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Climate Resilience of small-town water utilities in Eastern Ethiopia

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Abstract

Building a resilient water, sanitation, and hygiene (WASH) system is more important than ever since climate change threatens WASH, particularly in low- and middle-income countries. The Government of Ethiopia stresses climate-resilient WASH through its One WASH National Program, albeit it may be challenging to ascertain the resilience due to the absence of an easy-to-use monitoring tool. The "How tough is WASH" framework is a recently developed framework to monitor the community-managed rural water supply resilience to climate change. We investigated whether this framework might be used to assess the resilience of small-town water utilities by choosing 10 communities in eastern Ethiopia. The How Tough is WASH framework considers resilience along six domains: supply chain, institutional support, management and governance, community role and feedback, infrastructure, and catchment using a five-scale measurement. Due to its complexity to apply using a five-scale measure, we modified the framework into a simpler 3-point scale —low, medium, and high—to assess the climate change resilience of urban water utilities. Accordingly, the town water utilities rated moderately resilient, with primary failures including insufficient government support, a lack of flood protection, seasonal variation in yield, and leakage in the distribution system. Fixing the identified failures is essential for resilient services in the study towns. The current finding using the How Tough is WASH framework revealed the framework's versatility in determining the climate resilience of WASH, therefore, should be included and integrated into a WASH monitoring tool.

Keywords: Climate vulnerability, how tough is WASH, institutional support, piped water, professionalized water supply

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Introduction

Climate change poses severe challenges, which have been on the international agenda in recent years [1]. Its impacts are expected to be relatively severe in the developing world, given its urban societies are densely populated, and exposed to natural disasters with limited capabilities to tackle the impacts [2, 3]. Most impacts are experienced through more droughts, floods, and less predictable rainfall and water flows [4].

Water and sanitation are expected to be affected by climate change. A growing body of evidence shows that water supplies are experiencing the impacts of climate change (availability and quality), while the sustainable management of water resources remains crucial for urban climate resilience[5, 6]. Intense rainfall, severe storms, dry spells, extremely hot days, and storm surges, damage or destroy water supply infrastructure, reduce the availability of water resources and decrease the quality of water used for consumption [5, 6].

Water management with climate change adaptation is becoming increasingly relevant for the design, construction, and maintenance of water sector infrastructure for the provision of adequate and safe water. Creating sustainable improvements in water and sanitation services requires a holistic approach that addresses sector governance, finance, service provider performance, and water resources management [7]. Strategies for drinking water safety management that address risks related to climate variability and change are needed to deliver safely managed water supply in developing countries[8].

Integrating climate resilience into existing risk management approaches, such as water safety plans, is likely to be one approach to manage climate risks to drinking water supply but may be insufficient on its own [5]. To cope with the existing and future negative effects of climate change, it is strongly advised to build resilient water, sanitation and hygiene (WASH) infrastructure and incorporate resilience into drinking-water and sanitation management [5, 9]. The knowledge of elements that will need improvement to increase the sector's resilience to climate change in low- and middle-income countries is expanding. This includes the requirement to evaluate threats from existing climate variability and keep track of adaptation measures [10].

Ethiopia is one of the most vulnerable countries to climate variability and climate change due to its low adaptive capacity to deal with these expected changes[11-13]. Climate related risks are

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already apparent in the country, with evidence indicating that existing climate variability, along with rising demand for water, is already stressing systems and services[14, 15].

The number of small and medium towns in Ethiopia has significantly increased over the past few decades, and urbanization has increased quickly in the country[16, 17]. In these towns, water and sanitation services have been difficult to maintain because of weak institutional capabilities, insufficient economies of scale, difficulties with cost recovery, rapid population increase, and increasing demand [18]. Recognizing the challenges, the Government of Ethiopia launched the One WASH National Program in 2013 with the aim to achieve universal, sustainable, climate resilient and equitable access[19]. Complementary to this, the ONEWASH Plus is being implemented to improve the sustainable WASH services in such small towns [19]. The country developed a sustainability check employing a framework of financial, institutional, environmental, technical, and social factors, commonly known as FIETS, in the WASH projects being implemented with development partners to ensure better service delivery [20]. The sustainability checks revealed low levels of service reliability, cost recovery and technical capacity in small town utility-managed water supplies[21].

Even though climate resilient WASH is one of the top priorities of the government under the One WASH National Program, a lack of simple and easily applicable tools makes it difficult to measure the resilience of existing WASH facilities in the country. Haramaya University in collaboration with the University of Bristol has developed a framework that could be used in low-income countries to enhance decision-making climate resilient WASH [22]. The framework was tested on 20 community-managed water sources in Ethiopia, which is typical of rural sub-Saharan Africa but is linked to low service levels and a high vulnerability to climate changes [22]. The finding showed that the water infrastructure in selected rural towns had low to moderate resilience to climate change due to inadequate sanitary protection of water infrastructure and technical capacity of community-managers[23]. In urban setting, assessing the WASH resilience with a tool that should capture its complex nature can foster a more informed decision-making process [24].

The current research aimed at assessing the resilience of town water utilities to climate change as well as to identify the strengths and weaknesses of the How Tough is WASH framework in order to be improved and implemented nationally. The research team applied the framework to the water

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supplies of 10 towns in eastern Ethiopia to address the lack of evidence on climate resilience from towns in the country with government-managed water supplies.

Materials and methods

Study settings

We conducted this study in ten towns of east Hararghe Zone of Oromia region and Fafen Zone of Somali region, Eastern Ethiopia (

Figure 1). Oromia and Somali regions are the two of the most vulnerable regions in the country to climate change impacts [25, 26]. East Hararghe zone is one of the drought prone areas in 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 leads to thousands of people being displaced [27]. In the zone, 8.27% of the population are urban inhabitants, 1.11% is pastoralist, 17% agro-pastoralists, and the rest are agriculturalists (74%). Somali region, from where the two towns selected, is one of the mostly affected regions in the country[28]. Two towns are located in the Fafen zone of the region. This zone is located in Wahit Shebelle River Basin, which comprises the drainage of the seasonal rivers of Fafan, Jerar, and Dakhato. In Fafen zone, seasonal rivers play a significant role as a water resource and the most successful boreholes are locate.

