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RESEARCH ARTICLE

Climate resilience of small-town water utilities in Eastern Ethiopia

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Abstract

Climate change threatens the safety of water supplies globally, but small water supplies in rapidly growing and urbanizing towns in low- and middle-income countries are especially at risk. Despite the efforts of the Government of Ethiopia, research shows that that small-town water utilities in Ethiopia are poorly equipped to prioritize developing and maintaining climate-resilient water services. We applied the How tough is WASH framework for climate resilient water supplies to ten town water utilities in Eastern Ethiopia to identify their strengths and weaknesses in preparing for climate change. We found reports of weak institutional support from service authorities and exclusion of climate risk management from trainings, which cascades down to service providers in the form of lack of emergency response, inadequate staffing and financial mismanagement. This is consistent with previous studies on sustainability of town water utilities, and highlights the applicability of this tool into existing monitoring frameworks that have been proposed for town water utilities in Ethiopia. We also modified the How tough is WASH framework to capture these findings and better reflect the complexity of a utility-managed piped water supply.

Introduction

A growing body of evidence shows that water supplies are experiencing the impacts of climate change [1, 2]. Intense rainfall, severe storms, dry spells, extremely hot days, and storm surges damage or destroy water supply infrastructure and reduce the availability of water resources [1, 2], all of which have an impact on water supply and quality [1–7]. This has amplified concerns in the water and sanitation (WASH) sector, resulting in increased efforts to improve services in the low and middle-income countries, where climate change may have the most severe impacts [8–11]. In urban areas, climate change exerts additional pressure on the operation of water utilities [12]. Even though strategies for drinking water safety management that address risks related to climate variability and change are urgently needed [1, 2], resilience is frequently a secondary priority in low-income countries, due to financial limitations [13].

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Ethiopia is one of the most vulnerable countries to climate variability and climate change due to its low adaptive capacity to deal with these changes [14–16]. Climate-related risks are already apparent in the country, with evidence indicating that existing climate variability, along with rising demand for water, is already stressing systems and services [17, 18]. Small and medium towns in the country i.e., settlements with a population above 2000, face the additional stress of rapid population growth [19, 20]. It has been difficult to maintain water and sanitation systems in these towns due to rapid increase in demand, ageing infrastructure, weak institutional capacities, lack of finance, and difficulties with cost recovery [21].

Recognizing these challenges, the Government of Ethiopia launched the One WASH PLUS programme to strengthen piped water provision in small towns through town water utilities, which are autonomous enterprises regulated by a Water Board [22]. As part of this programme, a sustainability check framework was proposed to monitor the performance of such utilities [23]. Application of this framework in small towns revealed unreliable services with inadequate water supply quantities; low cost recovery and technical capacity in small-town utility-managed water supplies [24, 25]. This does not bode well for the ability of these systems to prepare for climate change. While utility-managed piped water supplies are considered more climate resilient than community-managed point-sources [26], and can result in lower overall costs compared to point source water supplies [27] the management of systems of increased complexity requires substantial training and post-construction technical support.

As the Government of Ethiopia seeks to improve access to piped water supplies and build resilience in the water supply sector, current weaknesses in these services must be addressed. This will require integrating climate resilience into planning and monitoring service provision [28, 29]. The recognition of the aspects that make services more resilient to climate change is growing, however more data is required to assess risks, develop indicators and plan adaptation at the service provider and service authority level [26].

Thus, the objectives of this study were to identify current and potential risks to town water utilities from climate stresses and propose indicators for monitoring. We used the How tough is WASH conceptual framework [30], which has previously been tested on community-managed rural water supplies in Ethiopia to assess the resilience of small-town water utilities to climate change. We also sought to adapt the indicators within the framework for town water utilities, based on our findings.

