frontiers in Water

TYPE Original Research
PUBLISHED 21 May 2026
DOI 10.3389/frwa.2026.1759307

OPEN ACCESS

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RECEIVED 02 December 2025
REVISED 09 April 2026
ACCEPTED 20 April 2026
PUBLISHED 21 May 2026

CITATION
Mosha DB, Kashaigili JJ, Samani LP, Kashaigili JJ and Kangile JR (2026) Community aspirations and hopes on groundwater governance: qualitative insights for climate change adaptation and resilience in semi–arid Dodoma, Tanzania.
Front. Water 8:1759307.
doi: 10.3389/frwa.2026.1759307

Community aspirations and hopes on groundwater governance: qualitative insights for climate change adaptation and resilience in semi–arid Dodoma, Tanzania

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Introduction: Aspirations and hopes play a vital role in shaping ideas about water resource management. Due to increasing climate variability and a growing population, reliance on groundwater has risen in the Dodoma Region, threatening its sustainable use. Over the years, the community has relied on indigenous knowledge (IK) and traditional methods to ensure that groundwater remains accessible and well managed for both current and future generations. Despite their importance, community aspirations, hopes, and IK regarding effective groundwater governance remain underexplored. This study examined the community's aspirations, hopes, and IK that contribute to the sustainable management of groundwater and land resources in the context of climate change in Tanzania.
Methods: The research employed a qualitative approach, including focus group discussions and interviews with key informants conducted from December 2024 to February 2025. Participants and respondents were water users and managers from community, government, and non-government organizations. Content analysis was used to group qualitative information into small, meaningful themes.
Results: The community's aspirations and hopes focus on urging the government to increase the number of both deep and shallow wells, expand water price subsidies, and strengthen pollution control initiatives to protect, conserve, and manage groundwater, ensuring equitable and inclusive access. There is a high level of "hydro-geological and biological literacy" that guides traditional decisions about groundwater exploration and site selection. The construction of the Farkwa Dam boosts hopes for economic and social progress, including the expansion of irrigated agriculture. Local water users maintain traditions for water and land care, rooted in their cultural heritage and overseen by traditional leaders, but these traditions are declining among youth. Building partnerships with communities and leaders and encouraging inclusive cooperation that respects indigenous practices are essential.

KEYWORDS
aspirations, climate change, climate resilience, groundwater governance, hopes, indigenous knowledge

1 Introduction

Climate-related impacts on nature and socio-hydrological systems have been extensively documented. Altered rainfall patterns and prolonged droughts, which cause severe, cascading effects on hydrological systems, influence the availability and accessibility of water (Bradford et al., 2020; Hssaisoune et al., 2020; Woodhouse and Nwankwo, 2022; Kikstra et al., 2022). Direct hydrological impacts reported include extended droughts, which lead to significantly lower streamflow and decreasing groundwater recharge, causing the water table to fall. On the other hand, degraded water quality, lower river levels, and shrinking wetlands, which destroy habitats for aquatic organisms, cause species loss and increase the risk of non-native species invasion, are indirect effects of climate change.

However, scholars have found that the effects of climate change are less visible in developed countries due to their advanced infrastructure and strong governance systems, with only a few cities, such as those in California (USA) and parts of Southern Europe, experiencing occasional water shortages (WHO and UNICEF, 2023). This contrasts with developing countries in Africa and Asia, where many people are adversely affected by climate change due to a lack of effective climate resilience strategies and high levels of poverty among communities (WHO and UNICEF, 2023). As a result, over the past two decades, a growing amount of effort has been devoted to determining how water resources can be managed to facilitate resource sustainability and equitable allocation between sectors and users without hindering socio-economic development (Pahl-Wostl, 2019).

Often, poor monitoring of groundwater extraction has led to overuse, conflict, and unsustainable development and management in many countries in Sub-Saharan Africa, including Tanzania's semiarid region, such as Dodoma. In the region, water availability is decreasing markedly, attributable to various factors; among those most frequently cited by scholars are rapid population growth, urbanization, industrialization, and climate change (Hssaisoune et al., 2020; Molle and Closas, 2020; Migdall et al., 2022). Recent years have witnessed a substantial increase in freshwater demand, estimated at approximately 134,000 cubic meters per day. This demand significantly exceeds the installed transmission capacities of the Makutupora and Mzakwe Wellfields, at approximately 61,600 and 7,000 cubic meters per day, respectively (ADF, 2022). The maximum pumping capacity of the wellfield is estimated at approximately 72,000 cubic meters per day (ADF, 2022). Projections suggest that regional freshwater demand will triple by 2051 (ADF, 2022). A primary concern for the government, through the Ministry of Water, is the sustainable management of groundwater resources, as the water crisis is primarily a governance issue rather than a physical scarcity (Meinzen-Dick et al., 2021).

As a result, there is an increasing focus on improving water governance methods, including the adoption of integrated water resources management (IWRM), community-based management, privatization, and river basin management (Pahl-Wostl, 2015; Komakech and de Bont, 2018; Mugumya et al., 2020). However, some of these strategies have been criticized by water governance scholars who argue that they often fail to reflect community aspirations and interests, causing shortcomings in inclusion, accountability, and transparency—all critical for meeting local communities' needs (Komakech and de Bont, 2018; Mehta et al., 2019)—and for conserving common-pool resources. The common pool theory highlights the significance of community knowledge and practices in creating legitimate institutions for effective resource management (Cleaver and Whaley, 2018).