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Figure 1: Study towns (Aweday, Babile, Bombas, Chalanko, Fafen, Kersa, Kullubi, Haramaya, Lange, and Woter), Eastern Ethiopia, 2022

The town with a high percentage of 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 as indicated in Table 1. Moreover, towns that chlorinate water on the regular basis are Bombas, Haramaya, Kersa, Kulubi, and Woter.

Table 1: Study towns, population and sample households in east Haraghe and Fafen zones, Eastern Ethiopia, 2022

S. no	Town name	Sample households for survey
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**

Description about the town water utility in Ethiopia

According to national guidelines for urban water supply and sewerage services [29], the water supply is managed by town water utility, established by the town administration, with a water board. 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.). The town water board is composed of representatives from the town administration, pertinent local government offices (such as the water office, health office, finance and economic development office, and education office), and customers.

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Study approach

We carried out a cross-sectional study employing both quantitative and qualitative methods in two rounds in August and December 2022. The study's objective was to assess how resilient the utility-managed urban water supply services were in selected district towns. For quantitative survey, we interviewed a 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. In order 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 town using a 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 simple random 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 water utility, from each town to explore the community role in the water utility. All the water supply sources and reservoirs in each town were assessed to explore its quality and potential risks including being flooded and inundation with rivers.

Method of data collection

A survey form was developed based on previous field application of the "*How tough is WASH?"[22]* framework to collect data from household heads or representatives. We used the set of indicators or domains in the *How tough is WASH* framework *[22]* to evaluate the government-managed urban water supplies to provide comparable data and allow for more transparent trade-off analysis. The survey was designed to collect household data on socio-demographic characteristics, water supply characteristics, household awareness on 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 expected and experienced exposure to climate hazards. Additionally, an observational checklist, based on the World Health Organization's sanitary inspection forms[30] was used by enumerators to record threats in the

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environment around the water infrastructure or in its immediate vicinity that may make them susceptible to climate threats. 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 were collected using a semi-structured interview developed with technicians, person in charge of managing the water utility, and community representatives in each town. Topic guides were developed to gather information on institutional and operational aspects of the water supply, to enable us to score these domains. 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 operation and maintenance of water infrastructure, and coping mechanisms of climate change impacts on water supply. The water utility manager from each town 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 to Oromiffa and Somali. The key informant interviews were carried out in the local languages. The sessions were taped, transcribed, and translated into English.

The WHO sanitary inspection form and microbial and free residual chlorine testing procedures were used to assess the water quality and its health risk. Both free residual chlorine and microbial testing of the water quality 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 [30]. Free residual chlorine was measured from the sample of water source and point-of-use of households claimed to treat prior to drinking. The residual chlorine measurement was done by Palintest DPD chlorine method by taking a 10 ml sample of water stored in the house and reservoirs, adding it to the viewing tubes and reading the mark after DPD free chlorine reagent table (DPD-1). Free chlorine reacts with diethyl-p-phenylene diamine (DPD) in 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.

Water utilities resilience measurement

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The outcome variable in this study was the resilience of the local government managed piped water supply to climate change. The measurement was based on data gathered from water user survey, technical evaluations of infrastructure, risk analysis in catchments, and in-depth interviews of town water utilities (operators and managers), and community knowledge about climate change impact and measures they take. The data from user surveys were checked for completeness and sent to main server, downloaded in excel form and analyzed descriptively to determine the user's role for resilience of water supply services. 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 were determined using Digital Elevation Modeling. For the 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 criteria were developed to ensure that the data from the interviews could be used to compare the town water utilities to the indicator criteria and offer a valid score (Table).

Table 2: Domains and respective metrics for government managed town water utilities Resilience to Climate change (adapted from How tough is WASH) [22]

No	Domains	Metrics	Assessment method
1.	Infrastructure/water source	Protective measures against risk of damage and inundation	Inspection
		Change in the water yield during extreme events	Technicians and managers interviews
		Water quality	Water quality test, Technicians and managers interviews
		Sanitary risks at source and within distribution system	Inspection using the WHO checklist
		Damage and leaks in the distribution network	Inspection
2.	Catchment	Location of the water source	Inspection and delineation using Digital Elevation Modeling
		Inundation with a river and flood protection measures	Inspection
		Population settlement and practices, pit latrines risk of inundation	Inspection
		Impact of other water use on water availability	Inspection
3.	Water utility Management	Management and action of town water utility	Community representatives, Technicians and managers interviews
		Understanding of climate adaptive management	Technicians and managers interview
		Risk assessments	Technicians and managers interviews
		Training	Technicians and managers interviews
4.	Community awareness and feedback	Awareness on climate change impact	Household survey
		Response to service provider	Household survey, community KII
		Coping mechanisms at household level	Household survey
5.	Institutional support	Risk management programme	Technicians and managers interviews
		Support to the water supply technicians, operators and managers to develop adaptive measures	Technicians and managers interviews
		Emergency response	Technicians and managers interviews
6.	Supply-chain	Source of consumables and spare parts	Technicians and managers interviews
		Routes to access spare parts, treatment chemicals	Technicians and managers interviews
		Status of infrastructure	Technicians and managers interviews
		Storage of spare parts and consumables	Technicians and managers interviews

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Town water resilience assessment using the How Tough is WASH framework

