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Special Paper No. 9/2024

Effect of Access to Clean and Safe, Adequate, Reliable and Affordable Water on Nutrition Status in Kenya

Foreign, Commonwealth & Development Office

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Effect of Access to Clean and Safe, Adequate, Reliable and Affordable Water on Child Nutrition in Kenya

Water, Sanitation and Irrigation Sector

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Abbreviations and Acronyms

BETA	Bottom-Up Economic Transformation Agenda
BMI	Body Mass Index
COHA	Cost of Hunger
FAO	Food and Agriculture Organization
FNSP	Food and Nutrition Security Policy
GoK	Government of Kenya
IFAD	International Fund for Agricultural Development
JMP	Joint Monitoring Programme
KDHS	Kenya Demographic and Health Survey
KIHBS	Kenya Integrated Household and Budget Survey
KNBS	Kenya National Bureau of Statistics
KNAP	Kenya National Nutrition Action Plan
MUAC	Mid Upper Arm Circumference
NIPFN	National Information Platform for Food Security and Nutrition
RoK	Republic of Kenya
UNICEF	United Nations Children's Fund
WASH	Water, Sanitation and Hygiene
WASREB	Water Services Regulatory Board
WFP	World Food Programme
WHO	World Health Organization
WSPs	Water Service Providers

Definition of Terms

Clean and Safe Water: Water that is free from contaminants and pathogens, meeting national or international health standards for drinking water quality. This includes being free from harmful chemicals, biological agents, and physical impurities.

Stunting: A condition characterized by low height for age in children, often resulting from chronic malnutrition and frequent infections.

Water Access: The ability of individuals to have non-discriminatory physical access to a water source within a 30-minute cycle, including queuing time in urban areas, and a round-trip distance of up to 2 kilometres in rural areas.

Water Adequacy: A provision of a sufficient quantity of water to meet the needs for drinking, cooking, personal and household hygiene, and other domestic purposes.

Water Affordability: The financial capability of individuals or households to pay for water services (should not exceed 3-5% of household income) without compromising their ability to afford other basic needs.

Water Reliability: Consistent, continuously or at predictable intervals of availability of water supplies to meet daily needs.

Abstract

Water security, which includes availability, physical accessibility, usage, and stability over time, is a crucial factor for improving nutrition. This paper goes beyond the dominant view of water access as mere 'coverage' to assess the relationship between the dimensions of water security and the nutritional status of children under five years old living in households with piped water in Kenya. Using data from the 2015/16 Kenya Integrated Household Budget Survey (KIHBS) and administrative records from the Water Services Regulatory Board (WASREB), a probit regression model was employed to estimate the effects of water accessibility, adequacy, quality, reliability, and affordability on child stunting. The findings of the study show that there is a rural-urban divide in water physical accessibility, quality, and adequacy. The study reveals that having sufficient drinking water at the household level significantly reduces child stunting. Adequacy of water of 20-49 litres per person per day as opposed to below 20 litres lowers the probability of stunting by 6.3 percentage points. Further, water reliability, affordability, access and quality have a potential to reduce stunting among children aged below five years. This evidence supports the importance of increased investment in water infrastructure to achieve universal access, improved water quality by implementing stringent monitoring and purification measures, strengthening the regulatory frameworks to ensure compliance and accountability, and expanded access to reliable water by developing efficient distribution systems, especially in rural areas where 65 per cent of people receive less than 20 litres of water a day. This strategic focus will not only improve child nutritional outcomes but also align with the country's constitutional mandate to ensure the population has access to sufficient quantities of clean and safe water for drinking and personal use.

1 Introduction

Malnutrition, in its various forms including undernutrition, deficiencies in vitamins or minerals, overweight, obesity, and resulting diet-related non-communicable diseases is a global concern, imposing substantial burdens on health. In 2022, an estimated 148 million children under the age of 5 years were stunted, 45 million wasted and 37 million overweight or obese in the same year (WHO, 2023). In Sub-Saharan Africa, undernutrition is widespread, with stunting and wasting rates reported at 31.3 per cent and 5.7 per cent, respectively in 2022 (FAO, IFAD, UNICEF, WFP, and WHO, 2023). Despite notable progress in improving various nutrition indicators in Kenya, the threat of malnutrition persists, with stunting reported among nearly one out of every five children (KNBS and ICF, 2023). The socio-economic implications of malnutrition are well documented, including compromised educational attainment, increased susceptibility to diseases, and substantial economic losses (Government of Kenya, 2018; Adebisi et al., 2019; Republic of Kenya, 2019; Breewood, 2018; World Bank, 2006).

Addressing malnutrition is complex due to its multifaceted causes, including water insecurity, poor sanitation, and inadequate hygiene practices (Chase et al., 2019; World Food Programme, 2014). Various nutrition conceptual models and frameworks, alongside factors such as access to healthcare services, climate change, and food security, underscore the critical role of water. Water thus serves as both an immediate risk factor directly impacting nutrition (nutrition-specific) and a more distal determinant of malnutrition (nutrition-sensitive) (UNICEF, 2021; Shekar et al., 2017; UNICEF, 1991). Consequently, ending malnutrition requires more than just proven nutrition interventions; it is necessary to incorporate interventions that address specific nutritional needs, such as those related to water access and quality, to achieve improved nutritional outcomes (Shekar et al., 2017; Ruel and Alderman, 2013).

Water plays a vital role in human nutrition and serves as a cornerstone of health and well-being. Water security, whose primary dimensions include availability, physical accessibility, use and stability across time is an essential input for improved nutrition (Miller et al., 2021; Chase et al., 2019). Water is a crucial nutrient for maintaining health and ensuring survival (Miller et al., 2021; Wenhold and Faber, 2009), and is associated with nutritional outcomes through pathways spanning across various sectors such as agriculture and health. Reliable access to water of sufficient quantity and quality enhances availability of a variety of foods and in turn dietary diversity (Miller et al., 2021; Hess and Sutcliffe, 2018). Inadequate water supply can reduce a household's food intake and alter their diets, causing them to opt for less nutrient-dense or more highly processed alternatives (Venkataramanan et al., 2020). Improved access to clean and safe water determines disease environments as it is linked to reduced risk of diarrhea and waterborne diseases, which in turn affect the ability to physically use nutrients for healthy growth. Water availability influences livelihoods and productivity, which indirectly affects nutrition through income, time use, and education of caregivers (Chase et al., 2019; World Bank, 2019; Hess and Sutcliffe, 2018; Wenhold and Faber, 2009).

Water is universally acknowledged as a fundamental human entitlement (UN General Assembly, 2015), a principle duly acknowledged by the government and enshrined within its legal and policy frameworks. The Constitution of Kenya (2010) stipulates that "Every individual has the entitlement to clean and safe water in sufficient quantities" (Government of Kenya, 2010). Furthermore, the Kenya Vision 2030 underscores the commitment that "every Kenyan has access to clean, safe water, and improved standards of sanitation by the year 2030." The Bottom-Up Economic Transformation Agenda (BETA) aims to ensure universal access to safe water by 2030 (The National Treasury and Economic Planning, 2024). Additionally, the fourth Medium-Term Plan (MTP IV) focuses on increasing the proportion of households with basic drinking water and enhancing water harvesting and storage, particularly in arid and semi-arid regions, by constructing water pans, small dams, and water harvesting structures.

Over time, policy and legislative frameworks have guided the protection, conservation, access, development, and management of water resources in the country (Republic of Kenya, 2021; 2016). Leveraging these frameworks has provided a significant opportunity to promote the human right to clean and safe water for Kenya's population. Consequently, the country has made substantial progress in improving water coverage, with the proportion of households accessing improved sources of drinking water rising from 57 per cent in 2007 to 70 per cent in 2022. However, there are disparities in access to safe water, with 60 per cent of households in urban areas having access compared to only 40 per cent in rural areas (KNBS and ICF, 2023; KIHBS 2015/2016, NWSS 2007-2015). Water scarcity persists in the country due to factors such as climate change-induced droughts, population growth, tightening environmental standards, changing customer expectations, economic development, and urbanization (Mulwa, Li and Fangninou, 2021; Engel et al., 2011). Challenges such as mismanagement of water resources, inadequate technical capacity, aging infrastructure, and societal reluctance to adopt interventions exacerbate water shortages and pollution, hinder irrigation development and sometimes ignites water-related conflicts (Chepyegon and Kamiya, 2018).

Nutrition-related policies in Kenya take cognizance of the role of access to sufficient and quality water in meeting nutritional needs for optimal health. The 2011 National Food and Nutrition Security Policy states that provision of clean, safe and adequate water could significantly reduce the disease burden and promote the production of diversified food that could help attain good nutrition. The Kenya National Nutrition Action Plan (KNAP) 2018-2022 recognizes the diverse determinants of malnutrition and outlines a multifaceted approach to addressing its root causes. This includes ensuring access to clean water in sufficient quantities. Specifically, the Plan highlights the importance of access to safe drinking water, sanitation, and hygiene (WASH) services in improving population health and nutrition status. Among the proposed strategies for promoting nutrition in WASH are the establishment of WASH facilities and the provision of safe drinking water; strengthening mechanisms for collaboration and stakeholder participation in WASH forums; and advocating for adequate WASH in households and institutions. On their part, the water sanitation and irrigation sector's existing water policies and strategies are designed to enhance access to safe, sufficient, quality, and affordable drinking water. These policies and strategies largely lack explicit linkages between the envisioned "human right to water" characteristics and nutrition, with most of them completely omitting any mention of nutrition. Even where nutrition is highlighted, for instance in the Ministry of Water and Sanitation Strategic Plan 2018-2022 (Republic of Kenya, 2018), there is no deliberate move in the policies to implement and track nutrition-related outcomes.