In Tanzania, as in other African countries, the government has developed various legal policies, rules, regulations, and organizations that guide the development and management of water resources. For example, the National Water Policy of 2002 (Version 2025), the Water Resource Management Act no. 11 of 2019, and various state- and community-led organizations, including water boards, water supply and sanitation authorities, community-based water supply organizations, and village and ward water management committees. The effort aims to increase local communities' participation in the water governance process. While ongoing efforts focus on adapting to climate change-related water uncertainties, they have not yet achieved their intended objectives (Myeya, 2021; Meinzen-Dick et al., 2021) because water users' aspirations and hopes have not been fully considered. This paper, therefore, seeks to address that research gap.

In this paper, aspiration is defined as "a future-oriented navigational compass shaped by individual agency, social structures, and cultural scripts…." (Leavy and Smith, 2021, p. 153). Leavy and Smith (2021) argue that aspirations are influenced by one's social environment, access to resources, past experiences, and perceived opportunities. They impact motivation, choices, and development outcomes (Leavy and Smith, 2021). Hopes are emotional expectations or desires for a better future and often emerge in uncertain contexts (Leavy and Smith, 2021). Unlike aspirations, hope is more effective, reflecting resilience and the belief that change is possible, even when pathways are unclear. "… hope provides a powerful psychosocial resource, often as a bridge between lived hardship and aspirations for change…" (Teti et al., 2023, p. 2). Building on previous governance scholarship, we define water governance as the processes that regulate the development, provision, and management of water resources in contexts characterized by availability, accessibility, inclusivity, and sustainability, or by the broader challenges of water insecurity exacerbated by climate change impacts, with a specific focus on the Dodoma semi-arid region in Tanzania.

The paper is organized as follows: a methodology section describes our case study and outlines the research design, data collection, and analysis methods. This is followed by findings and reflections on stakeholders' aspirations and hopes. The next section discusses lessons learned about how community hopes and aspirations can support the transformation of groundwater toward sustainable and equitable pathways. We conclude with a section presenting key messages for practice and recommendations.

2 Methodology

2.1 Description of the study area

The research was conducted in the Dodoma region, located in central Tanzania, between latitudes 6° 57′ and 3° 82′ South of the Equator and between longitudes 36° 26′ and 35° 26′ East of the Greenwich Meridian. Administratively' Dodoma is the capital of Tanzania and consists of seven districts: Dodoma Urban (Central Business District), Bahi, Chamwino, Chemba, Kondoa, Kongwa, and Mpwapwa. Dodoma Urban, Chamwino, Bahi, and Chemba were deliberately selected for this research due to their high dependence on groundwater. Eight wards (five urban and three rural) were purposively chosen across various geographic and administrative contexts, as shown in Figure 1. The district's climate is uniform, with an average annual rainfall of 600 mm and a unimodal rainfall pattern from April to October (Sumari et al., 2022). Daytime temperatures range from 17 °C to 29 °C, resulting in high evaporation (Myeya, 2021).

The study used a qualitative research approach combined with a literature review to gain a comprehensive understanding of the aspirations and hopes of various stakeholders. Data were collected simultaneously through Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). The qualitative data included life experiences related to groundwater access and the challenges posed by climate variability and change, as well as aspirations and hopes for how resources should be managed and used to ensure efficiency and sustainability. The research philosophy emphasizes finding practical solutions to local realities by integrating local ideas and perspectives into institutions and organizational structures (Creswell et al., 2018).

Using qualitative methods helps us gain detailed insights into the aspirations, desires, and hopes of groundwater users and managers. Flick et al. (2004) argue that qualitative methods are crucial for a better understanding of social realities, processes, and interconnected patterns. In this paper, a case study refers to an event, an entity, an individual, or a unit of analysis (Yin, 2018). Additionally, Noor (2008) defines a case study as an empirical investigation of a current phenomenon within a real-world context, utilizing multiple sources and tools.

2.2 Data collection and ethical considerations

Field data collection occurred in February 2025. Eight focus group discussions (FGDs) were held at the study sites, each with 7–10 participants selected with help from local leaders to ensure diversity in gender, age, wealth levels, education, experiences, and locations. Participants in the FGDs were divided into three age groups: young (18–29), middle (30–45), and older (46 and above). Additionally, key informant interviews were conducted with 12 individuals chosen from water supply authorities (3): the Wami-Ruvu Water Basin (1); local government (3); water user organizations (2); NGOs (1); and traditional leaders (2). Their characteristics are detailed in Table 1. The discussions adhered to a checklist of questions designed to explore experiences, aspirations, and hopes concerning future groundwater governance (Figure 2). Ethical clearance was obtained from both University College London (UCL) and Sokoine University of Agriculture (SUA). The methods employed in this study were obtained from the responsible authorities, including the Dodoma Regional Administration and Local Government.

2.3 Qualitative data analysis

The study used thematic content analysis to examine qualitative data collected through KIIs and FGDs. This approach helped researchers to identify key aspects of respondents and, with the assistance of Grok artificial intelligence (AI) software, to detect patterns and themes in the study topics. In exploring technological contributions to environmental stewardship, this study specifically leverages Machine Learning (ML) and Natural Language Processing (NLP) (Ghobadi and Kang, 2023; Kann et al., 2022; Matsui et al., 2022). NLP refers to the branch of AI that enables computers to understand, interpret, and generate human language from text or speech. In this context, NLP