The research team evaluated the applicability of a previously created methodology that employed six resilience domains on a five-point scale (Very low, low, intermediate, high, and very high). The team discovered that local WASH experts found it challenging to distinguish between high and very high, as well as low and very low on an objective basis. For instance, in the infrastructure domain, protective and comprehensive protective measures against risk of damage were rated as high and very high resilient, respectively, while limited and partial protective measures were rated as low and very low resilient. Distinction between these two scales (High versus very High, and low versus very low) could be difficult for local assessors. As a result, we refined the framework and developed a three-point resilience scale to score water along three categories—low, moderate, and high by combining high and very high to produce high, and very low and low to form low (Table 3). Each of the three levels contains criteria to score the resilience of water supplies. The criteria describe conditions to indicate what that level of resilience may look like. The resilience of each metric was scored based on which level described the water supplies most closely. The indicator was assigned the resilience score corresponding to the majority of metric scores. For example, if more than 50% of the metrics received a score of Low, then the indicator also received that score. The score for each indicator were added up to determine the overall system resilience scores for each town water utility. The water supply utilities were then ranked according to importance for enhancing resilience using these scores. The determination of resilience was based the domain adapted from previous studies [22, 23]. We used the framework to check its practicability in urban setting where the water service is controlled by utility.

Moreover, in the case of town water utilities, community is only minimally involved in the service delivery. Our assessment of community’s role in the case town water utility is limited to self-reported bill payment, awareness on climate change and actions they took when impacts on their water supplies happen.

266 *Table 3: Town water utilities climate resilience score adapted from How Tough is WASH* ***[22]***

Domain	Metrics	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
	Quality	If the utility has no data or microbial test result indicates high microbial load	The microbial test result is in the intermediate health risk	The result meets the standard/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	Management and action taken for resilient water utility	No finance personnel, number of technicians in the town not adequate, technicians have no skill to respond during emergency, no meeting on service delivery, no water quality testing, no treatment at all	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	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
	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 feedback and awareness	Awareness on climate change impact	No awareness	Limited awareness	Adequate awareness (if community knows the impact take actions
	Response to service provider	No timely bill payment, no involvement in maintenance and operation, reporting damage to utility	No regular bill payment or delay, limited involvement in maintenance, operation, reporting, no regular bill payment	Timely payment of bill, involve in maintenance, operation, reporting
	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
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	a medium risk of damage to roads, bridges, or communication networks from natural hazards	No risk of damage to roads, bridges, or communication networks from natural hazards,
	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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Indicator scoring and its implications for planning interventions

The total score of town water utility's resilience is from 18 points in which case the town with high score (13-18) is highly resilient to climate change therefore maintaining the performance is needed, intermediate score (7-12) which is taken as intermediate resilient and minor action based on the failure found is needed, and the one with low score (6) is take as low resilient which means complete or the systemic improvement is fundamental (Table 4).

Table 4 : Assigning overall resilience scores to water supplies

Score	Resilience	Priority	Meaning and implication
13-18	High	Low	The water supply service in the town is resilient therefore maintaining the status is required
7-12	Intermediate	Intermediate	There are domain/s with failure that need/s action for resilient water utility in the town.
6	Low	High	All the domains are with failure, therefore urgent action is needed across all the domains

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, prior to the start of research activities, an official letter was delivered to each study town, and a copy was given to data collectors for household interviews.

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Result

1. Water supply infrastructure

Deep wells and springs were the primary water sources in the study communities. The towns of Kersa, Kulubi, Haramaya, and Babile had multiple water sources. The sources in Bombas, Chalanko, and Woter were the towns had protection measures. The others had at least one source without any protection measures, like Babile, Haramaya, and Kersa (Table 5).

Table 5: Infrastructure characteristics of Water supply sources in study towns, Eastern Ethiopia, 2022

s.no	Town/utility	Water source	Characteristics
1.	Chalanko	Spring	There was a leakage in the distribution system, the sanitary risk is intermediate, there is protection measure around the sources, and the yield does not vary in season
2.	Kulubi	Deep borehole	There is no protection measure around the source, there is point leakage, and the sanitary risk assessment indicated that it is with an intermediate sanitary risk.
3.	Woter	Deep borehole	The source has protection measure against damage, the yield varies in season. There was crack and leakage in the distribution system specifically, the reservoir was with cracks and leaking water.
4.	Lange	Deep borehole	The water source was an intermediate sanitary risk score, there was protection measures around the source but not on the reservoir, the yield does not vary in season
5.	Kersa	Deep borehole	One source has protection measure but not the other, and there is no leakage, the yield does not vary in season
6.	Haramaya	Deep borehole	One source and all the reservoirs have no protection measures, there was leakage of tap, the yield does not vary in season and the sanitary risk score is intermediate.
7.	Aweday	Deep borehole	Aweday shares the same sources with Haramaya town. All the reservoirs have no protection measures, and there was leaking tap, the yield does not vary in season and the sanitary risk score fall in the intermediate score.
8.	Babile	Deep borehole	Has two sources with one without protection measures, there was leakage of pipe, with varying yields, and the sanitary risk score is within an intermediate score.
9.	Bombas	Deep borehole	The source has a protection measures, there was leakage in the pipes, the yield varies with season, and the sanitary risk assessment shows high risk
10.	Fafen	Deep borehole	The source has a protection measures, varying yield in season, and the risk assessment shows high sanitary risk

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Our sanitary risk assessment using a WHO inspection checklist shows that the town of Fafen and Woter had high sanitary risk, while the other eight had intermediate risks. The water supply yield in four towns: Babile, Bombas, Fafen, and Woter, varied seasonally and falls short of user demand, therefore the population switches to other water sources. Five towns, notably Bombas, Chalanko, Haramaya, Kulubi, and Woter, had leakages in the distribution system. There is no data on water quality and frequency of testing in all study towns. Our assessment on the water quality revealed that Chalanko, Bombas, and Fafen had more than 100 colony forming units (cfu) per 100ml, whereas Kulubi and Woter had between 1 and 10 cfu per 100 ml sample, and other towns had less than one cfu per 100 ml of water sample. We did not test the water quality of Babile town due to the water sources inaccessibility during the data collection time associated with due to road damage. The water quality test from reservoir shows that Kersa, Haramya, and Aweday water utilities had low coliform levels (less than 1 cfu per 100ml of water sample). According to the overall assessment of resilience, Chalanko, Kersa and Awaday are three towns that are intermediate resilient score while the others are low (Table 6).

