).

This profile paints a picture of a community with the labor force to implement adaptations but constrained by low education, small land holdings, and poverty. These factors directly shape both their access to water and the repertoire of adaptive strategies they can employ, consistent with the assets pentagon of the Sustainable Livelihoods Framework (Choden et al., 2020).

The sources of water for agriculture in Nakivale refugee settlement

Results show that residents of Nakivale Refugee Settlement rely on several key water sources to sustain farming activities and livelihoods. This section explores the primary sources of water available for agricultural use in the settlement.

Figure 3: hand-drawn picture shows population growth and water scarcity

Table 2: The sources of water for agriculture in Nakivale refugee settlement

Water source	Response	Frequency (n=384)	Proportion (%)	χ^2	p-value
Borehole	No	252	65.6	37.500	<0.001***
	Yes	132	34.4		
Well	No	289	75.3	98.010	<0.001***
	Yes	95	24.7		
Rain	No	63	16.4	173.344	<0.001***
	Yes	321	83.6		
Taps	No	371	96.6	333.760	<0.001***
	Yes	13	3.4		
River	No	228	59.4	13.500	<0.001***
	Yes	156	40.6		
Purchase	No	168	43.8	6.000	0.014*
	Yes	216	56.3		

The overwhelming reliance on rainwater aligns with findings from Murgor et al. (2021) in Kenyan refugee contexts, where its low cost and accessibility make it the primary source. However, this dependence creates acute vulnerability to climatic shocks. As noted by a key informant, *"Many people have adopted water harvesting technologies... for use during the dry season,"* indicating that rainwater use is intrinsically linked to storage capacity. The bimodal rainfall pattern in Nakivale means that without sufficient storage, this source is unavailable for long periods, directly impacting agricultural cycles and food security (Mukasa et al., 2020). This reliance on an unpredictable natural capital asset underscores the community's exposure to climate variability.

The high prevalence of purchased water is a telling indicator of economic water scarcity. This finding resonates with studies by Akello et al. (2022) and Calderón-Villarreal et al. (2022), who documented that poor households in displacement settings often allocate a substantial portion of their meager income to buying water. This diverts financial capital from other critical livelihood investments, such as agricultural inputs, education, or healthcare, thereby perpetuating a cycle of poverty. A key informant highlighted the strain: *"There is a constant cost... I have to send money and pay from my pocket."* This market-based solution, while filling a critical gap, effectively taxes the poorest for a fundamental human right.

The significant use of river water raises major public health concerns, directly impacting human capital through health outcomes. This aligns with research by Nkwanda *et al*. (2020) and Baguma *et al*. (2013), which associates the use of untreated surface water with elevated risks of waterborne diseases like cholera and dysentery. The Ministry of Health (2023) reported 320 cholera cases in Nakivale in 2022, underscoring the real-world consequences of this reliance. The use of contaminated sources reflects a failure in the provision of safe physical capital (water infrastructure).

The limited use of boreholes (34.4%) points to a critical gap in protected groundwater infrastructure. While boreholes are typically classified as an improved water source, their uneven distribution and frequent breakdowns limit their reliability. Studies in similar settings, such as by Stoler et al. (2021), note that boreholes in refugee-hosting areas often suffer from mechanical failures and long queues, especially during dry seasons. Their limited coverage signifies an insufficiency in the physical capital necessary for a resilient water system.

The minimal access to taps and limited use of boreholes (34.4%) underscores a severe physical capital deficit. This finding is consistent with UNHCR (2023) reports and analyses by Tumushabe (as cited in Hussein Ahmed & Isse Ali, 2024), which point to chronic underinvestment in durable water infrastructure in refugee settlements. The extremely high and significant chi-square value for taps (χ^2 = 333.76) indicates that this is the most inequitably distributed resource, reflecting a systemic failure in public service provision and a critical gap in the settlement's built environment.