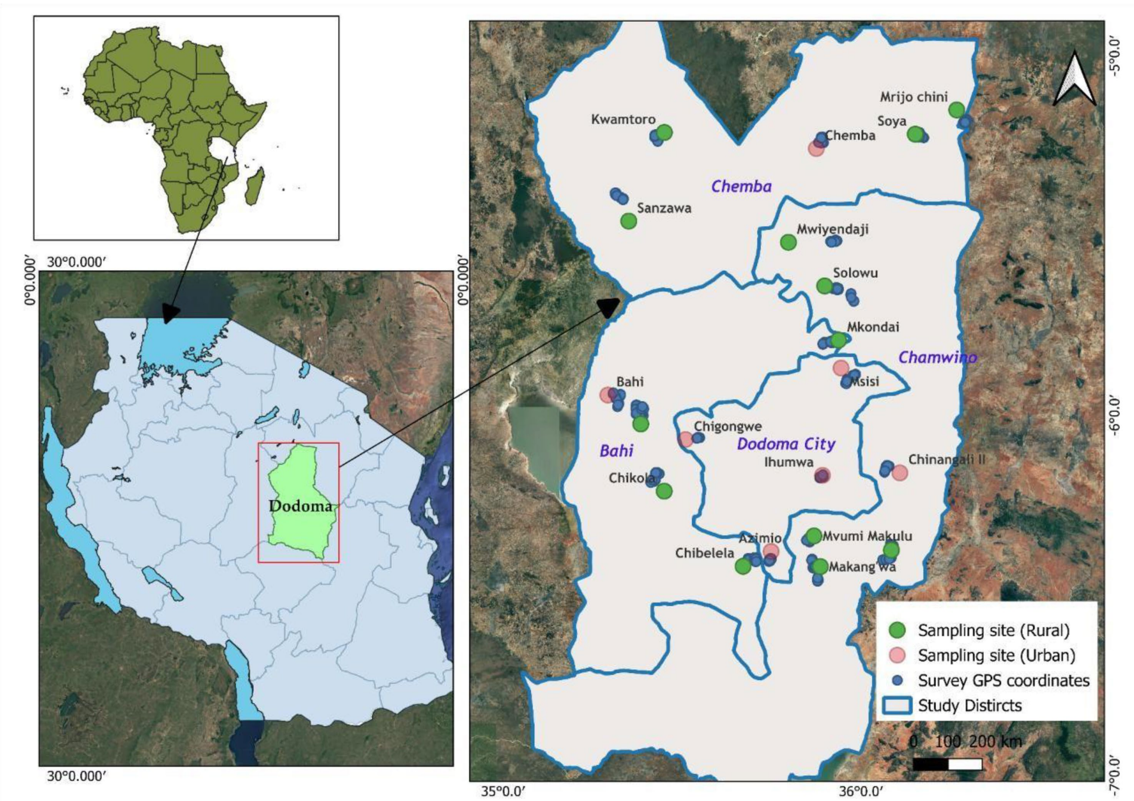

FIGURE 1
Map showing the study areas.

TABLE 1 Characteristics of key informant interviewees (KIIs).

Number	Sex	Age category	District	Urban/Rural	Organization
KII_P01	Male	Adult >35	Dodoma CBD	Urban	DUWASA
KII_P02	Male	Youth <35	Dodoma CBD	Urban	WRWB
KII_P03	Male	Adult >35	Dodoma CBD	Urban	NGO –LEAD
KII_P04	Male	Adult >35	Bahi	Rural	Local leaders
KII_P05	Male	Youth <35	Bahi	Urban	DUWASA
KII_P06	Male	Youth <35	Chamwino	Urban	DUWASA
KII_P07	Female	Youth <35	Dodoma CBD	Urban	MEO -Ihumwa
KII_P08	Female	Youth <35	Chemba	Urban	VEO
KII_P09	Male	Adult >35	Chemba	Rural	Local leaders
KII_P10	Male	Youth <35	Chemba	Urban	RUWASA
KII_P11	Female	Youth <35	Chamwino	Rural	VEO
KII_P12	Male	Youth <35	Chamwino	Urban	CBWSO

Source: CLARITY Field Data, 2025. DUWASA, Dodoma Urban Water Supply and Sanitation Association; RUWASA, Rural Water Supply and Sanitation Association; CBD, central Business District; MEO, Mtaa Executive Officer; VEO, Village Exclusive Officer; CBWSO, Community Based Water Supply and Organization.