2. Catchment

The assessment of catchments of both the water sources and reservoirs show 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. With the exception of 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 (details of digital elevation modeling result attached as sumplemetary material). 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 source of Haramaya, Aweday, Babile, and Bombas generally had low flood vulnerability risk. The catchment domain's resilience score revealed that Chalanko was the sole town with a high score, with Haramaya, Awaday, Fafen, and Babile had low scores and the other five towns had intermediate scores (Table 6) .

Table 6: Piped water supply resilience to climate, Eastern Ethiopia, 2022

S.no	Town	Catchment	Infrastructure	Management and governance	Supply-chain	Institutional support	community awareness and feed back	Total score	Identified problems
1.	Babile	1	1	2	2	1	1	8	One source has no protection measures, no flood protection, leakage in the distribution, yield varies in season, intermediate sanitary risk, open defecation around the sources, no regular meeting, high coliform in the water sample, no training specific to resilient service, POU water treatment is low, limited institutional support, no storage of spare parts, consumables
2.	Woter	2	1	2	2	1	1	9	No protection for reservoir, leakage in the distribution system, yield vary in season, open defecation around the sources, no adequate technicians, no regular meeting, intermediate coliform load, limited institutional support, small number of households treat water at the POU, single route to transport spare parts and products
3.	Aweday	1	2	2	2	1	1	9	One source has no protection measures, there is leakage in the distribution, intermediate sanitary risk, open defecation around the source, moderate flood vulnerability, no regular meeting, no risk assessment, no training specific to resilient service, low POU water treatment, limited institutional support
4.	Fafen	1	1	2	2	1	2	9	Water source has no protection measures, leakage in the distribution system, yield varies in season, high sanitary risk, open defecation around the sources, moderate flood vulnerability risk, no adequate staffing (inadequate technicians and

									finance personnel), no regular meeting, high coliform load, POU water treatment is low, limited institutional support
5.	Bombas	2	1	2	2	1	2	10	Source has not protection measures, there is leakage in the distribution, yield varies in season, intermediate sanitary risk, open defecation around the source, high flood vulnerability, weak water bill collection, no regular meeting, POU water treatment is low, limited institutional support, no spare part and treatment product storage
6.	Chalanko	2	1	2	2	1	2	10	Leakage in the distribution system, intermediate sanitary risk, high flood vulnerability, high coliform load, irregular treatment, no training specific to resilient services, POU water treatment is low, no support from government, no alternative power sources
7.	Kulubi	2	1	3	2	1	1	10	No protection measures against risk of damage, there is leakage in the distribution system, intermediate sanitary risk, open defecation around the source, moderate flood vulnerability, intermediate coliform load, no training specific to resilient utility, POU water treatment is low, no risk management, no alternative power source
8.	Haramaya	1	1	3	3	1	1	10	One source has no protection measures, leakages, intermediate sanitary risk, open defecation around the source, moderate flood vulnerability, no regular meeting, no risk assessment, no training specific to resilient service, low POU water treatment, limited institutional support
9.	Lange	2	2	2	2	1	1	10	No protection measures against damage and river inundation, open defecation

									around the sources, high flood vulnerability, inadequate personnel (finance), no regular meeting, no training specific to resilient utility, no quality testing, POU water treatment is low, limited institutional support
10.	Kersa	2	2	2	2	1	1	10	No protection measures against damage and river inundation, high flood vulnerability, inadequate personnel (finance for bill collection and technicians for proper maintenance), no regular meeting, no training specific to resilient utility, POU water treatment is low, limited institutional support

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3. Management and Governance

Our assessment showed that the towns with appropriate personnel including finance personnel and adequate technicians that is facilitated with office are Chalanko, Haramaya, Aweday, and Babile. Bombas, Fafen, Kersa, and Woter are the water utilities with limited technicians for maintenance of damages. Only in Kersa and Kulubi water utilities monitor water quality, including microbial testing. According to the town water utilities' response, chlorination of water is taken place in Bombas, Haramaya, Kersa, Kulubi and Woter. The water utility in Chalanko and Lange treat water inconsistently. With the exception of Haramaya and Kulubi, other eight towns scored intermediate resilience in the management domain, which suggests failures including irregular water quality monitoring and treatment, inadequate staff, a lack of risk assessment, and limited support from higher offices. The domain scores using its indicators revealed that Haramaya and Kulubi are the towns with high scores and the others are intermediate scored (Table 6).

4. Community awareness and feedback

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. Even if our quantitative survey shows more than half respondents paying water bill on regular basis, key informant interviews indicated inconsistent bill payment by customers due to interruptions in the water service delivery. 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 overall. 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 demonstrate 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 (Supplementary table). According to all domain assessment criteria, Chalanko, Lange, Bombas, and Fafen are moderately resilient, but the other towns receive low scores (Table 6).

During the period of a lack of primary water supplies, every household in the remaining three towns shifted to unimproved water sources. Even in times of need, no community had more than a quarter of its residents treat water at point-of-use. The overall resilience score of the users' role

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is intermediate in four towns, Chalanko, Lange, Bombas and Fafen and in other towns it is low score (Table).

