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Using Causal Loop Diagramming to Explore the WASH Challenges in Simanjiro District, Northern Tanzania: A System Thinking Approach in Humanitarian Settings

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Abstract **-** The Simanjiro District in northern Tanzania faces recurring challenges of drought and water scarcity, particularly during dry spells. The issues related to water, sanitation, and hygiene (WASH) are complex, and the conventional linear approaches have proved to be ineffective. This study aims to comprehensively understand the factors contributing to these challenges in five villages within the district. A systems thinking approach was employed, utilizing both primary and secondary data. Interviews, observations, water quality testing, and a questionnaire survey were conducted. Data collection involved unstructured interviews with government and traditional leaders, questionnaires distributed to the villages, and physical observations. Water samples from five villages underwent extensive laboratory analysis for various parameters. Results reveal that 93% of households rely on surface water, with limited access to public taps. The average distance travelled to water sources exceeds recommended standards, leading to the use of donkeys for transport. There is a significant regression between household size and water consumption. Simanjiro depends on unprotected surface water sources, posing health risks due to contamination. Most households lack awareness of the health implications of using contaminated water. Limited access to hand-washing facilities, improper waste disposal practices, and low confidence in water safety contribute to sanitation challenges. The study emphasizes the urgent need for improved water access and sanitation facilities in Simanjiro, as current conditions hinder health and impede development.

Keywords**:** Water, Sanitation, Hygiene, WASH, System thinking, Causal loop diagramming

1. Introduction

Water, Sanitation, and Hygiene (WASH) are vital for global well-being and development, impacting public health, environmental sustainability, and economic growth. Despite safe drinking water being recognized as a human right, many lack access to reliable sources, especially in low-income communities[1]. This scarcity, along with contamination and distribution challenges, leads to waterborne diseases and reduced quality of life[2].

Sanitation, including waste disposal and toilet facilities, is essential for disease prevention and preserving dignity. However, inadequate facilities result in widespread open defecation, causing health and environmental issues. Basic hygiene practices like handwashing are crucial for disease prevention but are inaccessible to millions[3].

The World Health Organization (WHO) reports that 2.2 billion people lack access to safely managed drinking water and sanitation services, disproportionately affecting vulnerable populations and leading to preventable deaths, mainly from waterborne diseases[4]. The United Nations recognizes the importance of WASH in its Sustainable Development Goals (SDG 6), aiming for universal access to clean water and sanitation to achieve multiple SDGs[3].

Despite abundant water resources, Africa faces challenges in providing reliable access due to inadequate infrastructure, contamination, and climate change[5]. Over 400 million and 779 million people struggle with water scarcity and insufficient sanitation facilities respectively, leading to waterborne diseases, poor hygiene, and social burdens[3].

In Simanjiro, Tanzania, there's a lack of research using systems thinking in the Water, Sanitation, and Hygiene (WASH) sector[6], [7]. However, Causal Loop Diagramming, as demonstrated by Ram and Irfan (2021), helps understand WASH obstacles[8].

Limited rainwater sources in Simanjiro undermine sanitation, hygiene, and productivity. Many rely on small, unprotected ponds shared by humans and livestock. Women's lack of decision-making power exacerbates challenges, with young girls and women traveling long distances daily for water[6].

Access to safe water remains inadequate, with many households depending on unreliable sources[9]. Non-functional water points exacerbate the problem, with some villages lacking water for human consumption during the dry season. Additionally, sanitation facilities are basic, contributing to WASH-related illnesses[6].

These challenges require immediate government attention[10]. Traditional policies aren't sufficient due to the complexity of the issues[8], [11]. Innovative approaches like System Dynamics, offer a way forward by comprehensively analysing WASH challenges and identifying effective solutions[8], [10]–[12].

To effectively tackle WASH challenges, non-linear approaches are essential, considering feedback processes and time delays[8], [12], [13]. Scholars emphasize the need to move beyond simplistic solutions and embrace complexity for better understanding and resolution.