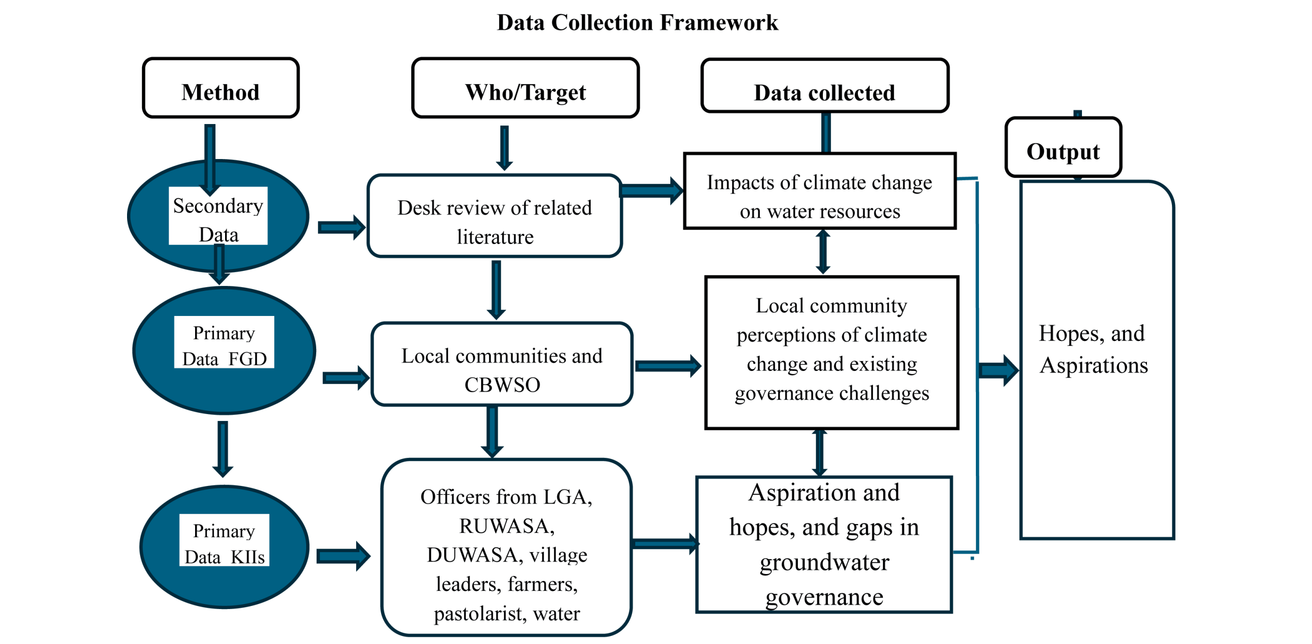

FIGURE 2
Presents a visual diagram indicating how the data were collected.

can analyze large amounts of indigenous oral stories, traditional stories, and environmental observations to extract ecological insights and document water and land management practices for broader application (Matsui et al., 2022).

The analysis process began with data preparation: raw data from FGDs and KIIs, including audio recordings and handwritten notes, were transcribed into text. The research team manually transcribed these materials to ensure accuracy. Transcripts were anonymized and labeled by session (e.g., FGD_1 for the first focus group, KII_P01 for the first key informant). Then, the transcripts were processed using the Grok AI tool (developed by xAI), which employs advanced NLP algorithms, including Latent Dirichlet Allocation (LDA), to identify recurring themes, semantic clusters, and patterns (Cambria, 2024; Longo et al., 2024). Specifically, LDA was used to categorize responses into themes such as climate resilience, governance, gender equality, and social inclusion. This AI-assisted step was especially effective at linking data to the study's focus on "hopes and aspirations," as Grok clustered phrases related to future-oriented ideas (e.g., "improved access," "community empowerment," "sustainable pathways") derived from participants' narratives on groundwater management under climate change.

To ensure reliability and address AI limitations—such as potential biases in topic modeling or misinterpretation of *Swahili*-English code-switching—two researchers independently reviewed the AI-generated themes. This process involved cross-referencing outputs with raw transcripts, calculating inter-coder agreement (e.g., Cohen's Kappa >

0.7), and iteratively refining clusters as suggested by Bender et al. (2021). Selected participant quotes were used to illustrate themes and deepen insights into governance dynamics and institutional factors. Table 2 shows the workflow for this analysis, from audio data to final themes.

2.3.1 Rationale for AI tool selection

To support qualitative analysis, including theme identification, data interpretation, and linking to aspirations, we selected the Grok AI tool over other large language models (e.g., ChatGPT/GPT-4 from OpenAI, Claude from Anthropic, or Gemini from Google) because it is vital for a dynamic field like tropical drylands resilience, where models with fixed cutoffs (e.g., GPT-4's, 2023 limit) fall short (Khaydarov, 2025). Additionally, Grok's strengths in advanced reasoning and unfiltered handling of complex queries allowed for nuanced exploration of participants' hopes and aspirations without the excessive safety restrictions that can limit other models when addressing sensitive socio-hydrologic topics. Benchmark comparisons from 2025 (e.g., LMSYS Arena rankings) demonstrate Grok's superior performance on scientific reasoning tasks and its competitiveness with, or even superiority to, peers in contextual understanding, particularly with large windows and real-time augmentation (Khaydarov, 2025). We carefully evaluated all outputs, cross-verified them against primary data, and manually refined them, in line with responsible AI practices (e.g., no confidential inputs). This approach ensured Grok enhanced human judgment without replacing it.

3 Findings

3.1 Groundwater access, challenges, hopes, and aspirations

The FGD findings show that climate change creates many challenges for communities in both rural and urban parts of the Dodoma region. These issues come from unpredictable rainfall patterns and frequent, long-lasting droughts. As a result, both surface and underground water sources are impacted. Low groundwater levels have led to water rationing for community use, resulting in water supplies falling short of demand (Table 3). Table 3 presents findings on community aspirations and hopes.

TABLE 2 A table indicating the workflow for qualitative data analysis.

Start	Raw data collection (audio recordings and notes from FGDs/KIIs)
Step 1	Manual Transcription (Convert audio to text; verify for accuracy)
Step 2	Anonymization and Labelling (Assign codes like FGD_1; remove identifiers)
Step 3	AI Processing (Upload to Grok; Apply LDA for theme clustering, focusing on aspirations-related keywords) (Parallel Branch: Human Review for Bias Check)
Step 4	Iterative Validation (Cross-reference AI outputs with raw data; refine themes)
End	Final Themes & Quotations (Integrated into results on hopes, aspirations, and governance)

The FGD findings showed that an unreliable tap water supply, caused by low water availability, is common in urban areas. The issue is worsened by outdated water infrastructure, particularly the water conveyance pipes and storage tanks. A good example is the boreholes in Ihumwa village, established in 1972, which supply both domestic and agricultural water to the community. As explained by water users from the village in 2025, below:

> *The storage tank and pipelines are worn out, which affects the quality and quantity of water supply and access. This was supported by the narratives... "we depend on a borehole constructed in 1972, and another ten (10) deep wells under operationalization of DUWASA. The number of people who have access to and benefit from water from the Ihumwa borehole is very low because the borehole does not meet community demand. An outdated water storage facility was observed during the field visit (Ihumwa FGD, February 2025).*

Another concern raised by community members was water rationing, especially in urban wards, a concern that DUWASA supports. It was identified that immediate infrastructure upgrades are needed, including repairs and additions to storage tanks and the drilling of new wells. These findings align with the key informant narrative, which reported that "… DUWASA recognizes that people receive water on a shift basis and therefore works to increase the number of wells that can always serve the existing population (Community Member, Chinangali FGD 2025). The results in Table 2 further demonstrate that community aspirations highlight the need for interventions that pursue sustainable, long-term solutions such as replacing outdated wells and expanding supply networks rather than temporary remedies.