5. Supply-chain

It is essential for the water utility service to have a variety of sources for supplies of spare parts and routes to convey accessories and treatment chemicals. With the exception of 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 is not a concern. However, transferring the spare parts to a specific area when they arrive in the town might be difficult in some places, such as Woter and Chalanko (just one route with seasonal flooding). There is no town water utility with storage of spare parts mainly pipes, fittings, and treatment products that could be used during emergency. In addition, there is no multiple points of purchasing for products and spare parts, however community and utility can move to nearby towns to purchase the products and spare parts. Integration among sectors is limited in all the study towns. According to the aggregate ratings from the measures used to score the domain, Awedaya, Haramaya, and Kersa are highly resilient, while the other utilities are moderate (Table 6).

6. Institutional support

Our assessment on the existing institutional support revealed that there is limited support from the higher government offices to district towns. The managers claim that there is no risk management program and that each town water utility implement except annual tree plantation through a green legacy initiative. There is support from higher offices during emergency, although it is not promptly. Babile, Fafen, Haramaya, and Lange town water utilities had alternative energy sources if the main power sources damage. With the exception of Haramaya and Aweday town water utilities, others have no backup water sources in case the primary ones cease to function. According to the resilience score determined by the domains' metrics, the water utilities in the towns of Chalanko, Kulubi, and Woter generally have low resilience scores when compared to others that have intermediate ratings (Table 6).

Overall resilience of water utilities in Eastern Ethiopia

After adding domain scores, the overall resilience scores of the town water utilities were between 8 and 12, indicating intermediate resilience. The findings indicate that several resilience-related

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domains have failed, particularly institutional support, where all the towns had low scores, and infrastructure, where seven towns received low scores. The water utilities in the study towns have low resilience to climate change in terms of institutional support, community role and feedback, as shown in the total resilience score (Figure **2**). The towns, on the other hand, have an intermediate resilience score in terms of management and governance, Catchment, and supply chains, all of which could use some work, particularly regular water quality monitoring and treatment based on the results of the monitoring, as well as the modernization of bill collection methods.

Figure 2: Overall climate resilience score of town water utilities in Eastern Ethiopian, 2022

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Discussion

Climate change puts sustainable water supply at danger[10], thus slowing the momentum of development and health advancements e [9]. Ethiopia's commitment to ensure this is through One WASH National Programme under which climate resilient WASH is given a priority [19]. However, despite all the efforts by the government and its development partners, sustainability assessments in certain rural and small towns found that the water service deliveries do not comply with the country's plan [20, 31, 32]. A sustainability assessment in bigger cities of the country shows weak institutional capacity, ineffective governance, water loss and other factors making the water management complex [33].

We explored the existing climate resilience of small-town water utilities in district towns of eastern Ethiopia using a modified version of the How tough is WASH resilience assessment framework. The study revealed that the water supplies are only moderately resilient to climate change, failing to meet many of the resilience indicators. This is comparable with the findings on rural water supply resilience assessment in the country and Nepal[23]. Except for the supply chain, failures happen in every domain. Gaps in infrastructure include inadequate flood protection for water sources, irregular water treatment. Insufficient support from regional offices is common in the towns and gaps in management include irregular water quality monitoring vary.

Under the management domain, even if adequate personnel is one of the requirements for sustainable water delivery, based on sustainability check framework [20], our study indicated that some local water utilities lack adequate staffing, water treatment and water quality monitoring. The National One WASH program plus underlined the necessity of the proper training, and past experience shows that training can increase utilities' capacity and performance [18, 20]. Thus, integrating climate resilient water supply service in the training will increase the technician's capacity to respond to emergencies.

Resilient water infrastructure is adaptable to change and continues delivering services including during unexpected change [5, 34]. The current study showed that some water sources vary in both quantity and quality with the seasons, placing the infrastructure domain in the medium resilience category. The need for full assessment of water sources for year-round availability and minimizing

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nonrevenue water and wastage or loss through leakage should be in place for better resilience [35]. For some water sources, protection from open defecation is urgently needed in order to lessen associated health risk which would happen during extreme events notably flooding. Also, the limited or absent flood protection measures around the water sources in nine towns could increases the risk of water sources flooding during heavy rain.

In contrast to rural community-managed water supply, where most of the roles are being played by the volunteer community members [22], the customers' role in the current study towns is limited to paying bills. To lessen the worst effects of disasters related to climate change, communities must become resilient through strategies like point-of-use water treatment, which was described as one of the coping mechanisms elsewhere[36]. Yet, with little to no routine monitoring and treatment occurring in the study towns, it is crucial to establish an early communication channel on the effects of climate change and the proper course of action. Moreover, working to improve the publics' awareness and knowledge on climate change, and about disaster response and recovery should be in place to improve the resilience and reduce adverse health effect [37, 38].

In all of the study towns, there was low institutional support for local utilities to provide resilient and sustainable water delivery and limited communication with higher government officials. This contrasts with the national policies which states that regional Water Bureau is to continuously follow up on the performance of both Town Water Boards and Town Water Utilities, and to give training and technical support when needed [29]. In addition, ensuring backup power and water sources is essential to prevent water supply disruptions that could force the community to drink contaminated water.

Since certain towns have experienced a shortage of spare parts and products, the water utilities were only moderately vulnerable to climate change in this area, as was noted in the prior assessment of water supply funding [39]. Moreover, in some water utilities, the low utilities' capacity to collect the water bill, delayed bill collection and customers' low willingness to pay hints need for support to build the capacity of the utility.

The lack of a comprehensive monitoring tool for climate resilience in low- and middle-income nations led to the development of the "How Tough is WASH" framework[22], which has been demonstrated to be the best framework for displaying the resilience status of WASH facilities in

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rural settings. This framework may now be used to properly evaluate the climate resilience of small-town water utilities, including prior to building significant upgrades on the existing infrastructure.