Furthermore, the distance to water sources was a significant barrier (Table 3). While 35.7% of households traveled less than 1 km, another 35.7% traveled 1-3 km, and 28.6% journeyed over 4 km. These long distances, consistent with UBOS (2023) data, disproportionately burden women and children, who are primarily responsible for water collection, limiting their time for other productive activities and education (Bakiika et al., 2023)

Table 3: Distance to water sources (N=384)

Response	Frequency (n=384)	Proportion (%)	χ^2	p-value
Less than 1 km	137	35.7	97.042	<0.001***
1 – 3 km	137	35.7		
4 - 6 km	91	23.7		
More than 6 km	19	4.9		

The data shows that while 35.7% of households travel a relatively short distance (less than 1 km), an equal proportion travel 1-3 km, and over a quarter (28.6%) journey more than 4 km. The statistical test ($p < 0.001$) confirms the differences in distances moved by respondents are meaningful. This suggests uneven access to water, with many households facing long distances that could affect water use and increase burdens, especially for women and children. The results highlight the need for targeted improvements in local water infrastructure. These long distances, consistent with UBOS (2023) data, disproportionately burden women and children, who are primarily responsible for water collection. This time-consuming task represents a significant opportunity cost, limiting time for other productive activities, education, and rest, thereby eroding both human and social capital (Bakiika *et al*., 2023). The gendered nature of this burden reinforces existing inequalities, as the time and physical effort invested in water collection directly reduce women's capacity to engage in income-generating activities or community leadership.

Perceived causes of water scarcity for agriculture

Water shortage: The respondents were also asked if the water they got from the different sources was sufficient or not for their farming and household needs. The data on water sufficiency and shortage in Nakivale refugee settlement camps presents a nuanced picture of water availability for agricultural and household needs. Their responses were recorded and are presented below.

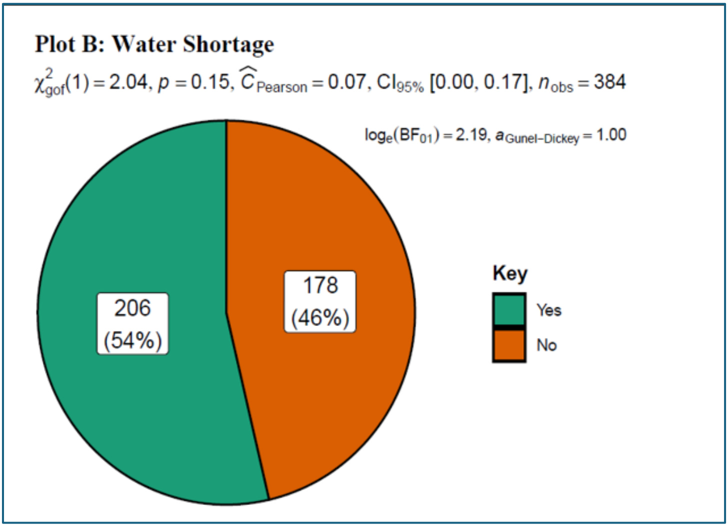

Figure 4: Water shortage

The data on water sufficiency and shortage in Nakivale refugee settlement camps presents a nuanced picture of water availability for agricultural and household needs. The statistical analysis reveals no significant difference in perceptions of water sufficiency (χ^2 (1) =2.04, p=0.15), with 54% of respondents reporting insufficient water and 46% indicating adequacy. Similarly, reports of water shortage mirrored this distribution (54% yes, 46% no) with identical statistical values, suggesting balanced but concerning divisions in water access experiences. The weak Pearson's C correlation

(C Pearson = 0.07) and Bayes Factor ($log_a(BF_{01})$ =2.19) leaning toward the null hypothesis indicate that these reports may not reflect extreme systemic scarcity but rather inconsistent access patterns. With 384 observations, these findings highlight that while half of the refugee farmers face water shortages that likely hinder agricultural productivity and domestic use, nearly half manage to meet their needs, pointing to uneven resource distribution within the settlement. Here, a key informant stated that

> *"It is a difficult situation as you see or feel. There are many days when there is no water and there is a constant cost that is not related to the arrival of water. For example, today if I do not have water, I have to send money and pay from my pocket".*

This disparity underscores the need for targeted interventions to improve equitable water allocation, particularly as climate variability and population pressures may exacerbate existing gaps in water security for vulnerable farming households.