2. Materials and methods

2.1. The study area

The focus of this study is Simanjiro District, situated in the northeastern region of Tanzania. It shares borders with Kenya, Kiteto district, Babati district, and Tanga region. Constituting part of the East African Rift Valley region, Simanjiro covers an area of 20,591 km2, characterized by semi-arid conditions with bimodal rainfall ranging from 400-600 mm[14].

With a population of 178,693, predominantly consisting of the Maasai ethnic group, the district is sparsely populated. The Maasai are known for their unique cultural heritage, reflected in their clothing and lifestyle. Their customary way of life involves semi-nomadic or nomadic practices, mainly focused on cattle rearing in acacia woodlands, thorny scrub, and grasslands[15].

The district's economy revolves around agriculture, with maize, beans, pigeon peas, wheat, and sunflower being the primary crops grown for commercial and consumption purposes. Livestock, particularly indigenous breeds, play a crucial role in the Maasai community's livelihoods and cultural identity[15].

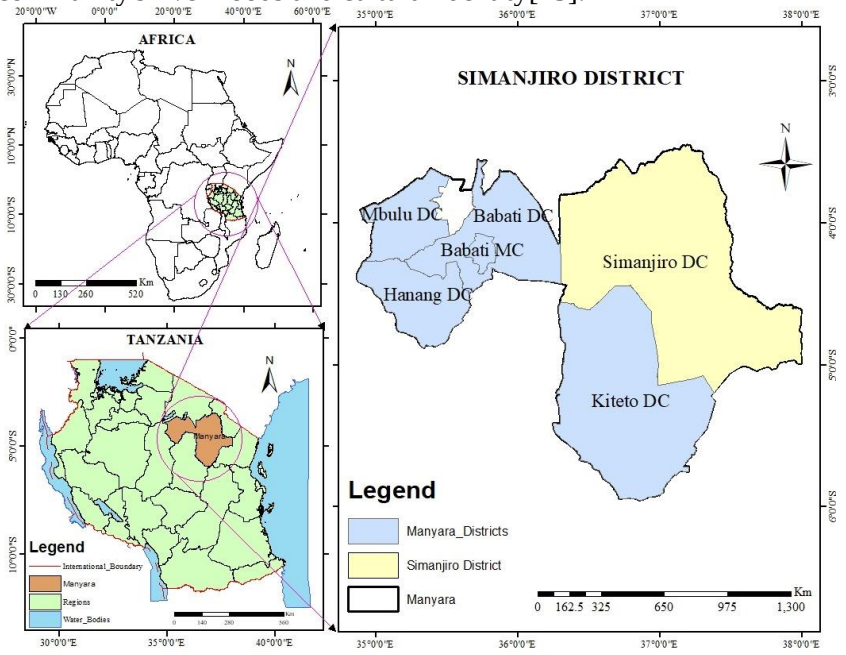

Figure 1: Simanjiro district.

2.2. Methods

Samples from five villages—Endonyongijape, Irkujit, Lormorijoi, Narosoito, and Orkurung'rung'—were sent to the the Manyara water quality laboratory for analysis. The laboratory examined various parameters, including physical (pH, Electrical Conductivity, Total Dissolved Solids, Color, and Turbidity), chemical (Total Alkalinity, Total hardness, Calcium, Calcium, Magnesium, Sulphate, Chloride, Iron, Manganese, Fluoride, Nitrate, Total Chromium, Sodium, Potassium, Phosphate, Copper, Ammonia, Nitrite, and Zinc), and biological (E. Coli and Total Coliform). Rigorous measures ensured reliability and accuracy, including sample replication, calibration, quality control, blank sample collection, chain of custody establishment, and adherence to quality assurance protocols.

Unstructured interviews with five government and traditional leaders provided insights into Water, Sanitation, and Hygiene issues, guiding decision-making by understanding leaders' perceptions and attitudes toward these critical matters.

140 questionnaires collected from the five villages focused on water quality, consumption, sanitation, and hygiene. Statistical techniques, considering gender, ensured precision, with participants over 18 providing anonymous responses to protect privacy.