Materials and methods

Study area

We conducted this study in ten towns of the east Hararghe Zone of the Oromia region and the Fafen Zone of the Somali region, Eastern Ethiopia (Fig 1). The two regions are the most vulnerable to climate change impacts in the country [31, 32]. East Hararghe zone is one of the drought-prone areas in the Oromia region. The zone is classified into three agro-ecological zones. *Dega* (highland) covers 7.67%, *Woinadega* (mid-altitude) 24.5% and the remaining 67.76% of the Zone represents *Kolla* (lowland). The zone is frequently affected by extreme drought affecting people and animals and leading to thousands of people being displaced [33]. In the zone, 8.27% of the population is urban inhabitant, 1.11% is pastoralist, 17% is agro-pastoralists, and the rest is agriculturalist (74%). The Somali region, from where the two towns were selected, is one of the most affected regions in the country [34]. Two towns are located in the Fafen zone of the region. This zone is located in the Wahit Shebelle River Basin, which comprises the drainage of the seasonal rivers of Fafan, Jerar, and Dakhato. In the Fafen zone, the most successful boreholes are available, and seasonal rivers play a significant role as a water resource. Of the ten towns included in the study, the town with a high percentage of

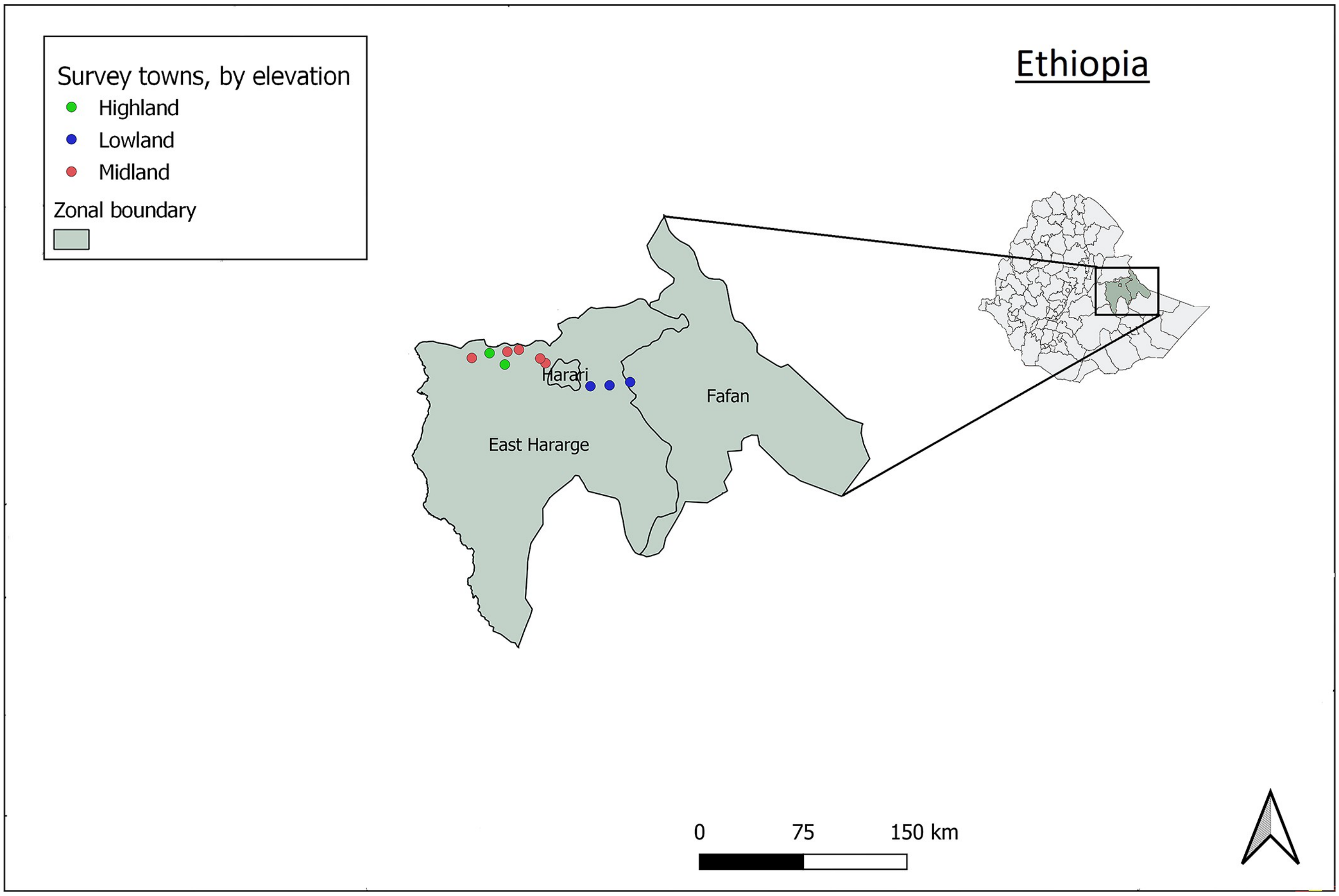

Fig 1. The map of study towns (Aweday, Babile, Bombas, Chalanko, Fafen, Kersa, Kullubi, Haramaya, Lange, and Woter), Eastern Ethiopia, 2022 (Base map is accessed from *United Nations Office for the Coordination of Humanitarian Affairs (OCHA)*: Ethiopia - subnational administrative boundaries - humanitarian data exchange (humdata.org) *under the following creative commons license. https://data.humdata.org/faqs/licenses#auto-faq-_Data_Licenses_Content_-Creative_Commons_Attribution_International_CC_BY_-a*).

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households having piped water coverage is Chalanko (85%), and the town with a low percentage is Awedaya (20%), according to the data we received from each town. Moreover, towns that chlorinate water regularly are Bombas, Haramaya, Kersa, Kulubi, and Woter.

The management of town water utilities in Ethiopia

According to national guidelines for urban water supply and sewerage services [35], the water supply is managed by the town water utility established by the town administration. There is a water board composed of representatives from the town administration, pertinent local government offices (such as the water office, health office, finance, economic development office, and education office), and customers to lead the overall activity of the service. The town Water Utility manager is responsible for organizing, directing, and administering the activities of the utility and its staff within the different sections (human resources development, finance and property administration, operation and maintenance, etc.).