Small-town water utilities have some strengths over community-managed water supply resilience[23]; such as having qualified technicians to run, an independent board that manages the service, and better monitoring and supply-chain of spare parts. Both share the drawback of having little support from high officials.

Our analysis of the framework suggests the possibility of using the framework in two ways, depending on the assessment's objectives. If the assessment's objective is to produce resilience scores for particular water supplies in order to identify their shortcomings and track them over time, a three-point scale from low to high score to the indicators can be used. If the assessment's objective is to provide aggregate resilience scores of water supply systems to enable regional or national comparisons, it is advised that the sub-indicators be graded on a 5-point scale from very low to very high resilience. For a better measurement of WASH's climate resilience, we strongly advise that this user-friendly approach be embedded into the current monitoring frameworks. This study's weakness is that we treat each indicator equally in the framework due to insufficient data from the fieldwork to warrant an alternative weighing system. However, after validation with sufficiently large datasets, indicators may potentially be weighted.

Conclusion

The current finding shows that the water utilities in the towns are moderately resilience to climate change. The major failures are lack of protection measures around the water sources, infrequent monitoring of the quality, limited support from the higher government offices and customer willingness to pay for the services. In the study towns, enhancing community engagement[40], catchment protection[41], and infrastructure improvements through the construction of suitable protective measures around the sources and reservoirs are needed for better resilience of the water utilities.

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References

1. IPCC: **Human Settlements, Infrastructure and Spatial Planning. Climate Change: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report**. In. United Kingdom and New York, NY, USA: IPCC(Intergovernmental Panel on Climate Change); 2014.
2. Carréon JR, Worrell E: **Urban energy systems within the transition to sustainable development. A research agenda for urban metabolism**. *Resources, Conservation and Recycling* 2018, **132**:258-266.
3. Kammen DM, Sunter DA: **City-integrated renewable energy for urban sustainability**. *Science* 2016, **352**(6288):922-928.
4. Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis M: **Climate change 2021: the physical science basis**. *Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change* 2021, **2**.
5. Howard G, Calow R, Macdonald A, Bartram J: **Climate change and water and sanitation: likely impacts and emerging trends for action**. *Annual review of environment and resources* 2016, **41**:253-276.
6. GWP U: **WASH Climate Resilient Development: Strategic Framework**. In.: Global Water Partnership and UNICER; 2017.
7. Özerol G, Dolman N, Bormann H, Bressers H, Lulofs K, Böge M: **Urban water management and climate change adaptation: A self-assessment study by seven midsize cities in the North Sea Region**. *Sustainable Cities and Society* 2020, **55**:102066.
8. WHO, UNICEF: **Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines**. In. Geneva, Switzerland: UNICEF and WHO; 2017.
9. WHO: **Summary and policy implications Vision 2030**. In: *The resilience of water supply and sanitation in the face of climate change.* Geneva, Switzerland: World Health Organization (WHO); 2009.
10. Howard G, Charles K, Pond K, Brookshaw A, Hossain R, Bartram J: **Securing 2020 vision for 2030: climate change and ensuring resilience in water and sanitation services**. *Journal of water and climate change* 2010, **1**(1):2-16.
11. **Climate Risk Profile: Ethiopia** [https://climateknowledgeportal.worldbank.org/sites/default/files/2021-05/15463A-WB_Ethiopia Country Profile-WEB.pdf]
12. Tesfaye K, Mamo G, Debela S, Tadesse M, Mekuriaw A, Debele B, Semane B, Gebrekidan B, Lemenih M, Zenebe M: **First assessment report on agriculture and food security. Working group Ii-climate change impact, vulnerability, adaptation, and mitigation**. In.: Ethiopian Panel on Climate Change (EPCC), Ethiopian Academy of Sciences (EAS …; 2015.
13. Bank-World: **Economics of adaptation to climate change: Synthesis report**. In.: World Bank Washington, DC; 2010.
14. Calow R, Ludi E, Tucker J: **Achieving water security**. *Lessons from Research in Water Supply, Sanitation and Hygiene in Ethiopia, Overseas Development Institute (ODI), Londres* 2013.
15. MacDonald AM, Bell RA, Kebede S, Azagegn T, Yehualaeshet T, Pichon F, Young M, McKenzie A, Lapworth DJ, Black E: **Groundwater and resilience to drought in the Ethiopian highlands**. *Environmental Research Letters* 2019, **14**(9):095003.
16. Tegenu T: **Urbanization in Ethiopia: Study on growth, patterns, functions and alternative policy strategy**. In.; 2010.