Existing literature in the Kenyan context tends to focus on the dominant view of access to water as 'coverage,' emphasizing access to improved water sources (Kiragu and Milelu, 2017). Only a few studies consider other aspects of water security, such as quality (De Vita et al., 2019; Stewart et al., 2018). This gap underscores the need for a more nuanced understanding of the role water plays in nutrition. It is crucial to go beyond merely having access to improved water sources and analyze the link between 'deep access' (Obeng-Odoom, 2012) and nutrition. Consequently, this research aims to examine the water-nutrition nexus by focusing on households with piped water sources. Specifically, this study investigates the relationship between clean and safe (quality), physically accessible, affordable, adequate, and reliable domestic water and nutrition outcomes among children under five years. The policy recommendations of this study will guide interventions to ensure that water investments effectively support improvements in nutrition outcomes.

2 Water Security, Stunting Status, Legal and Policy Arrangements in Kenya

2.1 Status of Water Security Dimensions and Stunting in Kenya

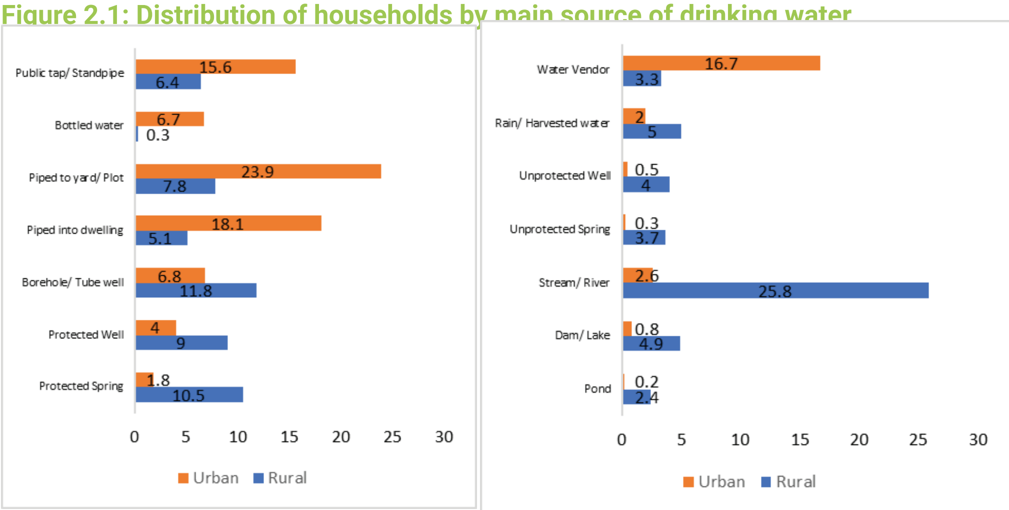
In Sub-Saharan Africa, water availability per capita has declined by 40 per cent over the past decade. Northern Africa, Southern Africa, and Western Africa each have less than 1,700m³ per capita, a level at which a nation's ability to meet water demand for food and other uses is compromised. A country is defined as water-stressed if the per capita water availability is below 1,700m³ per year. Kenya is among the water-scarce countries across the world, with per capita availability below 1,000m³ annually. The country's current water resource available per capita is estimated at 450m³/yr/capita down from 586m³ per year per capita in 2013 (Annual Status Report, 2023; National Water Master Plan 2030).

The scarcity of water poses a significant challenge in meeting the demands for domestic, industrial, and agricultural use. This scarcity is exacerbated by rapid population growth, urbanization, and increased agricultural and industrial activities. Challenges such as inadequate infrastructure, poor water management, and insufficient investment further aggravate the problem. Climate change also plays a critical role by altering precipitation patterns and increasing extreme weather events (UN-Water, 2021; Mulwa et al., 2021; World Bank, 2018). Collectively, these factors hinder the ability of developing nations to access water of sufficient quantities, impacting food security and nutrition, health, and economic development (FAO, 2019; WHO, 2019). Approximately 1.8 billion people worldwide lack access to safe drinking water, resulting in diseases that cause about 400,000 deaths annually among children under the age of five, which equates to over 1,000 young children dying daily (UNICEF, 2023).

Improved water sources, such as piped household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collection, are designed and built to provide safe drinking water by minimizing contamination risks. In contrast, unimproved water sources such as unprotected dug wells, springs, rivers, dams, lakes, ponds, streams, canals, and irrigation canals lack these protective measures and may pose greater contamination risks (UNICEF and WHO, 2012). In Kenya, an estimated 80 per cent of the population have access to improved drinking water sources, with urban areas having higher access (94%) compared to rural areas (71%). The 2022 Kenya Demographic Health Survey reveals that piped water within the dwelling, yard, or plot is the primary improved drinking water source for most Kenyan households, available to 40 per cent of urban households and 15 per cent of rural households (KNBS and ICF, 2023). WASREB reports indicate that 62 per cent of the population resides in areas potentially served by Water Service Providers (WSPs) (WASREB, 2023), highlighting a significant portion of the population lacking access to formalized utilities despite the presence of piped water systems. This lack of access may impact household availability of quality, reliable, and affordable water.

Despite improved access to drinking water sources such as piped water, urban areas often rely on unimproved sources, particularly water vendors, to supplement existing water services and address reliability gaps, as shown in Figure 2.1. Vended water can be costly and may compromise quality due to the methods used in its abstraction, storage, and transport, which create opportunities for contamination and expose households to health risks. Rural areas, on the other hand, rely mostly on natural and unimproved sources such as streams/rivers, protected and unprotected wells, springs, and rain-harvested water, which poses a health risk for rural based households.

Figure 2.1: Distribution of households by main source of drinking water



Source: 2019 Kenya Population and Housing Census: Volume IV

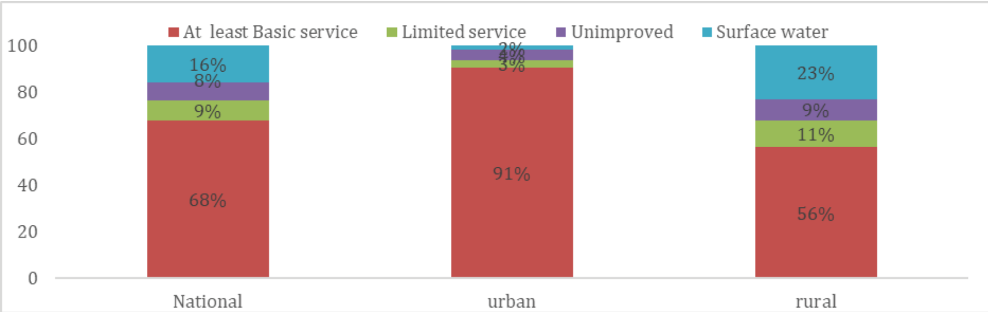
The WHO/UNICEF Joint Monitoring Programme (JMP) 2017 report reviewed the definition of improved and unimproved water sources to include additional criteria relating to service levels. For a water source to be considered a safely managed drinking water service, it must be accessible on the premises (accessibility), available when needed (availability), and free from contamination (quality). A drinking water source is defined as a basic water service if it can be collected within a 30-minute round trip but does not meet all criteria for a safely managed service. If collection from an improved source exceeds a 30-minute round trip, it is classified as a limited water service (WHO, 2017).

The JMP categorization not only evaluates access to safe drinking water but also indirectly addresses the dimensions of water security (WHO, 2017). The JMP's availability component typically assesses whether households have access to sufficient and available water when needed, during the last week or month, thereby capturing adequacy and reliability. In the absence of such data, the number of hours of service per day from water service providers or utilities is used as a proxy, but this applies only to piped water sources. For example, in 2022, WASREB reported that Water Service Providers (WSPs) supplied water for an average of 17 hours per day and produced 83.4 litres per customer per day (l/c/d). However, this did not lead to an increase in per capita domestic water usage, which remained at 28 l/c/d. This discrepancy indicates a decline in service quality, particularly for domestic consumers. Such trends are concerning as they undermine the efforts and principles underlying the progressive realization of the right to water as a fundamental human right.

For drinking water to be considered safe, it must always be free from pathogens and elevated levels of harmful substances. JMP assesses drinking water quality with the highest priority water quality parameter globally being contamination of drinking water with faecal matter. In Kenya, the testing of drinking water for faecal or chemical contamination of piped water is primarily conducted by Water Service Providers (WSPs). This implies that households using unimproved sources of drinking water are at a higher risk of waterborne diseases and contamination, as their water is not tested for quality. Consequently, safely managed and basic drinking water services are grouped together as 'at least basic service.' While JMP does not directly measure affordability, several indirect indicators can provide insights into this dimension; high access to improved water sources could indicate better affordability, since such sources are often regulated and potentially subsidized (WHO, 2017).