Study approach

We carried out a cross-sectional study employing both quantitative and qualitative methods in two rounds in August and December 2022. For the quantitative survey, we interviewed a

Table 1. Sample size and distribution of sample households to each study town.

S. no	Study town name	Sample households from each study town
1.	Aweday	54
2.	Babile	108
3.	Bombas	60
4.	Chalanko	141
5.	Fafen	12
6.	Haramaya	171
7.	Kersa	34
8.	Kulubi	15
9.	Lange	14
10.	Woter	21
	Total	**630**

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representative sample of households. We estimated 630 households using a single population proportion formula with the assumption of 50% resilience, 4% margin of error, 95% CI, and 10% non-response rate. To investigate how the framework might be applied, we purposefully chose ten towns from two of Ethiopia's regions, Oromia and Somali. All households within the town using piped water were identified based on the information gathered from each town water utility. We then distributed the sample proportionally to each study town (Table 1). We used a simple random sample technique to select households from each town. Household selection was made after obtaining the list of households from the town water utility.

For qualitative data collection, all the operators and managers of the water utility in each town were included. We also interviewed one community representative, who is a board member of the water utility, from each town to explore the community's role in the water utility. All the water supply sources and reservoirs in each town were assessed to explore their quality and potential risks including being flooded and inundation with rivers.

Method of data collection

We used the six domains in the *How Tough is WASH* framework [30] to design data collection tools including household surveys and key informant interview guides. The household survey was designed to collect data on socio-demographic characteristics, water supply characteristics, household awareness of climate change impacts, the frequency and duration of climate hazards experienced, the extent to which climate hazards disrupt water supply service or access, and household responses to the expected and experienced exposure to climate hazards. Additionally, an observational checklist, based on the World Health Organization's sanitary inspection forms [36] was used by enumerators to identify risks in the environment around the water infrastructure or in its immediate vicinity that may make them susceptible to climate threats (See S1 Appendix). The tools (survey and observational checklist) were developed in English, translated to the local languages Oromiffa and Somali, and then translated back to English to ensure consistency before being administered digitally using portable devices. The data were stored using Kobo Toolbox (Kobo collect version v2022.1.2) for easy storage and sharing.