Water shortage frequency

The results in the figure above reveal a severe and frequent water shortage problem in the refugee settlement, with 55.8% of respondents (115 out of 206) experiencing shortages "sometimes," 31.6% (65) facing them "often," and 12.6% (26) dealing with shortages "always" - a highly significant pattern (χ^2=134.85, p<0.001). The extremely significant pattern confirms that these patterns are not random occurrences but reflect structural deficiencies in water provision.

This situation has grave implications: the "always" group likely represents the most vulnerable households in the worst-served zones of the settlement, possibly facing permanent water insecurity that threatens basic survival needs. The high percentage facing frequent shortages ("often") suggests the water system operates at a consistent deficit even during normal conditions. These findings demand an urgent humanitarian response, Interventions should address both immediate water supply needs in the most affected areas and long-term infrastructure improvements to prevent households that experience occasional shortages from transitioning into more severe and frequent water scarcity categories. The universal experience of shortages highlights how water access remains a fundamental failure in meeting basic rights for displaced populations.

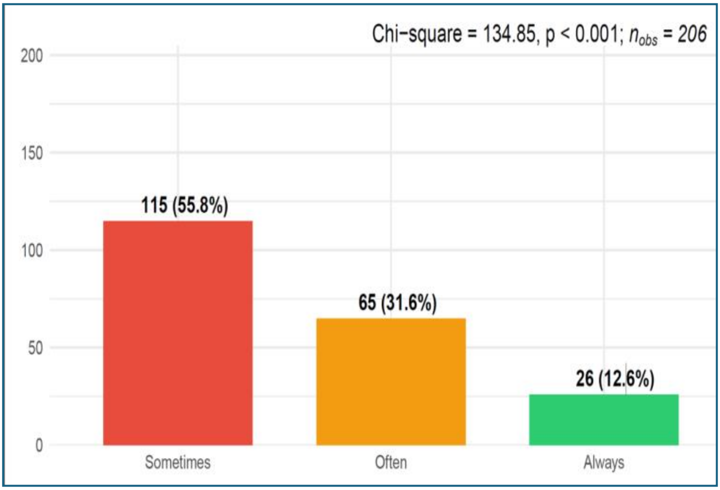

Figure 5: Water shortage frequency

Causes of Water Scarcity

Climate change as a cause of water scarcity

More than half of the respondents, i.e., 67% of respondents (257 out of 384) identified climate change as one of these water shortages, supported by extremely strong statistical evidence (χ^2=44.01, $p<0.001$) and a moderate Pearson's C correlation (0.32).

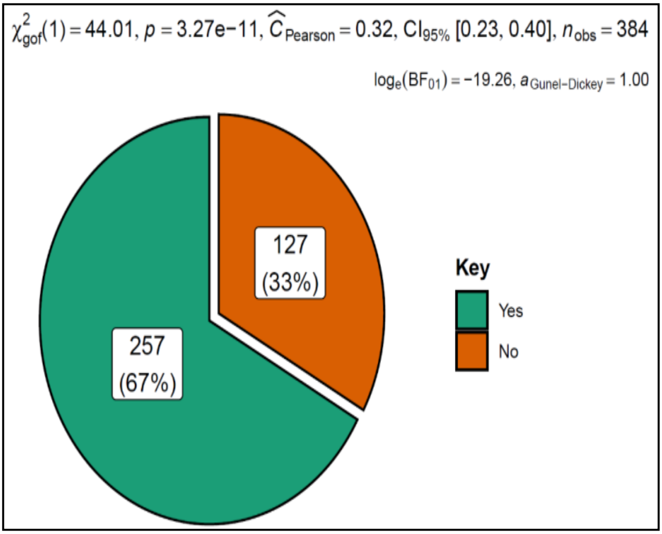

Figure 6: Climate change as a cause of water scarcity

The Bayes Factor ($\log_e$ (BF_{01})=-19.26) provides decisive evidence against the null hypothesis, confirming climate change's substantial role in exacerbating water scarcity. These findings paint a troubling picture of how climate impacts are disproportionately affecting vulnerable refugee populations, with frequent water shortages disrupting agricultural livelihoods and household stability. The results underscore the urgent need for climate-resilient water management strategies in refugee settlements, including improved water storage, drought-resistant farming techniques, and international support to address this growing humanitarian crisis