Nationally, 68 per cent of the population has access to at least basic drinking water services, but a significant portion relies on limited service and unimproved sources, especially in rural areas (KDHS, 2022). This brings to the fore the significant proportion of the population relying on limited service and unimproved water sources, underscoring the need for targeted interventions to improve water access, quality, reliability, and affordability, particularly in rural areas, to achieve equitable water security and advance national and global water-related goals

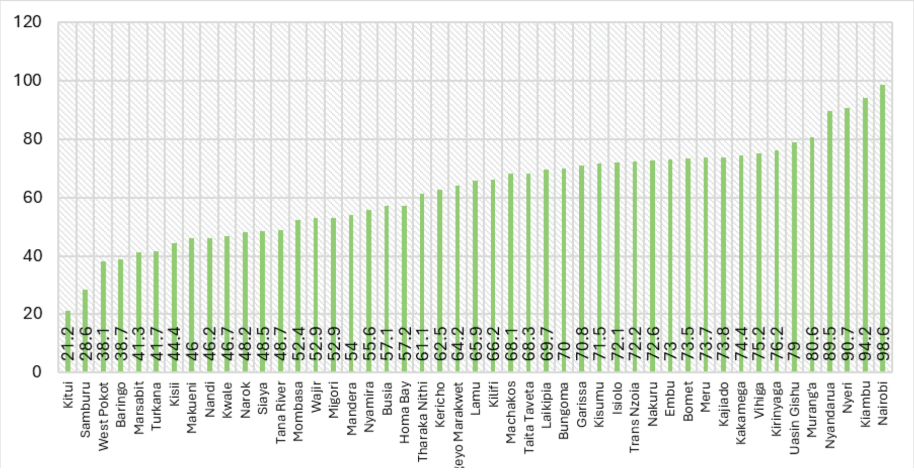
Figure 2.2: Proportion of households by drinking water service ladder



Source: KNBS (2022) Kenya Demographic and Health Survey 2022

Access to safely managed water sources varies across counties as presented in Figure 2.3, from 28.6 per cent in Kitui County to 98.6 per cent in Nairobi County. Many regions fall between 50 and 80 per cent, indicating moderate access levels but still leaving significant portions of their populations without adequate and safely managed water services. This disparity calls for targeted policies and strategies to develop infrastructure; enhance the resilience of water infrastructure to climate change and natural disasters; establish comprehensive data collection and monitoring systems to track water access, quality, and usage patterns; and enhance the capacity of local water service providers in these underserved areas.

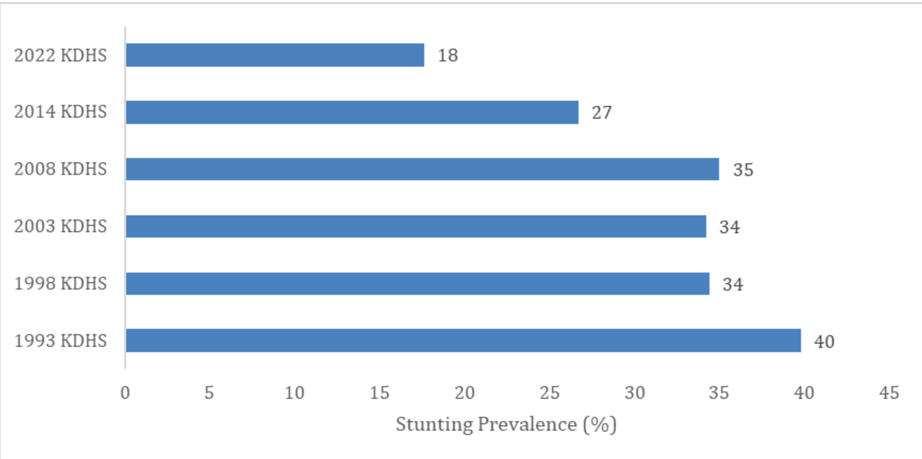
Figure 2.3: Proportion of population using basic drinking water service



Source: KNBS (2022) Kenya Demographic and Health Survey 2022

Kenya has made substantive strides in reducing the prevalence of stunting nationally from 40 per cent in 1993 to 18 per cent in 2022. The highest decline of 17 percentage points was observed between 2008 and 2009 (35%) and 2022 (18%). The 2022 KDHS reveals that stunting status differs by area of residence, mother's level of education, wealth status and across counties (KNBS and ICF, 2023).

Figure 2.4: Under-five years children stunting trends

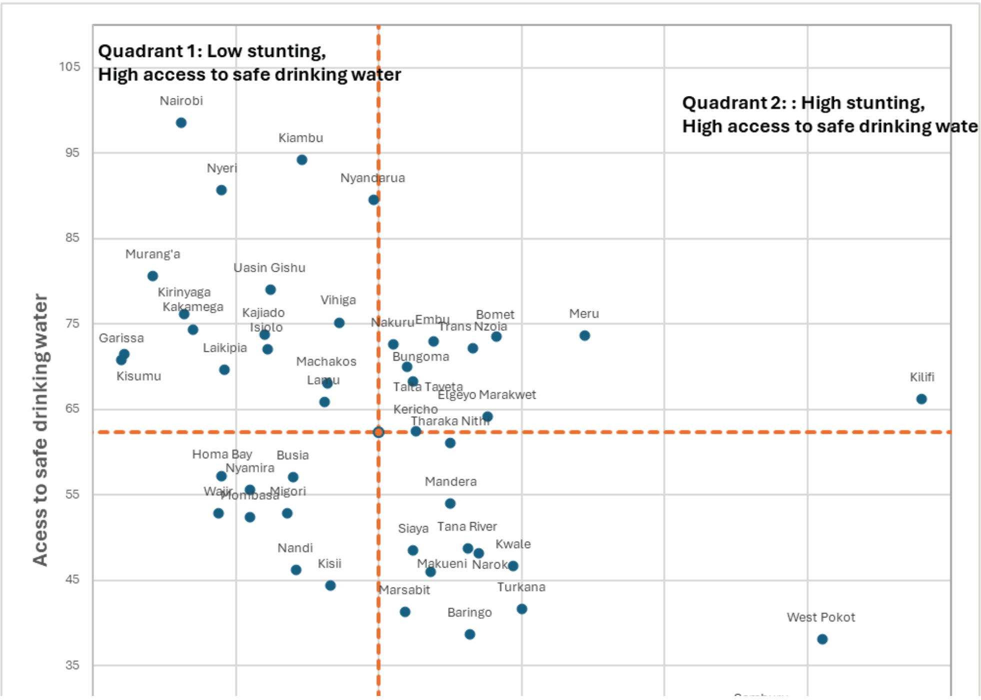


Source: KNBS (2022) Kenya Demographic and Health Survey

Under-five years stunting status is closely linked to access to safe drinking water. Figure 2.5 illustrates this relationship, showing how varying levels of access to basic drinking water services correlate with stunting rates across different counties. Overall, counties in the upper left quadrant such as Nyandarua, Kiambu, Uasin Gishu, Nyeri and Nairobi have a high proportion of households with access to basic water services and low prevalence of stunting, exemplifying the ideal scenario where good access to basic drinking water is associated with low stunting rates. Counties in the lower right quadrant including Kitui, Samburu, West

Pokot, and Turkana are of particular concern as they suffer from both poor water access and high stunting rates, indicating a need for targeted interventions in these areas. This highlights the critical importance of ensuring widespread access to clean and safe water to combat malnutrition and improve children's health outcomes. The presence of counties in the other two quadrants (upper right and lower left) suggests that water access is not the sole factor influencing stunting rates, highlighting the importance of a multifaceted approach to addressing malnutrition.

Figure 2.5: Relationship between access to safely managed drinking water and child stunting by counties



Source: KNBS (2022) Kenya Demographic and Health Survey

2.2 Legal and Policy Framework Governing the Water Sector

The Constitutional right to access to clean and safe water in adequate quantities for all Kenyan citizens is protected through several laws and policies governing protection, conservation, access, development, and management of water resources. These policies address various dimensions of water security, including availability, physical accessibility, usage, and stability over time, ensuring a holistic approach to water management. Table 2.1 presents an overview of select laws and policies addressing the dimensions of water security in Kenya.

Table 2.1: An overview of select legal and policy framework on water security

Kenya's legal and policy framework	Water Security Related Provisions
Water Act, 2016	This mandates the establishment of the Water Resources Authority (WRA), tasked with regulating water resources to ensure their availability. It promotes the development of new water sources and the efficient use of existing resources to meet the growing demand for water. Emphasizing infrastructure development, the Act focuses on constructing and maintaining water supply systems to bring water closer to communities. Water service providers are mandated to meet specific quality standards, with the Water Services Regulatory Board (WASREB) responsible for setting and enforcing these standards to ensure the provision of safe and clean water to the public. Addressing the need for reliable water supply, the Act includes provisions for disaster preparedness and response to ensure that water services are maintained even during periods of drought or other emergencies. Furthermore, it includes mechanisms to ensure that water services are affordable to all segments of the population, with WASREB tasked with regulating tariffs to balance affordability with the need for cost recovery and sustainability of water services.
The National Water Master Plan 2030	The Plan provides a long-term view of the availability, reliability, quality, and sustainability of a country's water resources up to the year 2050. It places a high priority on enhancing access to water services in both urban and rural areas; delineates strategies for expanding and modernizing water supply infrastructure, encompassing the construction of new systems and the rehabilitation of existing ones and puts in place measures to safeguard water sources and ensure compliance with safety standards through monitoring and treatment. Climate resilience is also addressed, with strategies designed to manage water resources effectively in the face of climate variability, and ensuring reliable access to water. Furthermore, the plan underscores the importance of sustainable water resource management, advocating for integrated approaches that protect catchment areas, promote conservation, and manage demand to ensure the long-term sustainability of water resources.
National Water Resources Strategy, 2020-2025	Provides a framework for the implementation of government policies with respect to water supply, sewerage, and basic sanitation in rural and urban settings. The Strategy sets out objectives and action plans for improving water service delivery in Kenya. It focuses on increasing access to clean and safe water by increasing per capita water availability through water resource planning, promotion of water use efficiency, streamlining water allocation systems and enhance strategic water reserves; enhancing water quality through monitoring and provision of guidelines, promoting sustainable water management practices, and ensuring affordability and reliability of water services.