A five-day observation during the dry season assessed living conditions, water quality, sanitation, and hygiene facilities in the five villages, complementing interviews and questionnaires to uncover additional issues.

Data from interviews, questionnaires, and observations were cleaned, analysed, and presented using Kobo collect tool and Microsoft Excel, with visual aids aiding in understanding relationships between WASH challenges and district issues.

Results were analysed, and causal loop diagrams (CLDs) were developed using Vensim software, serving as decision-making tools to understand water crisis challenges in the district, categorized into water, sanitation, and hygiene models.

The study obtained research permit No. 2023-803-NA-2023-863 from the Tanzania Commission for Science and Technology (COSTECH), ensuring participants' informed consent and confidentiality of their data.

3. Results and discussions

A survey of 140 households, found that most households were extended, with sizes ranging from 5 to 18 members. The average household size was 12 individuals. Participants surveyed were all adults over 18 years old, with ages ranging from 22 to 61 years old, and a mean age of 44 years.

The results indicate that 93% of households rely on surface water as their primary water source, while only 7% have access to public taps. The average distance travelled to reach these sources is approximately 5674.46 meters, taking an average of 334.1 minutes for a round trip. Unfortunately, these figures exceed the recommended standard of 1000 meters and 30 minutes set by the United Nations.

As a result, households often utilize donkeys to transport water over long distances. There is a significant regression between household size and water consumption, with a calculated F value of 2.8549E-39 and a p-value of less than 0.05.

The Simanjiro community relies on unprotected surface water sources, such as rivers and ponds, for a variety of activities, including drinking, domestic chores, and livestock keeping. Unfortunately, these sources are both inadequate and contaminated with high levels of turbidity, color, smell, nitrate, faecal coliform, and total coliform, posing a significant risk to public health.

Ponds in Simanjiro are used for both drinking and household purposes and are shared by various animals, including livestock and elephants. Water is primarily purified through boiling, as reported by 36% of surveyed households. Another 8% of households allow their water to settle before consumption, while 56% do not treat their water before consumption.

The suboptimal quality of water sources in Simanjiro is concerning, as 89% of surveyed households are unaware of the health implications associated with using contaminated water. Only 19% of households surveyed have access to hand-washing facilities, such as tippy taps, cups, and buckets. The majority of households, approximately 73.57%, dispose of child faeces in bushes. In comparison, only 15.71% of households have opted for waste pits to discard solid waste, while 12.1% have designated waste pits for liquid waste.

According to the collected data, 59.29% of individuals believe that diseases can be transmitted through contaminated water sources, and a staggering 97.14% of individuals lack confidence in the safety of the water they use. A significant

number of households, approximately 69%, have reported possessing a water storage facility. Many of these households rely on home treatment methods as their primary approach to managing instances of diarrhoea.

3.1. Water access models in Simanjiro

The model features a single input variable, rain, affecting surface water sources, and two output variables: and demand, creating a reinforcing feedback loop.

During the rainy season, substantial precipitation boosts surface water volume, providing resources for community domestic and agricultural needs.

Climate change worsens atmospheric conditions, elevating global temperatures and intensifying evaporation rates, thereby reducing water stock.

Unprotected surface water sources are vulnerable to contamination from faecal matter, turbidity, color, and nitrates. Protecting these sources is vital for maintaining water safety, particularly in regions relying on surface water.

Insufficient investment in water infrastructure and poor maintenance hinders water access, forcing women and girls to travel long distances. Lack of hygiene education and poverty result in untreated water consumption, contributing to contamination risks.