The results also demonstrate that financial constraints limit households' ability to access pipeline connections and pay water bills. This presents a major barrier to fair access to reliable water services, especially for low-income households. Connection fees ranging from TZS 350,000 to TZS 700,000 and tariffs of TZS 100 to 200 per 20 liters of water effectively exclude impoverished and female-headed households. The findings are consistent with the key informant's argument.

> *… improved water access is the responsibility of DUWASA to enhance water supply by increasing pipeline connections; however, this is more evident for households with higher incomes…" (Government official Ihumwa, KII, 2025). This argument suggests that the government should invest in groundwater development using modern technologies to address water access issues.*

Furthermore, the results show communities' desire for policy reforms that include water exemptions for poor household heads and address factors that hinder affordability and contribute to groundwater mismanagement. This reflects a broader aspiration

TABLE 3 Communities' aspirations and hopes across urban and rural study sites.

Site and stakeholder	Challenge	Short-term hopes and aspirations	Long-term hopes and aspirations
Urban Participants of FGD, and key informants CBD (P2, P6, and P7).	• Prolonged droughts • Unreliable rainfall patterns, reducing water availability. • Less access to groundwater (more pounced for poor and … incomplete)	• The DUWASA should make repairs to storage and conveyance pipes, • Construction of new boreholes • Improve shallow well quality • Subsidies for connection fees • Exemptions for vulnerable groups.	• Scalable, saline-free supply, • Expanded networks, • Farkwa dam and Lake Victoria project • Advanced water treatment, urban planning, anti-pollution laws, alternative energy (solar/wind). • Policies for free water, community governance, and inter-agency coordination.
Rural Participants of FGD, & key informants (P4, P8, 9, 10, 11, 12, 2)	• Access in underserved areas; new wells (28 Towns Project, Gwaibe) • Dam rehabilitation	• Affordable/free access for vulnerable groups. • Community-led conservation (fines, tree planting), education on trenches/Berega.	• Comprehensive well/tap networks, hydropower, reforestation, watershed management. • Free water policies, sustainable pricing, and water treatment • Improved CBWSO leadership • Integration of formal and traditional knowledge
Cross–cutting issues Source – FGD participants and KIIs from NGO and Government Institutions.	• Less rain affects water availability • Degradation of catchment areas • Lack of accountability • Financial constraints	• Community empowerment. • Train in nature-based solutions (trenches, Berega), • Protect natural resources.	• Climate-resilient strategies • Planting tree species, • Recognizing indigenous methods, • Building the capacity of the community in water catchment areas conservation • Equitable access and social justice • Decentralized and localized Management • Protection of quality and quantity • Integration of Traditional and Technical Knowledge

Source: CLARITY Field Data, 2025.

for equitable access to groundwater. The use of contaminated water sources highlights significant health risks. For example, typhoid outbreaks in Ihumwa occurred in 2023, affecting many people in the area, as narrated in KIIs. The findings reveal that many residents and stakeholders tried to control the typhoid outbreak through regular borehole maintenance. Notably, the Wami-Ruvu Basin Water Board (WRBW) proposed drilling in 10 villages to address these issues. Additionally, community education was a priority, focusing on training residents in safe water use and rainwater harvesting techniques. This aspiration was supported by one of the key informants, who narrated "… DUWASA's plan to construct underground storage tanks, which will provide an appropriate solution to typhoid outbreak (Community Member, Ihumwa FGD 2025).

3.2 Hopes and aspirations of rural water users concerning groundwater access and management

During the long dry seasons in Dodoma, a key goal for the community, including water authorities, was to achieve seasonal reliability and rehabilitate the dam to ensure a steady water supply. This goal mainly aimed to reduce the region's water scarcity. To do this, there was a strong push to rehabilitate existing dams in Bahi and Chemba, which are in poor condition and may not be suitable for water storage and supply. Additionally, communities hoped to dig deeper into the riverbed to access more reliable groundwater sources that are less affected by seasonal changes. This approach highlights the urgent need for improved water infrastructure and management to ensure a reliable year-round water supply, especially during dry periods. This was confirmed by one of the respondents at the Wami-Ruvu Water Basin Board (WRWBB) Office.

During the extended dry seasons in Dodoma, a primary objective for the community was to attain seasonal reliability and to rehabilitate the dam to secure a consistent water supply. This objective primarily aimed to reduce difficulties in accessing water. Accordingly, there was a concerted effort to rehabilitate the existing dams in Bahi and Chemba, which are currently in substandard condition and may be unsuitable for water storage and distribution. Furthermore, communities sought to drill deeper wells into the riverbed to access more dependable groundwater sources less susceptible to seasonal fluctuations. This adaptive option underscores the urgent need for improved water infrastructure and management to ensure a reliable water supply year-round. This finding aligned with narratives from one respondent from the WRWBB Office, who stated:

> *… Due to climate change, if we continue with the current water management system, we will not be able to sustain it because we receive little rain, and aquifer recharge becomes minimal. So, if the output exceeds the intake, there will be significant friction in water availability. Therefore, we propose implementing artificial recharge to enhance underground capture from surface runoff" (KII WRWB, 2025).*

Another goal of rural community members was fair access to water, achieved by offering free or subsidized water and affordable rates for vulnerable groups, including poor households. This was confirmed by a traditional leader who said: "High delivery costs amount to TZS 250 per 20 liters of water in Chemba District, and the cost for tap water ranges from TZS 50 to 100 per 20 liters, which burdens low-income households. Widows and the elderly should be supplied with water free of charge" (Traditional leader, Chemba, KII, 2025).