Sessional Paper No. 21 of 2021 on National Water Policy	The Sessional Paper presents a comprehensive strategy to enhance water security and accessibility in Kenya. It highlights the importance of increasing water availability through the development of new sources and improved management of existing ones. Moreover, it emphasizes the need to expand and rehabilitate water infrastructure to enhance physical accessibility; ensuring water quality through rigorous monitoring and treatment protocols; and development of resilient water systems to withstand climate variability and disruptions, alongside strategies for drought management and efficient water use. The paper addresses affordability issues, with proposals for fair tariffs and subsidies for low-income households and promotion of sustainable water resource management, emphasizing the importance of conservation efforts and the adoption of alternative water sources.

3 Literature Review

3.1 Theoretical Framework

Nutrition Transition Theory

The nutrition transition theory describes the shifts in diets, physical activity and causes of disease that accompany changes in economic development, lifestyle, urbanization, and demography. The theory offers insight into the shifting dietary patterns and nutritional status that accompany socio-economic development. This transition, often marked by a move from traditional, plant-based diets to those high in processed foods, is significant in understanding nutrition dynamics. Variation in access to clean water varies across regions, and socio-economic groups play a crucial role in nutrition status. Limited access to clean water heightens the risk of waterborne diseases such as diarrhoea, which can impede nutrient absorption and exacerbate malnutrition, particularly in vulnerable populations such as children and pregnant women. Moreover, inadequate access to clean water promotes reliance on processed foods, exacerbating the challenges posed by the nutrition transition. Poor nutrition stemming from water access issues contributes to long-term health consequences and economic burdens. Therefore, addressing water access alongside promoting healthy dietary habits becomes imperative for improving nutritional outcomes and mitigating the negative impacts of the nutrition transition (Breewood, 2018).

Ecological Systems Theory

Ecological Systems Theory, proposed by Urie Bronfenbrenner, offers a holistic framework to understand the complex interplay between access to clean water and nutrition status. This theory posits that individuals are influenced by multiple interconnected systems, ranging from immediate environments such as households and communities to broader societal structures and cultural norms. In the context of clean water access, the theory emphasizes how ecological factors at different levels of influence can shape dietary practices, hygiene behaviours, and ultimately nutritional outcomes. At the microsystem level, household dynamics and intra-family relationships play a crucial role in determining access to clean water and the availability of nutritious foods. For instance, women and children often bear the responsibility of fetching water, and limited access to clean water may exacerbate their caregiving burden, affecting their ability to prepare and access nutritious meals (Rosa and Tudge, 2013).

The Household Health Production Theory

The household health production theory describes how households combine market goods and services with their individual time and capacities to produce health outcomes (Grossman, 1972). Clean, safe, reliable, and adequate water is an essential input in the household health production function as it is crucial for food preparation and the maintenance of proper hygiene and sanitation, both of which are critical for improving nutrition status and overall health (Miller et al., 2021). Access to clean water reduces the risk of waterborne diseases such as diarrhoea and cholera, which can lead to malnutrition, particularly among children, and affect the body's ability to use nutrients from food. Therefore, improved water access can indirectly enhance nutrition by promoting better nutrient utilization from food consumed within the household.

3.2 Water to Nutrition Pathways

Water security dimensions play a key role in addressing malnutrition by influencing the underlying causes of nutritional outcomes.

(i) Water, Health, and Hygiene: Inadequate access to safe drinking water has an implication on the ability of households to practice good hygiene and maintain a sanitary environment, thus exposure to water- and fecal-borne pathogens which are a cause of a variety of health ailments that are linked to undernutrition. Water insecurity might result in long-term exposure to pathogens, leading to chronic systemic immune activation, which in turn suppresses nutrient absorption and growth hormone production, and increases nutrient losses (Dewey et al., 2011). In addition, water contaminated with metals such as arsenic and lead can impact the cognitive and physical development in children.

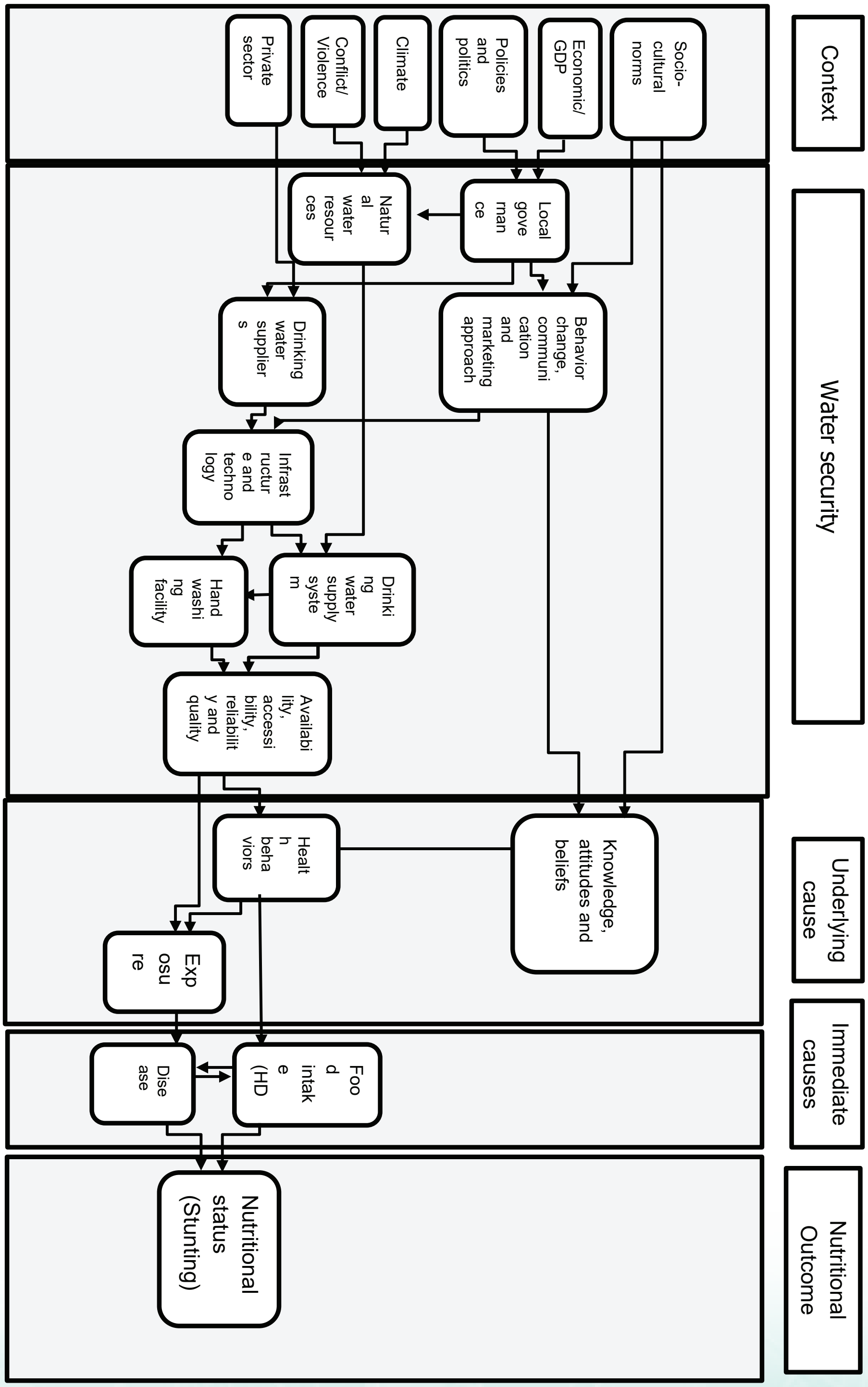
(ii) Water and Food Security: Water security is associated with each of the food security pillars (availability, access, stabilization, and utilization of food). This relationship may be bidirectional in that food systems are threatened by inadequate supply of quality water resources, whereas agricultural activity can diminish the quantity and quality of water resources.

(iii) Water and Care: Mothers and caregivers of the unborn and young children are expected to invest in healthy behaviours such as the provision of adequate nutrition, prompt health seeking behaviours and support early learning. Water insecurity limits the ability of caregivers to create nurturing environments for early child growth and learning through its impact on time use, educational attainment, mental and physical health, and livelihoods. Water insecurity and care are intrinsically linked with gender inequities as it disproportionately affects women and girls.

3.3 Water Security-Nutrition Conceptual Framework

The water security-nutrition framework presented in Figure 3.1 highlights the interconnectedness of various factors, from broad contextual elements to immediate causes affecting nutritional outcomes. It emphasizes the critical role of water security in improving child health and reducing stunting. Contextual factors such as economic growth and policies influence local governance and natural water resources, which are essential in shaping water security. Ensuring that water is available, accessible, reliable, and of good quality is crucial. This, along with the drinking water supply system and the availability of handwashing facilities, influences health behaviours. These factors, in turn, determine exposure to waterborne diseases and ensure access to better hygiene and food preparation, ultimately enhancing nutritional status and reducing stunting among children.

Figure 3.1: Water security and nutrition outcome



Source: Adopted from Zaval et al. (2021)

3.4 Evidence of the Effect of Water on Nutrition

The effect of WASH conditions on nutritional status is well documented, with available evidence indicating mixed results. Specifically, some studies have established that water, a key WASH variable, has an influence on various indicators of nutrition. Gaffan et al. (2023) sought to investigate the effects of household WASH conditions on nutritional status of children under five years. Using data from the Kenya Demographic and Health Survey, the study concludes that access to surface water increases the odds of stunting for the under five children by 1.35 times as opposed to access to basic water services. Mshida et al. (2018) reported similar results in a study assessing the association between WASH practices and nutritional status among the under-five years children from pastoral communities in Tanzania. The study found that children from households using surface water for domestic purposes were 13 times more likely to be stunted than children from households using tap water for domestic purposes after adjusting for water treatment at the point of use.