Qualitative data was collected from technicians, persons in charge of managing the water utility, and community representatives in each town through semi-structured interviews. Topic guides were developed based on the *How Tough is WASH* framework *[30]* to gather information on institutional and operational aspects of the water supply (See S2 Appendix). Ten technicians operating the water supply service were interviewed about the existing water supply services, changes in water quality and quantity due to climate change, challenges associated with the operation and maintenance of water infrastructure, and coping mechanisms of climate change impacts on water supply. The water utility managers were interviewed regarding the existing support and training provided by local and regional authorities, and challenges. Interview topic guides were prepared in English and translated into Oromia and Somali. The key informant interviews were carried out in the local languages. The sessions were taped, transcribed, and translated into English.

Free residual chlorine and microbial testing of tap water were conducted during the two rounds of data collection. The microbial test was done on the water samples collected from each water source using a membrane filtration technique [36]. Free residual chlorine was measured from the sample of water source and point-of-use of households claimed to treat before drinking. The residual chlorine measurement was done by the Palintest DPD chlorine method by taking a 10 ml sample of water stored in the house and reservoirs. Free chlorine reacts with diethyl-p-phenylene diamine (DPD) in a buffered solution to produce a pink color. The concentration of free residual chlorine was recorded by comparing the mark reading of a pink color to a color comparator.

Data analysis

The data from household surveys were checked for completeness and analyzed descriptively to determine the user's role in the resilience of water supply services. For the in-depth interviews, digital recordings of technicians, managers, and community representatives were transcribed and coded deductively based on the predefined list of codes. Codes based on the indicator from How tough is WASH framework were developed to ensure that the data from the interviews could be used to score the resilience of the water supplies. Environmental risks around the communities such as elevation, slope, and land cover/land use were mapped on ArcGIS and the risk proneness of the water sources was determined using Digital Elevation Modeling.

Ethical considerations

The research was carried out as a follow-up to the "How Tough is WASH" project, which was approved by the Ministry of Science and Technology in 2019. The Ministry waived ethical review due to the research project's non-sensitive ethical issues. However, we followed the principles of ethics and verbally consented to participate with each participant after presenting the study's objectives and advantages in front of a local water utility expert. Additionally, the confidentiality of the study participants' data was ensured. Moreover, before the start of research activities, an official letter was delivered to each study town administration, and a copy was given to data collectors for household interviews.

Results

1. Water supply infrastructure

Deep wells and springs were the primary water sources in the study communities. Out of ten water supplies, only three had protection measures at the water supply source. The others had at least one source without any protection measures (Table 2). Our sanitary risk assessment using a WHO inspection checklist showed that the water source for the town of Fafen high sanitary risks, while the other eight had intermediate risks. The water supply yield in four towns, Babile, Bombas, Fafen, and Woter, varied seasonally and fell short of user demand, therefore the population switched to other water sources. Five towns, notably Bombas, Chalanko, Haramaya, Kulubi, and Woter, had leakages in the distribution system.

Table 2. Characteristics of water supply sources and sanitary risks for each water supply.

S. no	Town/ utility	Water source	Seasonal variation in yield	Sanitary risks	Presence of animal or human faces near source	Risk of flooding at source, based on DEM	Microbial quality at source
1.	Chalanko	Spring	Yield does not vary by season	Low risk at source; intermediate risk around reservoir; leakage in the distribution system	Yes	High	11 CFU/100 ML
2.	Kulubi	Deep borehole	Yield does not vary by season	Intermediate risks at source; low risks around reservoirs	Yes	Medium	6 CFU/100 ML
3.	Woter	Deep borehole	Yield varies by season	Low sanitary risk at source; high risk around reservoir	Yes	High	4 CFU/100 ML
4.	Lange	Deep borehole	Yield does not vary by season	Intermediate risks at source; low risks around reservoir	Yes	High	< 1 CFU/100 mL
5.	Kersa	Deep borehole	Yield does not vary by season	Low risks at both sources; intermediate risks at reservoirs	Yes	High	< 1 CFU/100 mL
6.	Haramaya	Deep borehole	Yield does not vary by season	Low risk at source; intermediate risks around reservoir	Yes	Low	< 1 CFU/100 mL
7.	Aweday	Deep borehole	Yield does not vary by season	Intermediate risks at source; Low risk at reservoir	Yes	Low	< 1 CFU/100 mL
8.	Babile	Deep borehole	Yield varies by season	One source with low sanitary risks, second source with intermediate risks, intermediate risks around reservoir; leakage in the distribution system	Yes	Low	
9.	Bombas	Deep borehole	Yield varies by season	Intermediate risks at source and around reservoir; leakage in the pipes	Yes	Low	26 CFU/100 mL
10.	Fafen	Deep borehole	Yield varies by season	High risk at source; no reservoir	Yes	Low	168 CFU/100 mL