Non-Climate Causes of Water Scarcity

Apart from climate change being the leading cause of water shortage i.e., mentioned by 67% of the respondents, the following were also cited as other causes of water shortage.

Table 4: Non-climate causes of water scarcity

Causes of water scarcity	Frequency (n=384)	Proportion (%)	χ^2	p-value
More people using water				
No	152	39.6	16.667	<0.001***
Yes	232	60.4		
Deforestation				
No	246	64.1	30.375	<0.001***
Yes	138	35.9		
Poor water management				
No	235	61.2	19.260	<0.001***
Yes	149	38.8		

The data highlights several significant non-climate factors contributing to water scarcity in the refugee settlement, with population pressure emerging as the most prominent cause. A striking 60.4% of respondents (232 out of 384) identified "more people using water" as a key factor, showing strong statistical significance ($\chi^2=16.667$, $p<0.001$). In line with this, a key informant stated that

> "*The few waterpoints available have been over powered by the high population, which sometimes lead to fights and conflicts over water. This is common in the dry seasons when the problem of water scarcity is faced by a very big proportion of the residents.*"

Other notable causes included poor water management (38.8%) and deforestation (35.9%), both demonstrating significant associations (χ^2=19.260 and 30.375 respectively, p<0.001 for both).

The Adaptive mechanisms used by households in response to water scarcity

The presented results in the table 5 below demonstrate statistically significant patterns in Adaptive strategies employed by Nakivale refugee households facing water scarcity (N=384), with chi-square tests revealing particularly strong adoption disparities (all p<0.01).

Table 5: The adaptive mechanisms used by households in response to water scarcity

Response	**Frequency (n=384)**	**Proportion (%)**	χ^2	**p-value**
Using water-saving methods				
No	292	76.0	104.167	<0.001***
Yes	92	24.0		
Using stored water				
No	148	38.5	20.167	<0.001***
Yes	236	61.5		
Reducing cultivated land area				
No	162	42.2	9.375	0.002**
Yes	222	57.8		

Switching to drought-resistant crops				
No	254	66.1	40.042	<0.001***
Yes	130	33.9		
Adopting rainwater harvesting technology				
No	147	38.3	21.094	<0.001***
Yes	237	61.7		
Seeking alternative water sources				
No	161	41.9	10.010	0.002**
Yes	223	58.1		

The high adoption of rainwater harvesting technology (61.7%) represents a proactive investment in physical capital to enhance control over a volatile natural capital asset (rainfall). This aligns with global recommendations from (Mukasa *et al*, 2020)and successful case studies in Rwanda and Northern Ghana (Mukasa *et al.*, 2020). It indicates that households recognize the value of capturing seasonal rainfall. However, the term "technology" here often refers to simple gutters and small storage jars. The effectiveness of this strategy is contingent upon the capacity and quality of storage facilities. The study suggests that many households rely on small, inadequate containers, a limitation also found by Msongaleli et al. (2023). Scaling up this adaptation requires addressing the financial capital barriers to acquiring larger, more durable storage tanks.

The practice of using stored water (61.5%) is intrinsically linked to rainwater harvesting but represents the utilization aspect of this strategy. It highlights a household's ability to smooth water availability over time. However, the capacity of storage dictates the duration for which this strategy is viable. When stores are depleted, households are forced to revert to more precarious sources or negative coping strategies. The high adoption of both harvesting and storage indicates a logical and widespread attempt to create a buffer against rainfall variability, yet the scale remains insufficient for long-term drought resilience (Mwiturubani et al., 2025).