Liu, Balasubramaniam and Hunt (2015) in a study using individual level data from India Human Development Survey examined the relationship between physical access to water and nutritional status (BMI-for-age z-scores) of primary-aged children and noted that physical access to water decreased chances of being thin and extremely thin by 1 per cent. Anyanwu et al. (2022) investigated the association between WASH practices and nutrition indicators, mainly dietary diversity and mid upper arm circumference (MUAC) among pregnant and lactating women in Ethiopia. Using data from a longitudinal birth cohort study that focused entirely on a rural area, this study concluded that higher WASH score levels were associated with improvement in women's MUAC and dietary diversity.

In contrast, some studies do not find a significant effect of physical access to water on nutritional status. Bekele, Rahman and Rawstorne (2016) examined the effect of separate and combined WASH indicators on child nutrition outcomes. Applying the multivariable logistic regression models on the Ethiopian Demographic and Health Survey (EDHS), the study established that improved water and sanitation both separately and combined do not have an influence on under-five years children nutritional status, although combined water, sanitation and handwashing practices had a significant effect on child linear growth. van Cotet et al. (2019) conclude that WASH practice (access to water source and proper toilet facilities) was associated with lower incidences of wasting while access to water source and proper disposal of child waste was not associated with child malnutrition.

Other water qualities including reliability and adequacy could be the reason for the unobserved effect of water on nutrition. In a study to establish the association between nutrition practices and WASH infrastructure on nutritional status in a rural setting, Shretha et al. (2020) conclude that children from households with contaminated water (water with coliform bacteria in their drinking water sources) were nutritionally deficient compared to those with uncontaminated water sources. Null et al. (2018) conducted a cluster-randomized controlled trial to assess the relationship between WASH practices and nutrition practices on diarrhoea and child growth as indicated by length for age. While individual water, sanitation, and handwashing practices did not have any effect on a child's linear growth, a combination of interventions including water, sanitation, handwashing, and nutrition contributed to increased length among children in the control group.

Studies reveal that various household, parental, and child factors are associated with child nutrition status. Biological factors including a child's sex, child's age, mother's age, birth weight, parental height, and body mass index (BMI) have been reported to influence the status of stunting (Li et al., 2024; Karki et al., 2023). The maternal social determinants such as mother's education level and employment status, and household characteristics including place of residence and wealth index (Jo et al., 2024; Lai et al., 2024).

4 Methodology

4.1 Estimation Model

This study is based on the child health production function (Akin et al., 1992; Mwabu, 2007), which postulates that investing in certain inputs, which may include water, sanitation and hygiene, can lead to improved health outcomes for children. Notably, socio-economic factors also affect health outcomes of the children and thus need to be considered in modeling the child health production function (Mosley, 1984).

The general child health production function is as presented in equation 4.1:

$$H_c=f(W,P,Z,O) \tag{4.1}$$

Where H_c is the child health status as indicated by child nutritional status, which is measured by stunting. W is the key variable of interest, which measures physical accessibility; quality (clean and safe water); affordability (use/accessibility); adequacy (availability) and reliability (stability) of water. *P* represents the pathways linking water to nutrition and includes household dietary diversity and availability of a hand washing facility. *Z* are the household characteristics, including area of residence, household size and poverty status. O are other control variables including child and maternal characteristics.

The study applied the probit model to compute the probabilities of stunting prevalence given the status of a household's water physical accessibility, quality, affordability, adequacy and reliability and other control variables. This was done in three steps: In the first step, a probit regression was estimated on the relationship with water-related characteristics (physical accessible, affordable, quality, reliable and adequate). The second step includes the proxies for water to nutrition pathways, namely household dietary diversity and availability of a hand washing facility. The third step includes the control variables in the analysis.

In this probit model, we assume that the probability of a child being stunted is determined by an underlying latent variable Y^* representing the true stunting status. The disturbance term of this latent variable is normally distributed with mean zero and a constant variance, which is typically normalized to 1 for identification.

The probit estimation model is represented below:

$$Y=\beta X+\varepsilon \tag{4.2}$$

Where $Y=1$ if $Y>0$ and $Y=0$ if $Y\leq0$

The dependent variable *Y* takes the value 1 if the child is stunted and 0 otherwise. β is a vector of unknown parameters, *X* is vector of observed independent variables that include water-related characteristics, household characteristics, child, and maternal characteristics, ε is the unobserved factors that have an effect on child nutritional status.

Therefore, the probit model is denoted as follows:

$$Prob\ (Y=1|X=f(X'\beta) \tag{4.3}$$

Given that the probit model is inherently nonlinear in its coefficients, its estimated parameters do not by themselves represent the marginal effects of the explanatory variables on the dependent variables. Instead, the marginal effects of the regressors X, on the probabilities were obtained by taking the derivative of the function at the probability of the occurrence of stunting.

$$\partial\, prob\,(Y=1)/\partial X=\partial f(X'\beta) \qquad (4.4)$$

Since the occurrence of stunting is a dummy variable, we compute the difference in probability of the dummy taking value 1 and value 0 as indicated in equation 4.5 below.

$$1|X)=Prob(X,X_j=1)-prob(X,X_j=0) \qquad (4.5)$$

4.2 Definition and Measurement of Variables

Dependent variable

The outcome variable in this study is child nutritional status as measured by stunting; that is, height-for-age z-score, among the under-five years children. The z-score is calculated as the difference between individual child's height and the reference population median height divided by the standard deviation of the international reference population of the same age and gender. A z-score of minus 2 standard deviations (-2 SD) is used as a cut-off point for all nutrition status where those children whose height-for-age z-scores is below the cut-off are said to be stunted or too short for their height. Thus, the dependent variable is equal to 1 when stunted and zero otherwise.

Independent variables related to water

Water physical accessibility

Access to safe water is defined as non-discriminatory physical access to a water source within a 30-minute cycle, including queuing, and a round-trip distance of up to 2 kilometres (WHO, 2014; WHO and UNICEF, 2000; WASREB, 2018). This study focuses on a population whose primary water source is piped water supplied by authorized Water Service Providers (WSPs), available within their dwellings, yards, plots, or at public fountains/standpoints. If the round-trip distance to the piped water source is less than 2 kilometres and the time taken is under 30 minutes, the household is classified as "physically accessible." Otherwise, it is classified as "physically inaccessible." This water accessibility variable is constructed as a binary variable, where 1 indicates physical accessibility and 0 indicates lack of accessibility.

Quality water (clean and safe water)

Access to "improved sources" does not guarantee the provision of "safe drinking-water". Three factors, that is water storage; risks specific to piped water supplies; and household water management practices may affect the microbial safety of improved water sources (Shaheed et al., 2014). Unsafe water, sanitation and hygiene contributes to the burden of illness including diarrhea, cholera and dysentery. WASREB provides guidelines and standards for water quality and requires the Water Service Providers to conduct quality tests, including: Chemical Analysis -assessing the presence and levels of chemicals such as chlorine, fluoride, nitrates, arsenic, lead, and other contaminants; microbiological analysis - testing for bacteria, viruses, and other microorganisms to ascertain the potability of the water; physical analysis - examining physical attributes such as colour, odour, and turbidity to ensure aesthetic quality; Taste and Odor Analysis - evaluating taste and odour to ensure acceptability for consumption; pH and Hardness Testing - measuring acidity, alkalinity (pH), and water hardness to determine suitability for various uses; residual chlorine testing-checking for sufficient chlorine levels to disinfect the water effectively; and quality monitoring - regularly monitoring water quality at different distribution points to detect any fluctuations or issues. The WSPs conduct water quality tests, categorizing water as of acceptable quality if it scores 95 per cent or above.

Water scoring below 95 per cent is deemed unacceptable. Therefore, this study measures safe and clean water (quality water) as a binary variable, where "1" indicates acceptable quality and "0" indicates unacceptable quality.

Water affordability

The concept of water affordability extends beyond the mere provision of water services to consider whether the cost of accessing water is reasonable and manageable for individuals and households. Affordability is closely linked to the financial capabilities of individuals and households, emphasizing the need for water pricing that guarantees access for all, irrespective of socio-economic status (Bukachi et al., 2021). In the Kenyan context, water affordability is defined as water that is regulated, with the cost not exceeding 5 per cent of household income at maximum (WASREB, 2018). In this study, water affordability variable is computed by dividing the reported volume of water at the household level by 1,000 cubic metres to obtain the number of units. The units are then multiplied by the tariffs charged by water service providers to obtain the cost of water and sewerage. The total cost is then computed as a proportion of the total household's consumption expenditure and the variable constructed as a dummy where less than 5 per cent of the total household consumption expenditure equals to 1, and 0 otherwise.

Reliability of water supply

The concept of water reliability encompasses ensuring a constant and predictable availability of water resources in terms of both quantity and quality. This assurance relies on the stability of water infrastructure, including well-maintained pipelines, storage facilities, and distribution networks, which ensures uninterrupted water delivery. A reliable water system is resilient to various shocks and stresses, such as climate-related changes and natural disasters, guaranteeing continuous water supply even in adverse conditions. Effective management and governance, encompassing proper planning, allocation, and sustainable utilization of water resources, are pivotal components of water reliability (Karamouz et al., 2013). WASREB defines water reliability as an average of at least 12 hours of service per day. Information on water reliability is collected by the Water Service Providers and reported to WASREB. This study adopts this definition of water reliability and constructs the reliability variable as 12 hours of service and above equals '1' and less than 12 hours equals to '0'.

Water adequacy

The concept of water adequacy for household use is connected to the element of availability and entails a continuous supply of an amount sufficient for drinking, food preparation, personal and household hygiene and washing. The quantity of water available for domestic use influences hygiene and promotes good health. The recommended amount of water required to meet basic level of health and survival needs is at least 50 litres per person per day (WHO, 2023). WASREB domesticates this variable and categorizes it into below 20 litres per person per day, 20-49 litres per person per day, and 50 litres and above per person per day, which is adopted in this study and the variable is coded as below 20 litres=1, between 20 and 49 litres=2 and 50 litres and above=3.