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No operator records on water quality or frequency of testing were available in any of the study towns. The water quality assessment at the water source revealed that Bombas and Fafen had the highest colony forming units (CFU) per 100ml, 26 and 168 CFU/100 mL, respectively. However, single water quality measurements cannot be used to draw links between sanitary protection and contamination. In the absence of long-term water quality data, no associations between coliform levels and sanitary risks were explored.

2. Catchment

The assessment of catchments of both the water sources and reservoirs showed that there is less dense habitation around each town's water sources. No other human activity affects the availability of water except Haramaya, where irrigation and truck transportation of water to other communities occur. Except Chalanko and Kersa, open defecation did occur near the catchment areas of the water sources for the other eight study towns. The flood vulnerability assessment of the water sources and reservoirs in the study towns revealed that the Chalanko water source is quite prone to flooding whereas the Kulubi water source is just moderately vulnerable. Moreover, one of Kersa's water sources is extremely vulnerable to flooding, as are the water sources in Woter and Lange. From the digital elevation modeling, the water sources of Haramaya, Aweday, Babile, and Bombas generally had low flood vulnerability risk.

3. Management and governance

Our assessment showed that the towns with technicians and personnel for financial management are Chalanko, Haramaya, Aweday, and Babile. Bombas, Fafen, Kersa, and Woter are water utilities with limited personnel for repair and maintenance. Only two water utilities—in Kersa and Kulubi—monitored water quality, including microbial testing. According to the town water utilities' response, chlorination of water is taking place in Bombas, Haramaya, Kersa, Kulubi, and Woter. The water utility in Chalanko and Lange reported treating water inconsistently.

The lack of adequate personnel made it challenging for utilities to plan for system upgrades and develop emergency plans. Utilities are unable to expand the water supply to meet the demands of a growing population or monitoring rainfall or groundwater levels. However, some managers gave anecdotal evidence of change in ground water. In Fafen, the water supply manager reported hand dug wells drying up in recent years. It was also reported that in areas where previously pit latrines could not be dug because of high groundwater table, now communities were able to dig deeper without hitting water.

The utilities also struggle with financial mismanagement. Although more than half the household respondents reported paying water bills regularly, key informant interviews with managers indicated inconsistent bill payment by customers. This is in part due to limited staff in the utilities to read meter readings and accurately bill all households. Instead, households are charged based on estimates. Secondly, there were reports of vandalism of meters by residents to avoid paying their bill and finally, not all households with water connections were given a meter. To address this, utilities are planning to introduce metering services to all households with the goal of improving financial sustainability and incentivize customers to engage in water conservation. Without this added financial inflow, the managers reported that they would not be able to respond to the growing threats to their water supplies.

4. Community governance and engagement

Our analysis of the water users' awareness of how climate change would affect their water supply and ways to adapt indicated that Bombas, Chalanko, Fafen, Lange, and Woter are the towns with the highest percentage of residents who are aware of the issue. Bombas, Fafen, and Woter were the towns where more than 70% of families felt that they were exposed to climate change.

Less than one-tenth (9%) of houses in the study towns treat water at the point of use. Woter and Babile are the towns with the highest percentage of households that treat water at the point of use. Even though chlorination was the most frequent treatment method, our results demonstrated that less than half of the treated water contained free residual chlorine.