Reducing Cultivated Land Area (57.8%) This is a classic *coping*, rather than *adaptive*, strategy. It is a distress response that immediately reduces agricultural water demand but at the cost of lower food production and income, directly undermining financial capital and food security. This finding is consistent with the work of Moser and Ekstrom (as cited in Crawford et al., 2016), who categorize such strategies as those that reduce vulnerability in the short term but can increase long-term susceptibility by depleting asset bases. It highlights the severe trade-offs households are forced to make between conserving water and maintaining their food sovereignty.

Switching to drought-resistant crop (33.9%): The relatively low adoption is surprising given their potential to build resilience. This can be attributed to several barriers identified in the literature: limited access to quality seeds (a physical and financial capital constraint), lack of knowledge on their cultivation (a human capital constraint), cultural preferences for traditional crops, and limited land for experimentation (Chepkoech et al., 2020). A key informant noted that despite distribution efforts, adoption rates remain low due to "insufficient technical guidance." This points to a significant gap in agricultural extension services within the settlement.

Water-Saving Methods (24.0%): The remarkably low use of techniques such as drip irrigation or mulching, despite their proven efficiency in conserving water and improving crop yields, is a critical finding that highlights gaps in knowledge, access to technology, and resource availability among smallholder farmers. This aligns with research by Inkani et al. (2021) that identifies cost as the primary barrier. Technologies like drip irrigation kits are often unaffordable for refugee households, representing a major financial capital hurdle. Furthermore, the human capital constraint, evidenced by the low education levels, plays a role. As Nkonya et al. (2021) found, knowledge and skills are prerequisites for adopting such technologies. The complexity of managing and maintaining these systems often requires a level of technical understanding that may be lacking.

The support systems intended to bolster these adaptive capacities are themselves inadequate, as shown in Figure 8 and Table 5.

The Training or Support Received By the Farmers for Water Conservation

The analysis of training received for water conservation reveals a marginally significant divide (χ^2=4.17, p=0.04), with 55% (212) reporting having received some form of training or support, while 45% (172) had not.

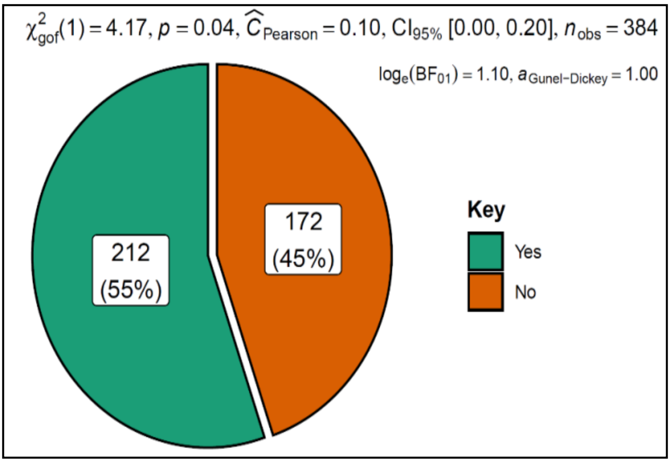

***Figure 7**: The training or support received by the farmers for water conservation*

The weak Pearson's C (0.10) and ambiguous Bayes Factor ($\log_e(BF_{01})$=1.10) suggest this training may not be sufficiently widespread or effective. These findings collectively demonstrate that while climate change remains the primary driver of water shortages, anthropogenic factors - particularly population pressure and inadequate water management - significantly compound the problem (Brown et al., 2019; Talat, 2021). The modest levels of water conservation training indicate an area for potential intervention, suggesting that enhanced education and resource management programs could help mitigate some of these human-exacerbated water scarcity issues in the settlement (Denis & Che, 2021).