Water to nutrition pathways variables

Dietary diversity

Better water access has an influence on availability and consumption of a variety of food groups and in turn may enhance nutrition outcomes. This study includes a variable on dietary diversity among the under five years children as one of the pathways to the link between a household's access to water and child nutritional status. The World Health Organization recommends that children aged between 6 and 59 months should consume at least five out of eight food groups, which include breast milk, grain/roots, pulses/legumes, dairy products, flesh foods, eggs, vitamin A-rich food, and other fruits and vegetables. The dietary diversity is a continuous variable indicating the number of food groups consumed on average by the under-five years in 7 days.

Handwashing facility

Inadequate access to clean water may lead to poor sanitation and hygiene practices, which may contribute to illnesses such as diarrhoea and intestinal infections in children (Checkley et al., 2008; Humphrey, 2009) and in the end enhance stunting prevalence (Prüss-Üstün et al., 2019; Spears et al., 2013). To measure this pathway, the study includes availability of hand washing facility in or near the toilet coded as 1 if available and 0 otherwise.

Control Variables

Child age and sex

Because this is a critical time for growth and development, stunting is more common in younger children, especially those under the age of two (Black et al., 2013; Prendergast and Humphrey, 2014). We include the age of children as a continuous variable measured in months.

Boys and girls may have different risks of stunting due to biological differences and different care practices. However, variations in the prevalence of stunting among the sexes can vary depending on the population and region (Dewey and Begum, 2011; Victora et al., 2010). The sex variable is included as a control and coded as "1" if male and "0" if female.

Mother's age

Maternal age is positively related to child nutritional status, since older mothers have experiences in attending to their children's health needs (Finlay, Özaltin and Canning, 2011). In this study, a mother's age is measured in years. The study also includes the square of mother's age to check for the possibility of an inverted u-shaped relationship between this variable and stunting status.

Mother's educational level

Maternal education is a significant predictor of child health and nutrition (Victora et al. 2010). Higher levels of maternal education have been linked to improved healthcare-seeking behaviour, better feeding practices, and greater knowledge of child nutrition and hygiene (Alderman et al., 2006; Fink et al., 2017). Mothers with lower levels of education may be less aware of best practices for childcare, leading to poor feeding, hygiene, and healthcare-seeking behaviours that contribute to stunting (Black et al., 2008; Cleland et al., 2006). The mother's educational level is constructed as a dummy variable; below secondary =0 and secondary school and above=1.

Overall poverty

Poverty has a significant impact on the prevalence of malnutrition among children under five years old. Households whose monthly adult equivalent total consumption expenditure per person is less than Ksh 3,252 in rural areas and less than Ksh 5,995 in urban areas are considered to be overall poor or live in "overall poverty". Construction of the variables resulted in a dummy variable where 1=Yes if a household is living below the poverty line and 0=No if a household is living above the poverty line.

Area of residence

Rural areas have higher stunting rates than urban areas due to factors such as limited access to healthcare, sanitation facilities, and a variety of food sources (Smith et al., 2017; UNICEF, 2020). Urbanization may increase access to healthcare, education, and sanitation, resulting in lower stunting rates (Fink et al., 2019). However, urban poverty and environmental factors can still contribute to stunting (Ruel and Alderman, 2013; UNICEF, 2020). We include area of residence as a control variable constructed as dummy indicator where rural=1 and urban=0.

Household size

Larger household sizes can put a strain on available resources such as food, water, and sanitation facilities, resulting in inadequate nutrition and an increased risk of stunting in children (Alderman and Garcia, 1994; Smith and Haddad, 2000; Dangour et al., 2013). However, the relationship between household size and stunting is complex and context-dependent, with factors such as socio-economic status, caregiving practices, and cultural norms within households all having an impact on the status of nutrition (Fink et al., 2016; Vyas and Kumaranayake, 2006; Corsi et al., 2017). The control variable is continuous and is measured as the number of members in a household.

Table 4.1: Summary of the study variables

Variable	Definition
Independent Variable	
Nutritional status	Dummy (stunted/low height-for-age=1; Not stunted=0)
Key Explanatory Variables	
Water accessibility	Dummy (accessible (less than 2km round trip and time taken is less than 30 minutes=1; not accessible (more than 2km round trip and more than 30 minutes=0)
Water quality (clean and safe water)	Dummy (water of acceptable quality=1; water quality not acceptable=0)
Water affordability	Dummy variable; Water and sewerage cost not more than 5 per cent of the household consumption expenditure=1, 0 otherwise)
Water reliability	Dummy variable; more than 12 hours minimum service hours=1; 0 otherwise)
Water adequacy	Categorical variable (below 20 litres per person per day=1; 20 to 49 litres per person per day=2; 50 litres and above per person per day=3)
Pathways	
Dietary diversity	Continuous variable measured as number of food categories consumed
Hand washing facility	Dummy (Handwashing facility available=1; 0 otherwise)
Control Variables	
Child age	Continuous variable measured in months
Child sex	Dummy (Male=1; Female=0)
Mother’s age	Continuous variable measured in years
Mother’s age squared	Mother’s age in years squared
Mothers’ education	Dummy (below secondary level=0; Secondary and above=1)
Poverty status	Dummy: (Overall poor=1, non-poor=0)
Area of residence	Dummy: Rural=0, urban=1

Household size	Continuous variable measured in number of members in the household

Source: Author's Computation

4.3 Data Sources

The study used two datasets from Kenya Integrated Household and Budget Survey (KIHBS) 2015/16 and the administrative data from WASREB to analyze the status of household's access to clean and safe water, reliable water supply, water quality and affordability and their association to under-five years nutritional status as measured by stunting. The KIHBS survey collected data on various characteristics, including individual child and maternal characteristics and socio-economic characteristics, household characteristics and anthropometric measures. The WASREB data collects information on water tariffs charged by the regulated water service providers, water service hours, which is an indicator of water reliability and water quality as determined by water quality tests. Based on the data and information collected, WASREB publishes impact reports on regulated Water Service Providers (WSPs) to aid in analyzing the specific indicators within the service areas of operation of the WSPs in relation to affordability, reliability, quality and adequacy of supply.

The two data sets (KIHBS and WASREB) were merged using location identifiers (KIHBS dataset by household and areas served by WASREB) to a single file with all the variables used in the study. This enabled the construction of the affordability, reliability and quality variables, which were linked to the households in the KIHBS data. The target population for the study were children under five years living in households whose main source of water is piped (into dwelling, yard or plot or public standpoint).

4.4 Descriptive Statistics

This section presents the summary statistics of the study sample, which consists of children under five years living in households with piped water. The study variables include child and maternal characteristics; information on water accessibility, quality, affordability, reliability, and adequacy; household-related characteristics such as poverty status and household size. The results in Table 4.2 show that 26 per cent of the children under five years were stunted, with a mean age of 33.2 months. The distribution of male and female children was equal at 50 per cent. The mothers of the children under five years had a mean age of 31.72 years, and the majority (62%) had an education level below secondary school. The average household size is 6 members implying a relatively large household. Further analysis reveals that most households with children under five are rural-based (63%), and 38 per cent of these households are poor.

Considering the water characteristics, 86 per cent of the households are accessible to water sources within a round trip distance of less than 2 kilometres and within 30 minutes. This could be explained by the study's focus on a population that already has piped water. Even so, it is important to note that about 14 per cent of households with piped water cannot obtain water within 2 kilometres or within 30 minutes, indicating that this population lacks basic water services. While there is progress in ensuring access to safe drinking water, the proportion of households relying on water sources deemed not acceptable in terms of quality stands at 42 per cent. Water is affordable and reliable for 94 per cent and 90 per cent of the households, respectively. A larger proportion (69%) have access to less than 20 litres per person per day, while those with water access between 20 and 49 litres and 50 litres and above were 27 per cent and 4 per cent, respectively. Cumulatively, 96 per cent of the households do not meet the World Health Organization's recommendation of a minimum of 50 litres of water per person per day. Overall, in assessing the water characteristics, we note that despite having access to improved sources, such as piped water, issues of water quality and adequacy persist.

The findings indicate a low level of hygiene in households with children under five years old, as only 17 per cent of these households had a handwashing facility. On average, these households had a mean dietary diversity score of 9.56, reflecting diverse diets and the potential to meet the recommended dietary diversity standards for children aged 6 to 59 months (Kathryn, 2003).