Furthermore, a major concern for communities, especially in the villages of Mkondai and Nghahelezi, was environmental sustainability, with strong aspirations for community-led conservation efforts. Discussions showed that community members were eager to protect their water sources and even suggested and enforced fines for environmental violations, such as a TZS 50,000 penalty in Mkondai village. There was also a push for planting trees to enhance groundwater recharge, as highlighted by local regulations: "We have regulations to protect streams" (VEO Nghahelezi, KII 2025). The traditional leader, a key informant in Bahi, called for fair water distribution by strengthening the village committee. Additionally, community education and training were vital hopes for groundwater users across the semi-arid region of Dodoma. About this, a key informant said:

> *"… There is hope for increased awareness, with aspirations to educate communities on conservation, infrastructure protection, and nature-based solutions like retention trenches, such as LEAD Foundation's fanyajuu[1], fanyachini (see text footnote 1), Berega (see text footnote 1) Practice. We train communities on trenching to retain water (KII, Dodoma, 2025).*

Stakeholders aimed for rural communities to be empowered to improve water management, envisioning stronger leadership within Community-Based Water Supply Organizations (CBWSOs), such as chairpersons in Chemba with secondary education, "We need better-educated CBWSO chairpersons" (KII, CBWSO Chemba, 2025), and the inclusion of traditional leaders in community-driven water governance. Rural residents also hoped for a reliable water network, working to develop comprehensive deep-well and tap-water systems powered by sustainable energy, exemplified by Mkondai's hydropower goals and Ngh'ahelezi's pump upgrades. Ultimately, these shared goals and hopes for sustainable aquifers merged, emphasizing large-scale reforestation, watershed management, and the incorporation of traditional knowledge. For example, Bahi used Acacia spp. to locate wells, while Chemba demonstrated its use through rituals to address climate-induced water scarcity.

1 Define or explain if briefly.

3.3 Aspirations and hopes on indigenous knowledge and traditional methods on groundwater governance and land conservation

The thematic analysis identified Indigenous Knowledge (IK) as a cornerstone of climate resilience and resource governance within the Wagogo community. Dodoma Region, Tanzania, is a typical semi-arid landscape marked by irregular rainfall, averaging about 550 mm annually, mainly during a brief wet season, high evaporation rates, limited surface water, and dependence on groundwater. These climatic conditions have helped preserve the indigenous knowledge (IK) for preserving water and land resources that ancestors have used for centuries. Wagogo agro-pastoralists have developed sophisticated rules for water and land preservation that are deeply embedded in their cultural heritage and enforced by traditional leaders. These governance structures are particularly vital for the collective management of shallow aquifers and dug wells, which remain the essential infrastructure for domestic and agricultural life in areas lacking formal piped water systems.

The dominant ethnic group, the Wagogo (Gogo people), are agro-pastoralists who have developed sophisticated indigenous knowledge systems over generations to cope with chronic water scarcity, soil degradation, and climate variability. The IK and traditional methods for preserving water and land were found to be deeply rooted in the cultural heritage of elderly individuals and traditional leaders. Besides, the chronic lack of piped water has driven rich IK to rely on shallow dug wells centered on shallow aquifers, which serve as primary sources for domestic use, irrigation, and livestock in sub-urbs (Shemsanga et al., 2018).

FGD findings with water users and managers in Ihumwa, Msisi, Bahi, Ng'ahelezi, Kanzawa, and Chilangali indicate that IK is commonly used for groundwater exploration and site selection. These include biological (plant) indicators, as well as geological and hydrological indicators.

Concerning the biological indicators, the findings revealed that termite mounds were the most frequently cited indicator of high soil moisture and shallow water tables. One of the elders in Ihumwa said, "Communities prefer digging shallow wells on or near mounds for higher yields at shallower depths" (KI, Ihumwa 2025). Additionally, the presence of specific deep-rooted vegetation during the peak dry season, such as *Acacia albida* (Photo 1), *Adansonia digitata* (Photo 2), and *Ficus sycomorus* (Photo 3), serves as a community-validated marker for moisture availability. In most cases, wells are suited near these pre-existing trees. This methodical approach to site selection helps avoid "trial-and-error" drilling, thereby reducing land disturbance, soil degradation, and excavation costs.

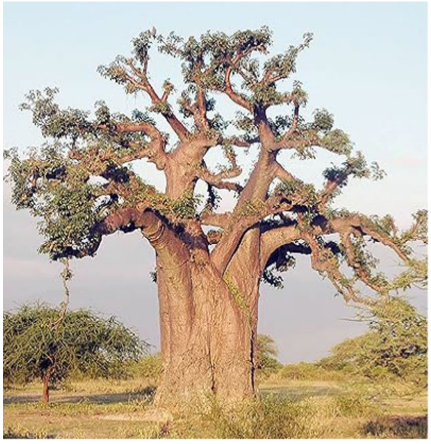

Photo 1: *Acacia albida* tree (Baobao)

Photo 2: *Adansonia digitata* tree

Photo 3: *Ficus sycomorus* tree

The FGD participants reported that farmers engaged in irrigated agriculture use traditional methods such as terracing, mulching, intercropping, and mixed cropping systems to manage soil moisture and fertility. This helps reduce the amount of groundwater used for irrigation. Additionally, prioritizing the preservation of well-maintained ancestral sites for water extraction reflects a governance approach grounded in cultural continuity and resource reliability. Overall, the use of these traditional practices demonstrates a community-led effort to optimize resource use for future generations.