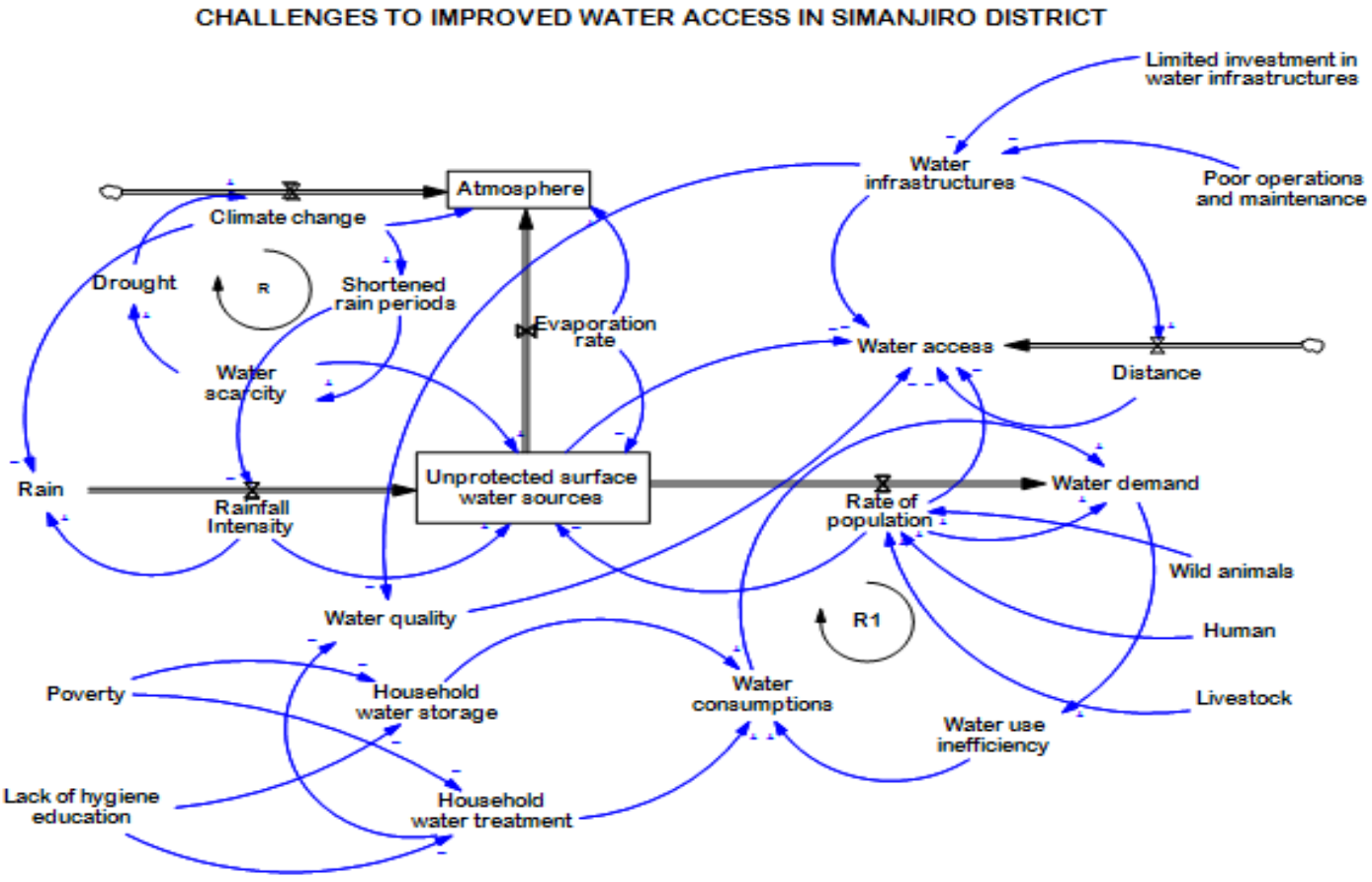

Figure 2: Challenges to improved water access in Simanjiro.

Proposed strategies aim at both adaptation and mitigation. Mitigation focuses on improved water management, infrastructure investment, rainwater harvesting, and community education. Adaptation involves diversified water sources, climate-resilient crops, early warning systems, and adaptive infrastructure.