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17. Ozlu M, Alemayehu E, Gebratsadik S: **Ethiopia—Urbanization Review: Urban Institutions for a Middle-income Ethiopia (Washington, DC, World Bank Group)**. In.; 2015.
18. UNICEF: **ONEWASH Plus in Urban Areas in Ethiopia-Results from the First Phase** In.; 2020.
19. FDRE: **ONE WASH National Program**. In: *Program Operational Manual (POM) for the Consolidated WASH Account (CWA) Phase II.* Addis Ababa, Ethiopia: FDRE (Federal Democratic Republic of Ethiopia); 2019.
20. Adank M, Godfrey S, Butterworth J, Defere E: **Small town water services sustainability checks: development and application in Ethiopia**. *Water Policy* 2018, **20**(S1):52-68.
21. Adank M, Dimste D, Hailegiorgis B: **Sustaining rural water services in Ethiopia: Rural water service levels report**. In.: USAID Sustainable WASH Systems Learning Partnership Concept; 2018.
22. Howard G, Nijhawan A, Flint A, Baidya M, Pregnolato M, Ghimire A, Poudel M, Lo E, Sharma S, Mengustu B: **The how tough is WASH framework for assessing the climate resilience of water and sanitation**. *npj Clean Water* 2021, **4**(1):1-10.
23. Nijhawan A, Howard G, Poudel M, Pregnolato M, Eunice Lo YT, Ghimire A, Baidya M, Geremew A, Flint A, Mulugeta Y: **Assessing the Climate Resilience of Community-Managed Water Supplies in Ethiopia and Nepal**. *Water* 2022, **14**(8):1293.
24. Sharifi A, Yamagata Y: **Towards an integrated approach to urban resilience assessment**. *APN Science Bulletin* 2017.
25. Deressa T, Hassan RM, Ringler C: **Measuring Ethiopian farmers' vulnerability to climate change across regional states**: Intl Food Policy Res Inst; 2008.
26. Devereux S: **Vulnerable livelihoods in Somali region, Ethiopia**: Institute of Development Studies Brighton; 2006.
27. **Central Statistical Agency [Ethiopia] and ICF International: *Ethiopia Demographic and Health Survey*** [https://dhsprogram.com/pubs/pdf/fr255/fr255.pdf]
28. Acacia-Water: **An assessment towards building resilience through ecosystem restoration in Somali Regional State, Ethiopia**. In: *Atlas of the Upper Fafan Catchment.* Gouda, The Netherlands: SCRSE Project; 2016.
29. MoWIE: **National Guidelines for Urban Water Supply and Sewerage Services**. In. Addis Ababa, Ethiopia: Ministry of Water Resources, Irrigation and Electricity (MOWIE); 2013.
30. WHO: **Guidelines for drinking-water quality. Vol. 3, Surveillance and control of community supplies. Vol. 3, Vigilancia y control de los abastecimientos de agua a la comunidad**. In., 2nd edn. Geneva: World Health Organization; 1997.
31. Adank M, Butterworth J, Godfrey S, Abera M: **Looking beyond headline indicators: water and sanitation services in small towns in Ethiopia**. *Journal of Water Sanitation and Hygiene for Development* 2016, **6**(3):435-446.
32. UNICEF: **Summary Findings from Sustainability Checks for Rural WASH in Ethiopia** In.: UNICEF; 2021: 17.
33. Beker BA, Kansal ML: **Complexities of the urban drinking water systems in Ethiopia and possible interventions for sustainability**. *Environ Dev Sustain* 2023:1-31.
34. Kohlitz J, Chong J, Willetts J: **Rural drinking water safety under climate change: the importance of addressing physical, social, and environmental dimensions**. *Resources* 2020, **9**(6):77.
35. Henson B: **Urban WASH in Small Towns**. In: *The 'ONEWASH Plus' Programme in Ethiopia.* New York, USA: UNICEF (United Nations Children's Fund); 2019: 11.
36. Achore M, Bisung E, Kuusaana ED: **Coping with water insecurity at the household level: A synthesis of qualitative evidence**. *International Journal of Hygiene and Environmental Health* 2020, **230**:113598.
37. Pamidimukkala A, Kermanshachi S, Adepu N, Safapour E: **Resilience in Water Infrastructures: A Review of Challenges and Adoption Strategies**. *Sustainability* 2021, **13**(23):12986.

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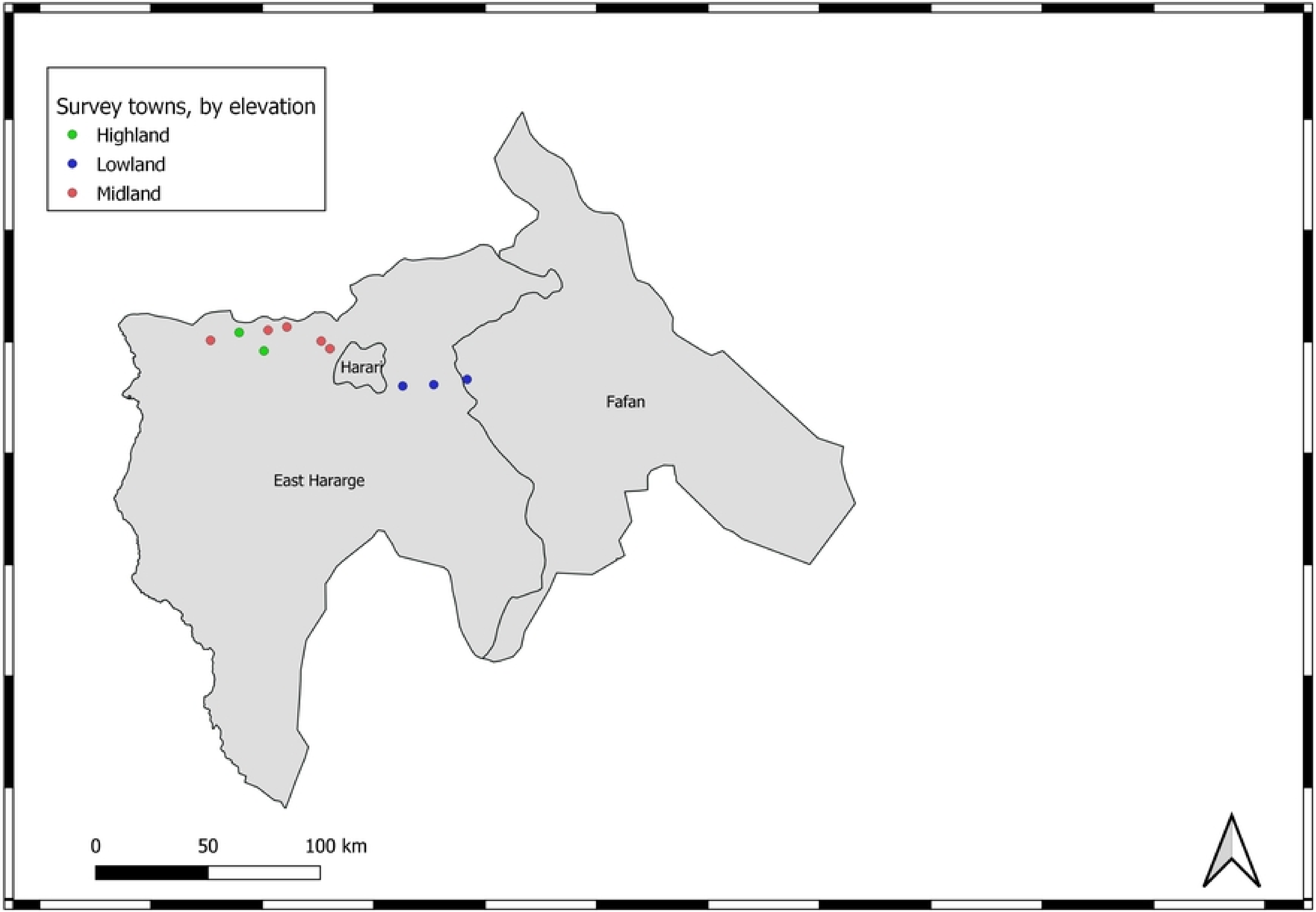
38. Glik DC: **Risk communication for public health emergencies**. *Annu Rev Public Health* 2007, **28**:33-54.