Table 4. 2: Sample characteristics

Variables	N	Mean	Standard Deviation	Min	Max
Water characteristics					
Water accessibility (Accessible=1)	4,935	0.86	0.34	0	1
Water quality (Acceptable=1)	3,794	0.58	0.49	0	1
Water affordability (Affordable=1)	4,703	0.94	0.24	0	1
Water reliability (Reliable=1)	3,791	0.90	0.30	0	1
Water adequacy					
Adequate=<20 litres	5,356	0.69	0.46	0	1
Adequate=20-49 litres	5,356	0.27	0.44	0	1
Adequate=>50 litres	5,356	0.04	0.19	0	1
Child Characteristics					
Stunting status (stunted=1)	5,373	0.26	0.44	0	1
Child age in months	5,373	33.18	15.27	6	59
Child sex (Male=1)	5,373	0.50	0.50	0	1
Mother's characteristics					
Mother's age in years	5,341	31.72	9.32	11	95
Mother's age squared	5,341	1,093.09	722.72	121	9,025
Mother's level of education (secondary and above=1)	5,342	0.36	0.48	0	1
Household Characteristics					
Household size	5,373	6.48	2.63	2	28
Area of residence (Urban=1)	5,373	0.37	0.48	0	1
Poverty status (Overall poor=1)	5,373	0.38	0.49	0	1
Pathways					
Handwashing facility (Available=1)	5,277	0.17	0.38	0	1
Household dietary diversity score (HDDS)	5,367	9.56	1.70	1	12

Source: Author's Computation

The summary statistics in Table 4.3 show that most households in both rural and urban areas experienced a reliable water supply and could afford water costs. However, there is a rural urban divide in water accessibility, quality, and adequacy. Among rural households, 17 per cent did not have access to within 2 kilometres round trip and collection time of 30 minutes compared to about 4 per cent of the urban population. This mirrors the current situation in the country, where a large portion of the rural population lacks access to basic drinking water services, which refers to drinking water from improved water sources located on the premises or with a round trip collection time of 30 minutes or less (KNBS and ICF, 2023). The proportion of the population with water of unacceptable quality was higher in rural areas (47%) compared to urban areas (36%). Water adequacy was also a more significant issue in rural areas, with 65 per cent of the rural population having less than 20 litres of water per person per day, compared to 62 per cent of the urban population.

The analysis of water characteristics by poverty status reveals observable disparities in water accessibility, quality affordability, reliability and adequacy between non-poor and poor households. Most households have accessible water, with non-poor households (88.5%) having better access than poor households (82.5%). Additionally, more than half of the poor households (54.6%) receive water of unacceptable quality compared to non-poor households (49.3%). Although most households can afford water costs, a higher percentage of poor households (10.5%) spend more than 5 per cent of their income on water compared to non-poor households (3.6%), indicating a greater financial burden on the poor. The reliability of water supply is a greater issue for poor households (24.9%) compared to non-poor households (18.2%). Non-poor households (65.8%) have slightly better water adequacy compared to poor households (57%). Only a small fraction of households (2%) receive 50 litres or more per person per day, with non-poor households (3.5%) being more likely to meet this threshold. These insights highlight the need for targeted interventions to address the water security issues faced by poor households.

Table 4.3: Water-related characteristics by residence and poverty status

Water Characteristics	Area of residence			Poverty Status		
	Rural (%) (n=3310)	Urban (%) (n=2032)	Total (%) (N=5342)	Non-poor (%) (n=3337)	Poor (%) (n=2036)	Total (%) N=5,373
Water Accessibility						
No	17.90	3.60	12.50	11.5	17.5	13.9
Yes	82.10	96.40	87.50	88.5	82.5	86.1
Water Quality						
Not acceptable	46.90	36.20	41.60	49.3	54.6	51.1
Acceptable	53.10	63.80	58.40	50.7	45.4	1,856
Water Affordability						
Exceed 5%	7.40	4.60	6.10	3.6	10.5	6.1
5% and below	92.60	95.40	93.90	96.4	89.5	93.9
Water Reliability						
No	9.60	9.10	9.30	18.2	24.9	20.4
Yes	90.40	90.90	90.70	81.8	75.1	79.6
Water Adequacy						
<20 litres	64.90	61.50	63.40	65.8	57.0	80.2
20-49 litres	31.20	33.50	32.20	30.7	38.5	17.8
=>50 litres	3.90	5.10	4.40	3.5	1 4.5	2.0

Source: Author's Computation

Distribution of child stunting based on water, individual and household characteristics

The bivariate analysis results presented in Table 4.4 show that there was a significant relationship between stunting among the under-five years and water accessibility (P = 0.0008) and water adequacy (P=0.0006). This implies that there is a relationship between these water characteristics and stunting prevalence. Other variables that had a significant relationship with child stunting were mother's level of education, child sex, household poverty status and area of residence and availability of a handwashing facility. The means for household dietary diversity, household size and mother's age are statistically different between the rural and urban based households.

Table 4.4: Bivariate analysis of stunting by selected explanatory variables

Variables	Stunting status			
	Not stunted	**Stunted**	**Total**	**p-value**
Water Accessibility				
No	491 (13.28)	194 (15.66)	685 (13.88)	P=0.0008
Yes	3205 (86.72)	1045 (84.34)	4250 (86.12)	
Water Affordability				
No	204 (5.73)	81 (7.1)	285 (6.06)	P=0.2940
Yes	3358 (94.27)	1060 (92.9)	4418 (93.94)	
Water Reliability				
No	579 (20.15)	195 (21.26)	774 (20.42)	P=0.1048
Yes	2295 (79.85)	722 (78.74)	3017 (79.58)	
Water Adequacy				
<20 litres	2607 (64.35)	916 (70.19)	3523 (65.78)	P=0.0006
20-49 litres	1292 (31.89)	351 (26.9)	1643 (30.68)	
>50 litres	152 (3.75)	38 (2.91)	190 (3.55)	
Water Quality				
Not Acceptable	1458 (50.59)	480 (52.63)	1938 (51.08)	P=0.7838
Acceptable	1424 (49.41)	432 (47.37)	1856 (48.92)	
Child Sex				
Male	1987 (48.84)	728 (55.79)	2715 (50.53)	P=0.0005
Female	2081 (51.16)	577 (44.21)	2658 (49.47)	
Mother's Education Level				
Below secondary	2611 (64.64)	959 (73.6)	3570 (66.83)	P=0.0000
Secondary and above	1428 (35.36)	344 (26.4)	1772 (33.17)	

Handwashing Facility Available				
No	3404 (85.01)	1121 (88.06)	4525 (85.75)	P=0.0000
Yes	600 (14.99)	152 (11.94)	752 (14.25)	
Area of Residence				
Rural	2431 (59.76)	900 (68.97)	3331 (62)	P=0.0054
Urban	1637 (40.24)	405 (31.03)	2042 (38)	
Live in Overall Poverty				
Non-poor	2622 (64.45)	715 (54.79)	3337 (62.11)	P=0.0000
Overall poor	1446 (35.55)	590 (45.21)	2036 (37.89)	
Household Dietary Diversity	9.5 (0.02)	9.15 (0.03)		-0.36* (0.000)
Mother Age in Year	31.12 (0.11)	30.3 (0.19)		-0.83* (0.000)
Mother's age in year squared	1058.9 (8.76)	1001.21 (14.61)		-57.7* (0.001)
Household size	5.64 (0.03)	5.96 (0.04)		0.33* (0.000)
*t-test results				

Source: Author's Computation

5 Results and Discussion on Effects of Water Security on Nutrition

This section presents findings from the probit regression analysis. Multicollinearity tests were conducted, and an acceptable variance inflation factor (VIF) value of below 2.5 was achieved for each explanatory variable, indicating low correlation among the variables being tested. The model's goodness of fit was also assessed through the Hosmer-Lemeshow test, using a conventional significance level of 0.05. A p-value below this threshold obtained in this test would suggest inadequate fit of the model to the data. Despite this, the model's overall performance was deemed acceptable, supported by the low VIF values and the absence of severe multicollinearity.

In the first step, analysis was undertaken to establish the effect of the variables related to water, namely physical accessibility, affordability, quality, reliability, and adequacy on stunting. Table 5.1 presents the marginal effects from the probit regression. In the water characteristics only regression model, water accessibility and adequacy were significant determinants of stunting in the under-five years children. The findings show that having access to water decreases the probability of stunting in children under five years by 7.5 percentage points as opposed to non-accessibility. Having adequate water significantly decreases the probability of stunting by 6.3 percentage points for households receiving 20-49 litres per person as opposed to those below 20 litres per person per day. However, the effect of having 50 litres and above per person per day did not have a significant effect of stunting among the under five children years and above when compared to those with below 20 litres per person per day. Other water characteristics, namely reliability, affordability, and quality have a potential to reduce stunting among the children aged below five years, but were not statistically significant.

In the next steps, we estimated the effect of water-related characteristics on stunting in children under five years, while controlling for water-nutrition pathways (model 2) and other control variables (model 3). The findings show that water adequacy remains statistically significant across these models. Interpreting the results in model 3, households with access to 20 to 49 litres of water per person per day had a 6.3 per cent lower probability of stunting among children under five years compared to households with less than 20 litres per person per day. The effect of having 50 litres or more per person per day is not statistically significant, possibly due to the smaller sample size for this group, which comprises only 3.75 per cent of the sample (Jorge and Lilian, 2014). The significant effect of water adequacy can be explained by the fact that insufficient water for cooking, drinking, and sanitation increases the risk of waterborne diseases such as diarrhoea, which is a known cause of stunting (Septiyani et al., 2021). Additionally, an inadequate water supply can reduce a household's food intake and alter their diets, leading them to opt for less nutrient-dense or more highly processed alternatives (Venkataramanan et al., 2020). These findings support the call by the World Health Organization (2018) to address stunting through provision of clean and sufficient water.

The significant effect of water physical accessibility disappears with addition of control variables, implying that while water physical accessibility plays a crucial role in reducing stunting, its impact is somewhat mediated by other factors such as hygiene practices and nutritional diversity, underscoring the multifaceted nature of addressing childhood stunting.

Among the control variables, a child's age, mother's education level and poverty status were associated with stunting status of the under five children. Each additional month of a child's age reduces the probability of stunting by 0.1 percentage points. A child's age has been identified as a risk factor for stunting, with various studies pinpointing different ages at which stunting is more prevalent (Quamme and Iversen, 2022; Obasohan, 2022)

Female children had a 4.8 percentage points lower probability of being stunted compared to male children. Children whose mother's education level is secondary school and above had a lower probability of stunting by 7.1 percentage points when compared to those with primary level of education and below. The finding aligns with other studies; for instance, Gewa and Yandell (2011) established that a male child had a higher prevalence of all forms of undernutrition, possibly due to biological, inherent, and environmental factors.