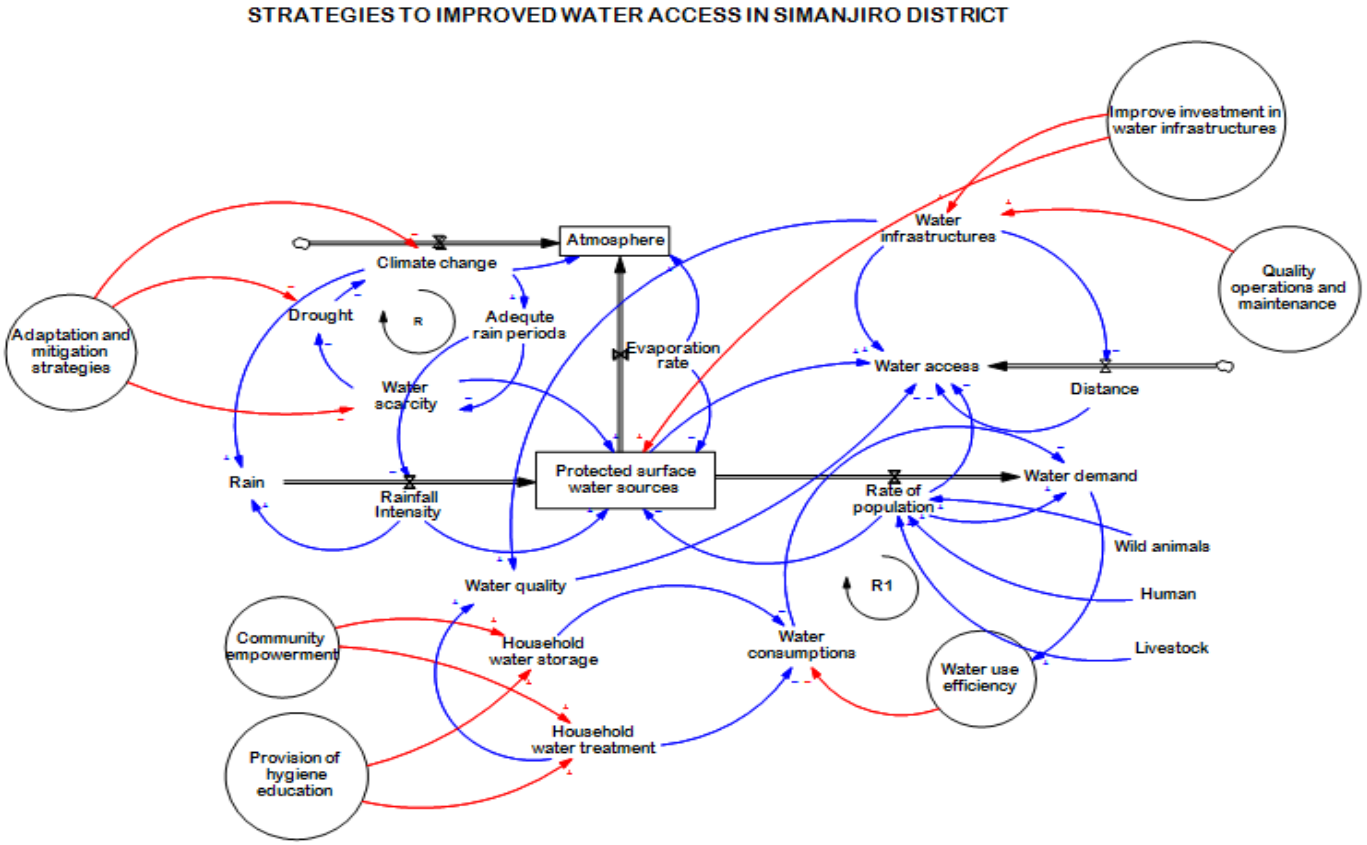

Figure 3: Strategies to improved water access in Simanjiro.

3.2. Sanitation and hygiene models in Simanjiro

In Simanjiro district, the availability of municipal waste management systems, latrines, and handwashing facilities faces various challenges, including insufficient hygiene education, cultural barriers, financial constraints, and limited access to clean water.