Table 6: The kind of Support or training received by the farm

	Response	Frequency (n=212)	Proportion (%)	χ^2	p-value
Water management training	No	33	15.6	100.55	<0.001
	Yes	179	84.4		
Irrigation equipment	No	134	63.2	14.79	<0.001
	Yes	78	36.8		
Financial assistance	No	145	68.4	28.70	<0.001
	Yes	67	31.6		

The data reveals significant disparities in the support received by refugee farmers, with water management training being the most commonly provided assistance (84.4% received it, χ^2=100.55, p<0.001), while access to irrigation equipment (36.8%) and financial assistance (31.6%) was markedly lower (χ^2=14.79 and 28.70 respectively, p<0.001 for both). This pattern suggests that while knowledge-based interventions have been prioritized, practical resources and economic support remain inadequate. The heavy emphasis on training without corresponding equipment and funding creates an implementation gap - farmers may understand water conservation techniques but lack the tools and capital to apply them effectively. This imbalance has important implications for program design, indicating a need for more comprehensive support packages that combine education with material resources and financial enablement (Ali & Shahreen, 2024). The findings highlight a critical disconnect between humanitarian training initiatives and the tangible requirements for sustainable agricultural water management in refugee settings (Yasmin *et al*, 2023).

Willingness to adopt new water-saving techniques if trained

The respondents were also asked if they were willing to adopt new water saving technologies if they were trained. The results in Figure 8 shows a cautiously optimistic outlook regarding farmers' willingness to adopt water-saving techniques, with 55% expressing definite interest ("Yes") and 45% indicating tentative openness ("Maybe") (χ^2=3.76, p=0.05).

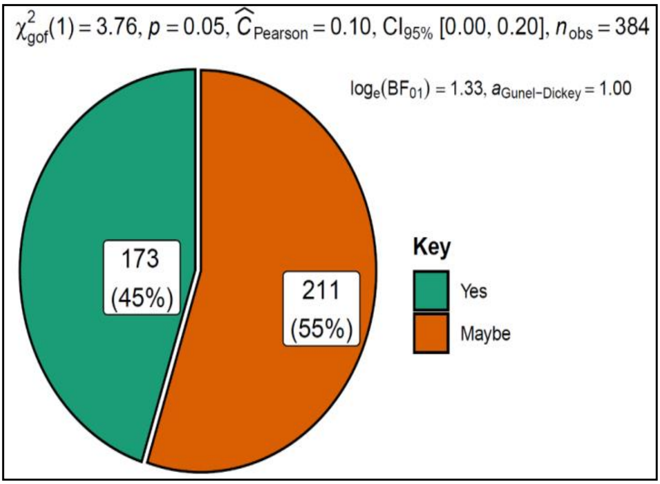

Figure 8: Willingness to adopt new water-saving techniques if trained.

The marginal statistical significance (p=0.05) and weak effect size (C=0.10) suggest this willingness is genuine but not overwhelmingly strong, likely depending on the specific techniques proposed and implementation support available. The nearly even split between definite and tentative responses implies that while there is substantial potential for introducing new water conservation methods, successful adoption will require addressing farmers' uncertainties through demonstration projects, peer learning, and guaranteed support systems. The Bayes Factor ($\log_e$ (BF_{01}) =1.33) showing only anecdotal evidence for willingness underscores the need for careful, phased implementation rather than assuming universal readiness. These findings highlight both an opportunity for water conservation programs and the importance of designing interventions that build confidence through practical, context-appropriate solutions with visible benefit

Integrated discussion: linking water sources and adaptive mechanisms

The results demonstrate a clear causal pathway: the precariousness of water sources dictates the nature of household adaptation**.** The high dependence on rainfall logically leads to the high adoption of rainwater harvesting and storage. However, when these stores are depleted, households are forced into negative coping strategies like reducing farm size or purchasing water. The low adoption of water-saving technologies and drought-resistant crops can be attributed to the "survival mode" imposed by economic scarcity. As the data shows, while 84.4% of those who received support got training, only 36.8% received irrigation equipment and 31.6% received financial assistance. This reflects a critical implementation gap. As one key informant succinctly put it, "While households purchase water for domestic use, agricultural activities remain entirely rain-dependent," highlighting how financial constraints force difficult trade-offs between domestic and productive water use.