Despite the technical effectiveness of IK systems, the study found a significant intergenerational divide that threatens the "hopes and aspirations" for future resource governance. While elders are the main custodians of these environmental laws, the analysis showed a trend of "knowledge erosion" among younger generations. Youth participants were less likely to inherit or practice these traditional methods, creating a vulnerability in the community's long-term adaptive capacity. These findings suggest that the future of resource sustainability under climate change depends not only on technological solutions but also on the successful transfer of this IK.

4 Discussion and finding implications

4.1 Aspiration and hopes on the impact of climate change on the availability and accessibility of groundwater

The findings reveal climate change and variability are occurring in the region. This is evidenced by prolonged droughts, reduced rainfall (averaging 500–600 mm annually), and rising temperatures (ranging from 10 to 28 degrees Celsius), which together affect water availability. Outdated water storage tanks limit the capacity to store and regularly distribute water to many households at once. This has led to water rationing. This finding aligned well with the narrative from one of the participants in FGDs, who reported that "...we often get water either once or 4 days per week, compared to the past years (2000–2010), when water was plentiful...." This finding, in collaboration with findings from other studies, suggests that prolonged droughts and erratic rainfall in semi-arid Tanzania, Ethiopia, and India.

Reduce recharge and increase dependence on groundwater, exacerbating scarcity. These perceptions aligned with hydrological assessments in Tanzania, where climate change is projected to reduce groundwater recharge by 30–40% in urbanizing semi-arid areas by 2050 due to increased evapotranspiration and land-cover changes, heightening reliance on groundwater amid unreliable rainfall (Myeya, 2021).

Another aspiration frequently mentioned by water users and managers is the need for immediate improvements to outdated water infrastructure systems, monitoring, and reductions in water tariff costs. Community advocates for reducing the costs of connecting water pipes to homesteads to enhance equality and inclusion of vulnerable households. The community calls for borehole drilling and dam construction for rural access in drylands, where population growth and climate change intensify pressure on limited resources. Such infrastructure demands, including the Farkwa Dam and borehole projects in Chemba, echo broader calls in African drylands for sustainable groundwater development through enhanced storage and recharge (URT, 2021). This implies a nuanced understanding of the climate-water nexus, with aspirations for seasonal reliability through dam rehabilitation and the installation of deeper riverbed wells to mitigate dry-season scarcity.

Conversely, rural water users aim for quick improvements in groundwater access in underserved areas. They are eager to either drill new deep wells or rehabilitate existing ones. The need for additional wells in Chemba District and for three wells under the "Sustainable Water Supply Projects in 28 Towns," with a modernized groundwater extraction system powered by solar or electricity. Incorporating renewable energy sources (e.g., solar, wind, hydropower) with water infrastructure reflects an energy-water nexus approach that is vital to ensuring rural communities have reliable groundwater access (Biggs et al., 2015).

The aspiration to construct the Farkwa Dam reinforces hopes for economic and equity gains. The community hopes that construction of the Farkwa Dam will increase the availability of water for irrigated agriculture. Enable horticulture/fisheries and provide reduced-cost access to water for vulnerable groups, contributing to improved incomes and livelihoods, aligned with Sustainable Development Goal No. 6, and aim to provide evidence that climate variability threatens livelihoods in the Dodma region (Sumari et al., 2022).

There was also a strong desire to implement borehole projects in the Chemba District to serve communities. These findings aligned with narratives from key informants: "… On my part, I only request that the government drill a borehole in our area, so we do not have to move from one village to another in search of water, as we do now. This affects our livelihood strategies (Community Member, Ng'ahelezi

FGD 2025). Additionally, while in some areas the improved goal for water access has been achieved in 50% of cases, the lack of dams at the study sites remains a primary challenge, as noted by an FGD participant in Chemba district (2025).

These water users' hopes to provide a clear picture of their desire to improve access to water for social and economic growth. Besides immediate household needs, there is a strong wish for the government to ease the burden of walking long distances to fetch water and to provide dedicated water sources for livestock, such as cattle dips. Importantly, communities have been calling for dam construction to create economic opportunities through horticulture and fish farming, a challenge they have faced since independence. Behind these specific requests is a broader goal of universal water access, with policies to provide free water for vulnerable groups and a commitment to maintaining existing water infrastructure through sufficient budget allocation.

4.2 Aspiration and hopes for community participation, institutional arrangements, and empowerment

In this section, the community identified institutional fragmentation as one of the challenges in undermining sustainable groundwater governance. Institutional fragmentation between water management institutions, top-down approaches, weak participation in pricing, rules in use, and low bylaw accessibility; and aspirations for coordination, strengthening CBWSOs, education on conservation and rainwater harvesting, and nature-based solutions (URT, 2021). Conflicts among agencies and sectors undermine governance, but community calls for improved inter-agency collaboration and water user associations align with principles for managing common-pool resources. This aspiration for improved inter-agency coordination and water user associations aligns with Ostrom (1990) "… community aspirations for enhanced coordination and water user associations (including CBWSOs) directly align with Ostrom's design principles for successful collective action in common-pool resource governance, which have been advocated for improving groundwater management in African contexts, including South Africa and broader sub-Saharan cases."

On CBWSO and education, enhancing leadership and integrating traditional elements bridges formal and informal institutions, fostering agency (Cleaver, 2012). Community education on rainwater harvesting, conservation, and safe water use, as advocated in urban and rural areas, fosters agency and resilience, resonating with Teti et al. (2023) view of hope as a psychosocial resource. The reported weak community involvement in decision-making, such as pricing and rules, contributes to low acceptability of conservation bylaws, consistent with findings that participatory models in East and Central Africa succeed when prioritizing local engagement, inclusivity, and conflict (Cohen-Shacham et al., 2016).