Limited awareness about hygiene contributes to risky behaviours like open defecation, increasing the risk of illness. Financial constraints hinder sanitation and hygiene improvements due to limited funding for infrastructure development, education, and maintenance. Cultural factors, such as the nomadic lifestyle of the Maasai community, pose challenges for establishing permanent sanitation facilities.

Water scarcity impacts hygiene practices, as the community heavily relies on natural sources for drinking and domestic use. Traditional homes often lack modern sanitation facilities, and close proximity of livestock to homesteads affects waste disposal and hygiene.

Gender roles assign household chores and water collection primarily to women and girls. Specific beliefs and taboos influence waste disposal and cleanliness practices, contributing to poor sanitation and hygiene and the spread of WASH-related diseases.

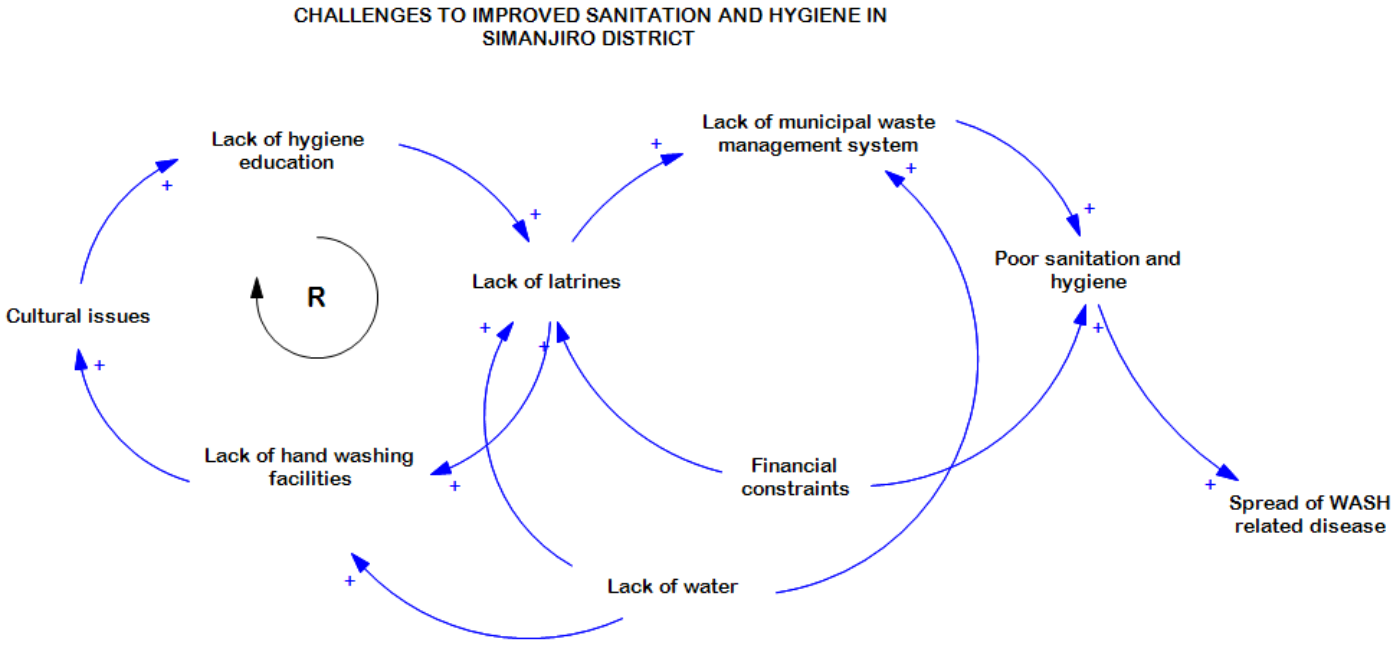

Figure 4: Challenges to improved sanitation and hygiene in Simanjiro.