39. Lemecha G: **Improving rural water supply financing in Ethiopia**. In. Addis Ababa: IRC Ethiopia; 2022.

40. Hallegatte S, Vogt-Schilb A, Bangalore M, Rozenberg J: **Unbreakable: building the resilience of the poor in the face of natural disasters**: World Bank Publications; 2016.

41. WHO: **Climate-resilient water safety plans: managing health risks associated with climate variability and change**. In. Geneva: World Health Organization; 2017: 92.


Survey towns, by elevation
Highland
Lowland
Midland
Harari
Fafan
East Hararge
0
50
100 km

Study area

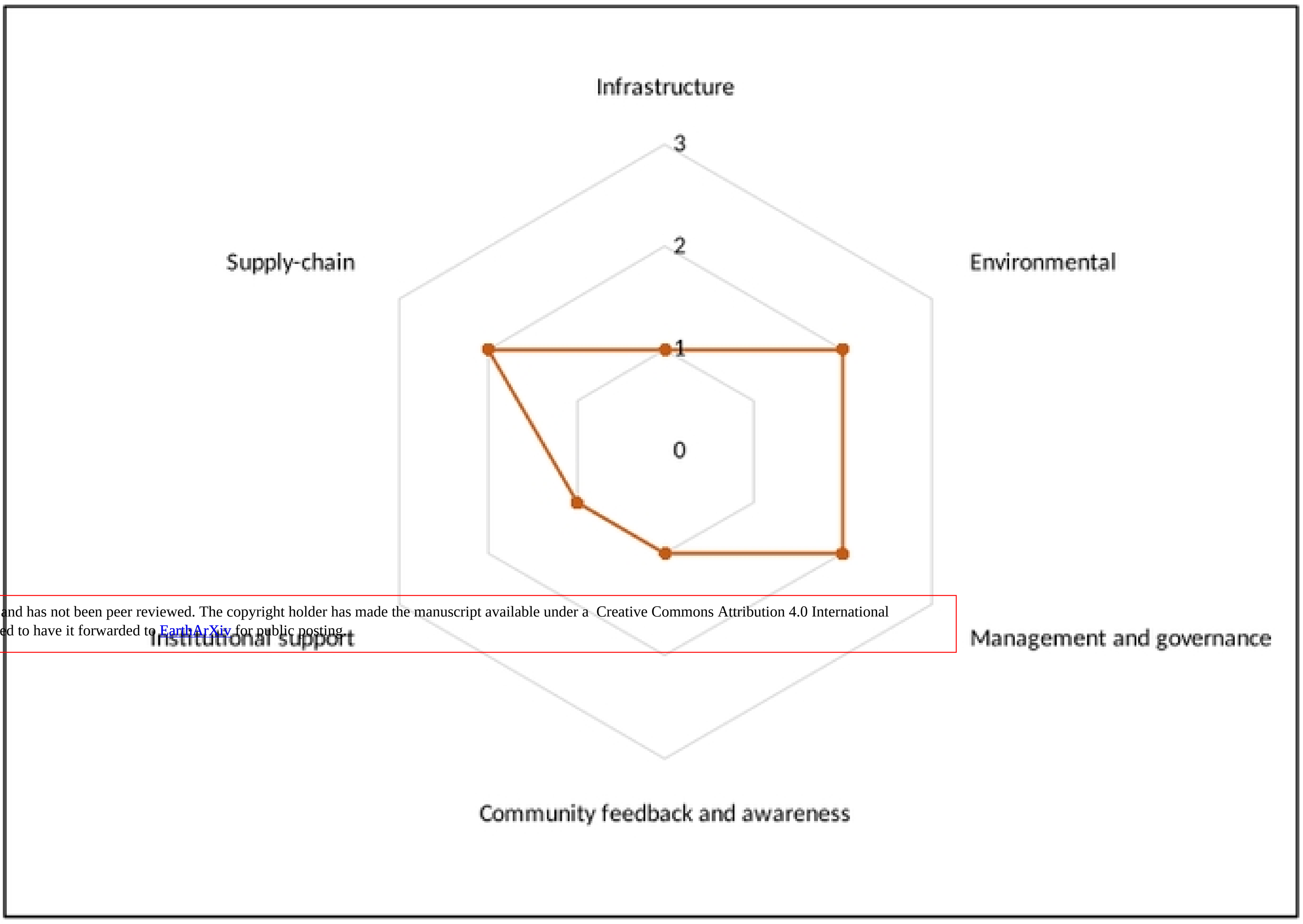


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Figure 1: Overall climate resilience score of town water utilities in Eastern Ethiopian, 2022

Resilience score