4.3 The use of indigenous knowledge and traditional practices for groundwater and land conservation

The findings highlight a robust IK system that underpins climate resilience and sustainable governance of scarce water and land resources in a semi-arid environment (annual rainfall ~550 mm). The use of oral narratives from six villages identified a "Triad of Indicators": biological (termite mounds and deep-rooted species such as *Acacia albida*, *Adansonia digitata*, and *Ficus sycomorus*), geological (fault lines and river intersections), and hydrological, which help guide accurate well-siting, reduce salinity risks, and lessen land disturbance.

The use of terraces and intercropping has successfully enhanced soil moisture retention and fertility in irrigated agriculture. These practices show a high level of hydrogeological knowledge and collective resource management. Such skills are often passed down through generations through practical experience and are useful to farmers in the absence of modern technologies. These are well-suited as adaptive mechanisms for climate variability in most semi-arid regions. These findings strongly corroborate with documented indigenous practices across Africa. In Tonga, southern Zambia, IK on totemism, taboos, sacred water sources, and traditional authority similarly support soil, water, and biodiversity despite intensive farming (Kanene, 2016).

In East and West Africa, spiritual relationships, rituals, and habitat taboos are integrated into watershed management, offering culturally grounded alternatives to conventional scientific methods (Obiero et al., 2023). Evidence from South Africa further confirms that indigenous techniques, rainwater harvesting, terracing, and wetland management provide low-cost, resilient solutions to water scarcity while promoting community empowerment and climate adaptation (Sahani et al., 2025). Traditional practices, such as the Shexian Dryland Stone Terraced System in China, highlight the potential of traditional landscape engineering to effectively conserve soil and water while providing ecosystem benefits that exceed those of other land uses (Jiao et al., 2024). Redvers et al. (2023) emphasize that such IK systems, rooted in reciprocity and holistic worldviews, are essential yet often overlooked strengths for indigenous climate responses worldwide.

The Wagogo groundwater and land management governance model demonstrates how IK functions as an adaptive socio-ecological system, optimizing the use of limited groundwater resources while preserving cultural continuity. However, the study reveals a decline in knowledge across generations, with younger members less involved, which threatens to weaken long-term adaptive capacity amid climate change. In South Asia, where monsoon variability and water scarcity present considerable challenges, the use of IK and traditional methods is also declining (Sahani et al., 2025). The erosion of knowledge reflects broader African trends in modernization and shifting livelihoods (Obiero et al., 2023; Sahani et al., 2025).

Maintaining these systems requires intentional intergenerational transmission and collaboration with scientific methods, as indicated by Bremer et al. (2021). Integrating Wagogo indicator-based siting and terracing into formal water planning through policy could reduce environmental damage, lower well-drilling costs, and advance SDG 6 targets in Tanzania and other semi-arid regions.

5 Conclusion and recommendation

This qualitative analysis provides strong evidence of the potential of indigenous community knowledge, hope, and aspirations for sustainable groundwater management amid climate change. Due to ongoing water shortages and harsh climatic conditions in the Dodoma region, local groundwater users have identified various hopes and aspirations related to groundwater use and governance. Key aspirations included rehabilitating outdated storage facilities and conveyance systems, drilling boreholes, and building dams for water harvesting.

Hope for groundwater governance depends on integrating local realities, indigenous knowledge, and traditions, all of which are essential for managing groundwater, enhancing agricultural resilience, improving soil health, and adapting to climate variability in semi-arid areas. Communities' interests and practices should be considered when developing the governance framework. Local actors need to actively participate in identifying appropriate solutions and defining institutional roles for water security and climate change adaptation. This study highlights the importance of lowering water tariffs and connection fees, which can increase the likelihood that more people access and benefit from water.

Furthermore, due to ongoing water shortages and severe climate conditions in the Dodoma region, Wagogo IK systems and traditional groundwater management methods are still used, though to a limited extent. Typically, climate-induced droughts and reduced recharge increase dependence on groundwater, but community aspirations provide pathways to achieve sustainability through better infrastructure, increased fairness, and more inclusive development governance. Importantly, prioritizing the integration of local aspirations into national frameworks, supporting CBWSOs and WUAs in line with established principles, and promoting IK for water point determination and traditional methods in irrigated agriculture to conserve water will strengthen resilience to climate change. By linking local evidence with comparative African and global scholarship, underline the urgent need for water ministries and other organizations managing water resources to document, validate, and incorporate indigenous systems to enhance climate resilience and foster equitable development.

Building partnerships with local communities and traditional leaders, encouraging participatory, inclusive collaborations that value IK and traditional practices, will be essential to tackling the emerging challenges of climate change for global groundwater governance.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Research Ethics Service on behalf of the Chair of the Humanities, Arts, and Sciences Research Ethics Committee. All procedures were conducted in accordance with local legislation and institutional requirements. Written informed consent for participation was obtained directly from all participants prior to data collection.

Author contributions

DM: Methodology, Conceptualization, Writing – original draft. JohK: Writing – original draft, Methodology, Formal analysis. LS: Writing – original draft, Formal analysis, Investigation, Data curation. JapK: Writing – review & editing, Funding acquisition. JosK: Investigation, Writing – review & editing, Formal analysis.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This work was carried out with financial support from the UK Government's Foreign, Commonwealth and Development Office and the International Development Research Centre, Ottawa, Canada, as part of the Climate Adaptation and Resilience Program (CLARE).

Acknowledgments

The authors wish to thank participants, community, government, and non-government staff from Dodoma region for agreeing to participate and provide data for this research. We also acknowledge the editorial work of Kim Kayunze from Sokoine University of Agriculture (SUA) for the excellent and thoughtful feedback received that has resulted in significant improvement to this manuscript.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The author(s) declared that Generative AI was not used in the creation of this manuscript.

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