Our findings align with broader literature. Mwiturubani et al. (2025) found that infrastructure-dependent solutions dominate in resource-constrained environments. The maladaptive strategy of reducing cultivated land confirms findings by Abebe & Bisung (2025) on the spectrum of coping in humanitarian contexts, where immediate survival often trumps long-term sustainability. The barrier to adopting efficient technologies supports Hashimoto's (2025) argument that behavioral and economic hurdles are significant, even when the benefits are known.

The perceived causes of scarcity further contextualize these adaptations. With 67% of respondents identifying climate change as a primary cause and 60.4% citing population pressure, households understand the systemic nature of the problem. Yet, their capacity to respond effectively is systemically constrained by a lack of affordable technology, financing, and institutional support.

CONCLUSIONS AND RECOMMENDATIONS

Households in Nakivale mainly depend on a combination of water sources, including rainwater, purchased water, river water, boreholes, and wells. These sources form the backbone of daily agricultural and domestic needs, yet they remain highly constrained in both quality and quantity. Access to formal water infrastructure, such as piped taps, is extremely limited across the settlement. Only a small proportion of households benefit from such systems, leaving the majority reliant on unimproved and informal sources that are less reliable and more labour-intensive to access.

Most of the available water sources are seasonal, unreliable, and insufficient for consistent agricultural use. Streams and ponds often dry up during prolonged dry spells, while harvested rainwater is rarely adequate to sustain households through extended drought periods. This instability undermines both agricultural productivity and household food security. Climate change further exacerbates these challenges by intensifying rainfall variability and prolonging droughts. Erratic rainfall patterns disrupt traditional farming practices, while frequent dry spells reduce water availability, compounding the settlement’s vulnerability to food and livelihood insecurity.

Population pressure also plays a significant role in intensifying water scarcity. With the settlement hosting a large and growing refugee population alongside host communities, demand for already limited water resources continues to rise, leading to competition and occasional conflicts over access. Poverty and limited income further restrict households' ability to invest in improved water infrastructure. Many families cannot afford technologies such as storage tanks, filtration systems, or small-scale irrigation equipment, which would otherwise enhance their resilience to water scarcity.

Lastly, community-based collaboration on water use remains minimal. Collective action and governance structures are weak, limiting the potential for shared resource management and equitable access. Without stronger community-level organization, water scarcity challenges are likely to persist and deepen.

RECOMMENDATIONS

Expanding reliable water infrastructure, such as the installation of taps and piped systems, is essential to reducing dependence on seasonal and unimproved water sources. Access to safe and consistent water supply would not only improve agricultural productivity but also enhance household well-being by minimizing time and labor spent collecting water from distant or unsafe sources.

Promoting rainwater harvesting is another critical intervention for effectively utilizing seasonal rainfall. By investing in storage tanks, gutters, and simple collection systems, households can capture and preserve water during the rainy season, ensuring availability during prolonged dry periods. This strategy enhances resilience by reducing vulnerability to rainfall variability.

Fostering community-based water management is equally important to address the current minimal collaboration among households. Strengthening collective governance structures encourages equitable access to shared resources, reduces conflicts over water use, and builds trust between refugee and host communities. Such systems empower communities to take ownership of water infrastructure and ensure its long-term sustainability.

Integrating climate adaptation strategies into humanitarian programs is necessary to counter the effects of erratic rainfall and recurrent droughts. Incorporating practices such as drought-tolerant crops, small-scale irrigation, and ecosystem restoration helps align immediate relief efforts with long-term resilience building. This integrated approach ensures that water management contributes to both survival and sustainable livelihoods.

Finally, developing gender-sensitive approaches to water access and management is vital. Women and children often bear the greatest burden of water collection, which restricts their opportunities for education and economic participation. Ensuring their inclusion in decision-making processes and designing interventions that reduce their workload will promote equity, improve household resilience, and strengthen community-wide adaptation to water scarcity.

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