During times of emergency or water scarcity brought on by extreme events, the majority of people switched to unimproved sources. During disruption to their primary water supplies, every household in the remaining three towns either bought water from private companies or shifted to unimproved water sources.

Most of the community representatives interviewed were dissatisfied with their water supply, claiming that the water supply could not keep up with the growing population (Fafen water utility) and there were interruptions for at least five and sometimes up to 15 days per month (Awaday water supply).

5. Supply-chain

Water utilities need to have a variety of sources for supplies of spare parts and routes to convey accessories and treatment chemicals. Except Woter, all of the study towns are situated along the major routes connecting Addis Ababa with nearby regional towns (Harar and Jigjiga), therefore access by road was not a concern reported by managers. However, transferring spare parts to a specific location when they arrive in the town might be difficult in some places, such as Woter and Chalanko (with just one route through town that experiences seasonal flooding). None of the water utilities stored spare parts like pipes, fittings, and treatment products that could be used during an emergency. In addition, there were limited markets for purchasing products and spare parts to operate and maintain the water supply. Managers must move to nearby towns to purchase the products and spare parts.

Water supply performance was also hindered by weaknesses in the local power grid, which requires better coordination between the water supply and energy departments. Most of the water supply managers reported regular power interruptions, sometimes for three months and is made worse during heavy rainfall. Only four out of the ten town water utilities (Babile, Fafen, Haramaya, and Lange) had alternative power supplies in the form of generators. Intermittent power implied that the pumps required to operate the water supply could not operate continuously.

6. Institutional support

Our assessment of the existing institutional support revealed that there is limited support and follow-up from the higher government offices to town water utilities. The main focus of discussions of meetings at the Woreda and Zonal level were day-to-day maintenance, solutions to address water shortages including linking water supplies of neighbouring towns; and the need for utilities to be financially sustainable. However, these meetings are irregular and do not cover climate change and its impacts on water supplies. Despite some regional offices developing plans for new boreholes to address increased demand, no construction has taken place.

Water supply managers also claimed that there were no risk management programs for water supplies. The only form of catchment risk management was an annual tree plantation through a green legacy initiative. There is support from higher offices including provision of spare parts, during emergencies, although it is not provided promptly.

7. Revised *How Tough is WASH* framework

Based on our findings, we identified key factors that can make the existing version of the How tough is WASH framework more applicable for utility-managed water supplies. The revised version of the framework is presented in Table 3.

Discussion

Climate change puts sustainable water supply in danger [26], thus slowing progress towards Sustainable Development Goals. Ethiopia's commitment to climate-resilient WASH is through the One WASH National Programme [22]. However, despite efforts by the government and its development partners, sustainability assessments in certain rural and small towns have found that water service delivery did not comply with national performance standards [23, 37, 38]. A sustainability assessment in bigger cities of the country also showed weak institutional capacity, ineffective governance, water loss and other factors making the water management complex [8]. This has negative implications for the ability of these systems to prepare for climate change, which may put unforeseen stresses on services and will require more effective monitoring of risks. We applied a climate resilience framework [11, 30] to ten utility-managed water supplies in small towns in East Ethiopia to better understand their preparedness for climate change and identified weaknesses in nearly all aspects of service delivery.

Compared to community-managed water supplies in East Ethiopia, we found that small-town water utilities had some strengths [39]. This included the presence of qualified technicians to operate the water supply, an independent board to manage services, relatively better tariff collection and fewer infrastructure risks. However, utility managers receive no support from higher officials on risk management and climate impacts. Emergency support was also not available promptly. This is inconsistent with national policies that require the regional

Table 3. Modified How Tough is WASH [30] framework.