The findings suggest that in a household where the mother's education is secondary level and above, the probability of stunting prevalence is lower by 7.1 percentage points. An under five years child in a poor household has a higher chance of being stunted by 6.0 percentage points as opposed to a child who is in a non-poor household. Both education and wealth status reflect the socio-economic status of a household and affect a child's nutrition through various channels, including increased access to food and healthcare resources, better leaving conditions, and WASH knowledge (Gewa and Yandell, 2011). Several studies conducted in Kenya and Sub-Saharan African region corroborate the impact of these socio-economic indicators on the nutritional status of children (Mohammed et al., 2019; Guyatt et al., 2020; Adeladza, 2009).

Table 5.1: Marginal effects after probit estimation of determinants of under five stunting status

Model	(1)	(2)	(3)
	Marginal Effects (Water related characteristics only)	Marginal Effects (Water related characteristics and pathways)	Marginal Effects (All regression variables)
Water Accessibility			
Yes	-0.075** (0.033)	-0.062* (0.034)	-0.039 (0.032)
Water Affordability			
Yes	-0.015 (0.052)	-0.008 (0.053)	0.014 (0.052)
Water reliability			
Yes	-0.036 (0.038)	-0.041 (0.038)	-0.035 (0.039)
Water Adequacy (reference group =<20 litres)			
20-49 litres	-0.083*** 0.023)	-0.083*** (0.023)	-0.063** (0.025)
>50 litres	-0.083* (0.049)	-0.081 (0.050)	-0.054 (0.053)
Water quality			
Acceptable	-0.005 (0.024)	0.000 (0.024)	0.007 (0.024)
Household dietary diversity score (HDDS)		-0.011*(0.007)	0.000 (0.007)
Handwashing facility available			
Yes		0.030 (0.041)	0.039 (0.040)

Child age in months			-0.001* (0.001)
Mother's age in year			0.003 (0.005)
Mother's age in year squared			-0.000 (0.000)
Total household members			0.004 (0.005)
Sex of the child			
Female			-0.048** (0.023)
Mothers level of Education			
Secondary and above			-0.071*** 0.024)
Overall poverty status			
Overall poor			0.060** (0.029)
Area of residence			
Urban			-0.029 (0.025)
Observations	3,364	3,358	3,357
Standard errors in parentheses; *** p<.01, ** p<.05, * p<.1 Model 1: water predictors only Model 2: water predictors and pathways Model 3: water predictors, pathways and controls			

Source: Authors' Computation

Further, in the analysis, we assessed the differential factors associated with under-five stunting in rural and urban regions. Interestingly, while the association between water adequacy and stunting was evident when analyzing both urban and rural areas together, it remained significant only in rural areas when examined separately. The results presented in Table 5.2 show that children in rural households with 20-49 litres of water per person per day had a 17.8 per cent lower probability of stunting compared to those with below 20 litres of water per person per day. This finding could be explained by disparities in water accessibility and adequacy, which are more significant issues in rural areas.

Other variables that were found to increase the risk of stunting among children under five years in rural areas included maternal education, poverty status, and child sex. Again, the significant effect of maternal education and household poverty status could be attributed to their distribution, as mothers with lower levels of education and poor households are predominantly located in rural areas. Household size was significant for urban-based households, implying that an increase in family size by 1 member increases the chance of under-five stunting.

Table 5.2: Marginal effects after probit estimation of determinants of stunting prevalence in rural and urban regions

Variable	Marginal Effects (Urban)	Marginal Effects (Rural)
Water accessibility		
Yes	0.082 (0.296)	0.137 (0.099)
Water Affordability		
Yes	-0.181 (0.317)	0.145 (0.168)
Water Reliability		
Yes	-0.032 (0.235)	-0.149 (0.109)
Water Adequacy		
20-49 litres	-0.219 (0.146)	-0.178** (0.083)
>50 litres	-0.539 (0.422)	-0.020 (0.196)
Water Quality		
Acceptable	-0.116 (0.151)	0.102 (0.078)
Household Dietary Diversity Score	-0.004 (0.046)	0.003 (0.025)
Handwashing facility available		
Yes	0.094 (0.198)	0.188 (0.125)
Child age in months	-0.000 (0.004)	-0.006** (0.002)
Mother age in year	-0.005 (0.041)	0.012 (0.017)
Mother age in year squared	-0.000 (0.001)	-0.000 (0.000)
Household size	0.066* (0.039)	-0.006 (0.017)
Child sex		
Female	0.066 (0.143)	-0.293*** (0.072)
Mother's education level		
Secondary and above	-0.219 (0.143)	-0.230** (0.084)
Overall poverty Status		
Overall poor	0.030 (0.170)	0.283*** (0.091)
Constant	-0.537 (0.921)	-0.352 (0.415)
Observations	1,218	2,139
Standard errors in parentheses; *** p<.01, ** p<.05, * p<.1		
Model: water predictors, pathways and controls		

Source: Author's Computation

6 Conclusion and Policy Recommendations

This study examined the association between water security—indicated by water accessibility, affordability, reliability, quality, and adequacy—and stunting among children under five living in households with piped water regulated by WASREB. While the study population had access to improved water sources, physical accessibility, adequacy, and quality remained sub-optimal. Therefore, there is a need to move beyond the dominant view of 'access' as coverage to embrace "deep access," which entails a focus on other aspects of water security, including availability and affordability, especially in rural areas.

The regression results reveal that having adequate water could significantly reduce stunting among children under five years. This underscores the importance of ensuring that WHO-recommended water standards of 50 litres and above per person per day are met. Additionally, other variables crucial in reducing stunting among children under five include child sex, maternal education level, and poverty status. Overall, the findings suggest that targeted interventions focusing on improving water adequacy, maternal education, and household welfare could significantly reduce stunting rates among children under five in Kenya.

Therefore, the study recommends that the government, in collaboration with non-state actors, implement strategies to enhance water security, improve maternal education, and support household welfare, ultimately reducing stunting rates among children under five in Kenya. The specific recommendations are as follows:

Invest in water infrastructure: Expand water capacity by developing new water resources and managing non-revenue water to address the needs of most of the population currently accessing less than 20 litres per person per day. This includes constructing new reservoirs, upgrading distribution networks, and implementing water-saving technologies. Public-private partnerships can play a crucial role in financing and managing these initiatives.

Strengthen the regulatory framework: Ensure compliance with water supply regulations within Water Service Providers (WSPs) to guarantee that water supply targets are met. This involves regular monitoring and enforcement of standards, promoting transparent reporting practices among WSPs, and establishing penalties for non-compliance. There is need to put more emphasis on equity and inclusivity in water supply to support the hygiene, cooking, and consumption needs of all households. Furthermore, developing robust feedback mechanisms from communities to regulators can ensure that the water supply system remains responsive to the needs of all population segments.

Improve physical access to water: The Ministry of Water, Sanitation, and Irrigation should adopt a comprehensive approach, which includes constructing additional water points such as boreholes, wells, and community taps to increase the availability of improved water sources. Upgrading and repairing existing water infrastructure is also essential to ensure its functionality and reliability. Extending water distribution networks to reach more remote and underserved areas will help provide broader coverage. The goal is to ensure that every household has access to water within a 1-kilometre radius and within 30 minutes, particularly in rural areas. This strategy will significantly enhance both the availability and reliability of water sources.

Boost investment in quality water: This entails constructing large and small-scale reservoirs to ensure steady water supply, expanding, and upgrading water distribution networks, and implementing pressure management systems to optimize water flow. Investing in advanced water technologies, such as new treatment and desalination plants, and smart water management systems, is crucial. Additionally, enhancing water conservation and recycling through greywater recycling, rainwater harvesting, and public awareness campaigns is essential. Developing integrated water management policies, establishing regulatory frameworks, fostering public-private partnerships, and involving communities through local water committees and training programmes will ensure sustainable and equitable access to quality water for all regions.

Enhance access to basic education: It is crucial to prioritize vulnerable groups by implementing targeted support programmes, flexible learning options, community engagement efforts, safe and inclusive learning environments, access to healthcare and nutrition, empowerment programmes, and robust monitoring and evaluation mechanisms. While commendable initiatives such as achieving a 100 per cent transition to higher education and readmitting teenage mothers to school should be fully implemented, supplementing them with these measures will ensure that all children, regardless of background, have equal opportunities to access quality education and build a brighter future.

Improve targeting of poor households: Focus on programmes that not only provide immediate assistance but also support long-term sustainability and empowerment. This involves prioritizing initiatives that facilitate income-generating activities for vulnerable households while simultaneously promoting the education of children within these families. Implementing targeted cash transfer programmes can offer direct financial support, enabling families to meet their basic needs and invest in income-generating ventures.

Address declining per capita consumption: Despite growth in billed volumes and hours of supply, per capita consumption has been declining. This trend suggests that utilities prioritize commercial consumption over domestic consumption, undermining the right to water as a basic human right (WASREB-15). There is need therefore to refocus on adequate domestic water supplies to support the needs of the population.

Limitations of the Study

This study has the following potential limitations:

The study sample exclusively comprised households with access to piped water, potentially introducing selection bias and limiting the generalizability of the findings. By focusing solely on households with piped water, the study may have failed to capture the perspectives and experiences of households reliant on alternative water sources, such as wells or rivers, which could exhibit different socio-economic characteristics and face distinct challenges.

The study relied on reported information regarding the quality of water and reliability from the water service providers. This could introduce inaccuracies or biases in the reported information, as it may not fully capture the actual conditions experienced by households. Factors such as reporting errors, inconsistencies in data collection methods, or discrepancies in perceptions between providers and users could undermine the reliability and validity of the findings.

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