Strategies to address these challenges include the Participatory Hygiene and Sanitation Transformation (PHAST) Approach, which promotes community-based hygiene practices and infrastructure management. The Community-Led Total Sanitation (CLTS) Approach focuses on collective community behaviour to achieve open defecation-free status. The Children's Hygiene and Sanitation Training (CHAST) instils critical hygiene practices in children.

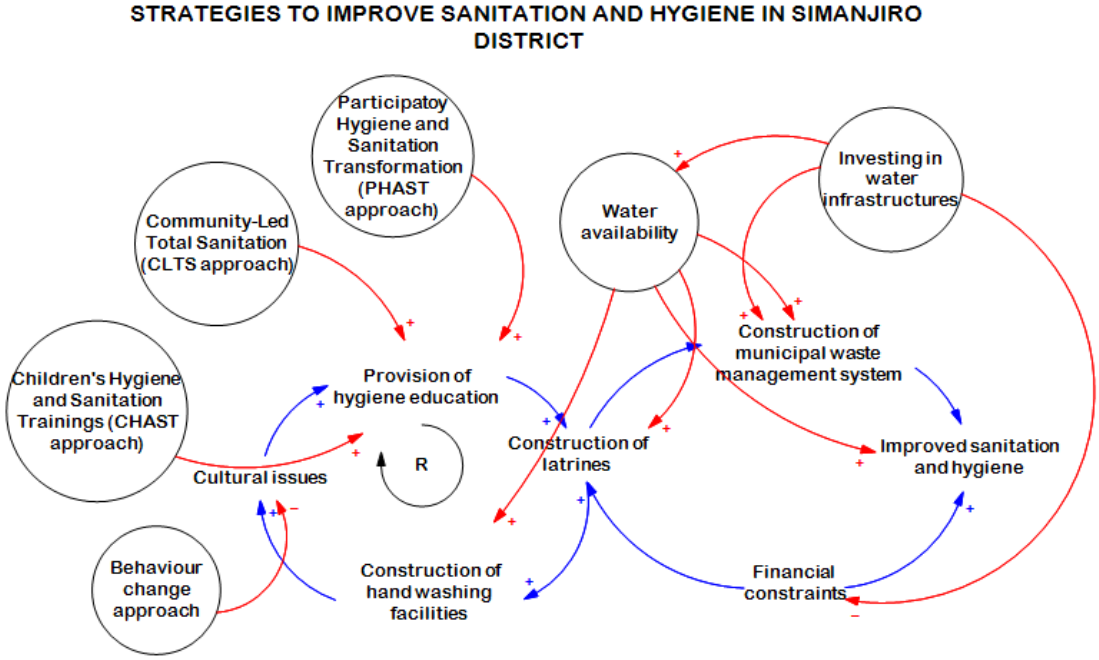

Figure 5: Strategies to improved sanitation and hygiene in Simanjiro.

4. Conclusion

The findings underscore the urgent need for enhanced water access and sanitation facilities in Simanjiro, as current conditions pose significant health risks and hinder overall development. Causal Loop Diagrams (CLDs) were used to illustrate challenges and proposed solutions, including insufficient investment in water infrastructure, inadequate operation and maintenance, lack of household storage and treatment, water use inefficiencies, limited hygiene education, and climate change impacts. Insufficient wastewater management, latrine absence, and lack of hand-washing facilities further complicate sanitation and hygiene efforts, negatively affecting public health and the environment.

Addressing these challenges demands collaborative action from local governments, private sectors, and civil society organizations to ensure sustainable and inclusive access to basic sanitation and hygiene. Strategic measures, such as increased investments in water infrastructure, community empowerment, quality monitoring, and promotion of better hygiene practices, are crucial. Utilizing approaches like Participatory Hygiene and Sanitation Transformation (PHAST), Community-Led Total Sanitation (CLTS), and Children's Hygiene and Sanitation Training (CHAST) can effectively improve sanitation and hygiene conditions.

The study's insights can inform policy and practice, guiding efforts to enhance water, sanitation, and hygiene in similar settings.

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