Domain / Indicator	Sub-indicators	Scale		
		Low	Medium	High
Infrastructure	Protective measures against risk of damage and inundation in place	No Protective Measures	Limited or partial protective measures (there are measures but not effective, flood damage)	Comprehensive protection measure is in place (animals cannot enter, full flood protection measure)
	Yield	There is major change in yield and users are forced to use from other alternatives, or reduce water use	The change in the yield is not major, or users not forced to use from other alternatives	There is no change in the yield throughout the year
	Microbial water quality testing	Utility does not test microbial water quality	Utility collects microbial data and microbial test results show low microbial load	Utility collects microbial data and the results consistently meet national standards/no microbes detected in the water sample
	Sanitary risks at source and within distribution system including damage and leaks in the distribution network	The risk score from the inspection is high, there is damage and leaks from the sources to distribution system	If the inspection score is intermediate, the damage in the distribution network is minor	If the inspection risk score is high/ very high, no damage in the distribution network
Catchment	Location of the source	The water source is downhill of steeply sloping managed or cultivated land	Source is downhill of moderately sloping managed or cultivated land	downhill of gently sloping managed or cultivated land
	Inundation with a river and flood protection measures	The water source is frequently inundated with river with no flood protection measures	Occasionally inundated with river with no flood protection measures	Never inundated with river and has flood protection
	Population density, open defecation, pit latrines risk of inundation	Densely populated setting with open defecation and latrines at high risk of inundation	a densely populated area with no open defecation but latrines at medium risk of inundation	No open defecation and latrines at no risk of inundation
	Impact of other water users on water availability	Other water users have impact on the water availability	other water users have limited impact on water availability	Other water users have no impact on the water availability
Water utility management	Strong management and action taken for resilient water utility	No finance personnel, number of technicians in the town are not adequate, technicians have no skill to respond during emergency, no meeting on service delivery, no water quality testing, no water treatment, tariff is collected from users but nor regularly and not based on volume of water used	number of technicians in the town not adequate, maintenance is not immediate, technicians have minor skill to operate/respond to damages, infrequent meeting, irregular reporting, irregular treatment, irregular testing/monitoring of water quality, tariff is collected regularly but is not based on volume of water used and does not cover both the costs of O&M and system upgrades	Organized financial system (personnel with office), adequate number of technicians, immediate maintenance of breakage, technicians are skillful to respond to the threats climate change on water supply, regular meeting and reporting of the service delivery, regular testing/ monitoring, regular treatment, tariff is collected regularly based on volume of water used and covers costs of O&M and system upgrades
	Understanding of climate adaptive management	No awareness on adaptive management	Limited awareness	Adequate awareness on adaptive measures
	Risk assessments	No risk assessment	Infrequent risk assessment	Regular risk assessment
	Training	No training	There is training but not adequate	Training adequate/comprehensive or includes how to respond during climate change related emergency
Community governance and engagement	Awareness on climate change impact	No awareness	Limited awareness	Adequate awareness (if community knows the impact take actions
	Response to service provider	No bill payment, no mechanism for reporting service disruption	No regular bill payment or delay, a mechanism for reporting service disruptions but no timely response from the utility, no regular bill payment	Timely payment of bill, timely response to reports of service disruption
	Coping mechanisms at household level	No storage, no treatment at POU, moved to unimproved sources	No adequate storage, treatment at POU, moved to improved sources	Adequate storage, treat at POU, moved to improved sources

(*Continued*)

Table 3. (Continued)

Domain / Indicator	Sub-indicators	Scale		
		Low	**Medium**	**High**
Institutional support	Risk management programme	No formal risk management programme in place	formal risk management programme in place but not fully functioning	formal and functioning risk management programme in place
	Support water supply technicians, operators and managers to develop adaptive measures	no steps taken to support water supply technicians, operators to develop adaptive measures,	Inadequate/ad hoc support to water supply technicians and operators to develop adaptive measures	ongoing support for adaptive measures with cooperation with all other sectors
	Emergency response	substantial delay in procuring parts or technical support after an emergency, no alternative power sources, alternative water source	slight delay in procuring parts or technical support after an emergency, alternative power sources not sufficient, alternative water source but inadequate	No delay in procuring parts or technical support after an emergency, adequate alternative power sources, adequate alternative water sources
Supply chain	Source of consumables and Spare parts	Only single source	Limited or no more than two sources	Multiple sources
	Routes to access	Only single route	At least one alternative routes	Multiple routes
	Status of infrastructure	a high risk of damage to roads, bridges, or communication networks from natural hazards, no centralized power supply	a medium risk of damage to roads, bridges, or communication networks from natural hazards, frequent interruptions to power supply	No risk of damage to roads, bridges, or communication networks from natural hazards, reliable power supply with backup generators
	Storage of spare parts and consumables	No storage of surplus parts needed to carry out repairs	No surplus parts in the store needed to carry out repairs	Store most or all parts needed to carry out repair

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water bureaus to continuously monitor the performance of town water boards and water utilities and provide training and technical support when needed [35].

Seasonal variation in water availability was reported for nearly half of the water supplies, with no utility data available on seasonal changes in yield. Lack of monitoring of water supplies has been associated with reduced functionality during drought in other studies from Ethiopia [40]. The presence of sanitary risks at the water source coupled with the lack of water quality testing by operators indicates another significant vulnerability in these water supplies. In a multi-country paper, Charles et al. (2020) found a correlation between sanitary risks and contamination [41], with a deterioration in water quality after heavy rainfall [42]. Therefore, we recommend that authorities develop protocols for utilities to test water quality and monitor source yield, which can offer public health protection from climate stresses. To reduce the possible health risks associated with extreme events and provide more resilient services, particularly during floods, the district government must also increase its efforts to prevent open defecation and implement flood protection measures around the water sources.

With little to no routine monitoring or trainings on climate risk management, it is impossible for utilities to detect changes in climate patterns and impacts on water resources, or to develop emergency plans. We recommend that Zonal and Woreda offices support utilities in developing protocols for disaster response and include risk management programs like climate resilient Water Safety Plans [43] into training programs for utility managers and operators.

Consistent with previous study [24] we found that several water utilities lack the personnel necessary for water treatment and quality monitoring, even though having a sufficient workforce is one of the requirements for sustainable water delivery [23]. This is inconsistent with the National One WASH program plus which underlines the necessity of proper training, and experience shows that training can increase utilities' capacity and performance [21, 23]. Utilities also struggle to accurately bill customers and recover operating costs, which inevitably affects their ability to upgrade the system and keep up with growing demand. This poses a significant threat to their capacity to prepare for climate change and adopt the recommendations made here and elsewhere [13].

Based on this study, we also revised the How tough is WASH framework to better reflect the complexity of operating a piped water supply. Specifically, we added metrics on microbial water quality testing by the utility, without which we cannot conclude that water supplies are safe for consumption or draw inferences about current and potential seasonal changes in water quality. In addition, we added metrics on tariff collection and cost recovery, availability of a reliable centralized power supply with backup generators; and modified the community indicator to reflect their role in paying user bills and the need for mechanisms to report service disruptions.

The indicators presented in this study have the potential to be integrated into monitoring frameworks for town water utilities in Ethiopia. Similar to the sustainability check framework [16, 32], the proposed indicators can be used to identify system weaknesses and track incremental progress at service-provider and service-authority levels. The district and sub-district indicators are also conducive to be integrated into system building block analysis tools, used by several WASH sector organizations as part of their district-wide approach [44].

Conclusion

Monitoring climate risks to piped water supplies in small and medium towns is essential to prepare for climate change and keep up with the demands of a growing population. We applied the How Tough is WASH to identify climate risks and system weaknesses of ten small town water utilities in East Ethiopia. Consistent with previous work done in similar settings, we found several weaknesses in service providers and authorities that negatively impact service delivery. These weaknesses are inconsistent with national policies and must be addressed to receive the full public health benefits of access to piped water supplies.

Based on this study, we added indicators to better align the How tough is WASH framework with the Government of Ethiopia's existing monitoring framework for town water utilities. A tool that applies a climate lens to a sustainability check has the potential to enhance evidence-based decision-making by policymakers in Ethiopia and other sub-Saharan African countries as they improve access to utility-managed piped water supplies.

Supporting information

S1 Appendix. Water sources inspection checklist.
(DOCX)

S2 Appendix. Interview guide for operators, technicians and officials.
(DOCX)

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