

Socio-political processes must be emphasised alongside climate change and urbanisation as key drivers of urban water insecurity

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Abstract

Urban water security is of critical global and local importance. Across many parts of low- and middle-income countries, urban water security either remains elusive or is becoming stressed. Rapid urbanisation and climate change are two key drivers of resource insecurity and at the forefront of urban water discourse. However, there are manifold and complex socio-political processes functioning alongside these megatrends that are often underemphasised. Drawing on three urban case studies in Ethiopia, we highlight these structural issues and the need for their continued consideration to fully understand and address urban water insecurity. Household water-use surveys, semi-structured interviews and participatory exercises with community residents, stakeholders and informal water vendors were used as part of a mixed-method approach in three urban areas. We found that government-managed urban water supplies were intermittent and unsafe, resulting in economic, health and time-use burdens for households, and that the socio-political dimensions reproducing urban water insecurity have historical roots. We argue that the uncertainty of climate change and unprecedented urbanisation do not offer sufficient explanation for why urban water insecurity persists. Moreover, we call for caution in only employing these narratives, to avoid obscuring deeply rooted challenges within socio-political systems. We call for socio-political processes to continue to be a central component of future interventions that seek to improve urban water insecurity.

Keywords: Ethiopia; Governance; Inequity; Urban; Water security

Highlights

- Urban water security is reproduced over time in urban Ethiopia.
- Residents face financial, health and time-use burdens.
- Urban water insecurity is underpinned by socio-political processes.
- These processes must remain in the dominant discourse of urban water insecurity.

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- Addressing non-functioning infrastructure, demand-supply gaps, insufficient financing, historical legacies and multi-sectoral challenges is key for urban water security.
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Introduction

Urban water security is of critical global and local importance (Hoekstra *et al.*, 2018; Grasham *et al.*, 2019). As with water security more broadly, access to water in urban areas is essential for human development, rights and capabilities (Jepson *et al.*, 2017). Urban water security is of central concern for environmental sustainability through preventing the over-abstraction of groundwater (Foster *et al.*, 2020) and surface water resources while managing pollution from urban areas (White *et al.*, 2017). Across sub-Saharan Africa, urban water security has been receiving high attention within the context of the United Nation's (UN's) Sustainable Development Goals (SDGs); goal 6 calls for access to sufficient safe and affordable water for all (UN, 2019).

Ethiopia is receiving significant investment for improving urban water supplies both internationally and nationally, but urban water security across the country remains elusive. Ethiopia's One WASH National Programme co-ordinated 2.4 billion USD from 2013 to 2018 for the WASH sector in Ethiopia (IRC, 2019). However, the latest available JMP (WHO/UNICEF Joint Monitoring Programme) data from 2017 suggest that only 38% of Ethiopia's urban population are covered by safely managed water supply services (JMP, 2019). Urban water supplies in the country are unsafe (Sisay *et al.*, 2017), unaffordable and unreliable (Adank *et al.*, 2016), and urban populations are unsatisfied with the water services they receive (Kassa *et al.*, 2017).

In an era of climate change (IPCC, 2014) and rapid urbanisation across sub-Saharan Africa (UN, 2018), these two key drivers are at the forefront of urban water security discourse. The recent World Water Development Report (WWAP, 2020) entitled 'Climate Change and Water' demonstrates how climate change is at the heart of much of the current thinking in the water sector. Recent events in Cape Town, South Africa, shone a light on how prolonged drought and urban population growth can lead to extreme urban water insecurity in cities (as illuminated in: Luker & Harris, 2019). We know that in a time of urban population growth, strong urban water governance is necessary to deliver urban water security (Dos Santos *et al.*, 2017).

In particular, notions of climate resilience are entering the urban water security arena, and there is a global shift to working for climate-resilient urban water supply systems. Ethiopia is no exception; there are calls to put climate change at the centre of urban water planning in the country (Rickert *et al.*, 2019). Climate change has prompted a 'climate study' of Addis Ababa at the urban scale (Arsiso *et al.*, 2018), and Worku (2017) has called for a transformative approach to urban water management in the capital city in the face of climate change. In 2018, the government approved a second phase of the One WASH National Programme with a fund of 6.5 billion USD from multi-lateral and bilateral donors, in order to create climate-resilient water systems and work towards universal access to drinking water (FDRE, 2018). However, Muller (2016, 67) has argued that for urban water security in developing countries, 'a specific focus on resilience may distract communities from more effective interventions'.

Urban communities across sub-Saharan Africa have been water insecure for generations before climate change and rapid urbanisation became compounding factors (Adams *et al.*, 2019). This leads us to seek explanations for the chronic experiences of urban water insecurity beyond climate change

and urbanisation. In order to do this, we unpack the socio-political processes and governance and institutional arrangements that underpin and continue to reproduce urban water insecurity in Ethiopia. We explore this across three diverse urban areas in Ethiopia, Wenji, Harar and Akaki Kaliti that offer unique insights into the barriers to urban water security.

This article begins by uncovering the socio-political landscape of urban water security in Ethiopia before exploring the experiences, implications and explanations for persistent urban water insecurity across the country. We conclude by arguing that, despite the real and unprecedented challenges that climate change and urbanisation present, climate and demographic changes offer insufficient explanatory power for persistent urban water insecurity. We call for caution when only employing these narratives for explaining urban water security to not obscure the deeply rooted challenges within the socio-political systems that govern urban water supply management.

The socio-political landscape of urban water security in Ethiopia

The socio-political landscape of urban water security in Ethiopia is highly complex consisting of policies, strategies and legal frameworks with multi-stakeholder involvement. Predominantly, urban water supplies are managed by local government-run urban water utilities that receive direction from the national Ministry of Water, Irrigation and Energy (MoWIE) and support from the regional water bureaus. This is a semi-devolved approach of urban water management that was instigated to improve the efficiency of service delivery (WaterAid, n.d.). It was also in alignment with wider political, administrative and economic decentralisation that was pursued following the dissolution of Mengistu Haile Mariam's socialist military regime (Aalen, 2002).

A series of policy frameworks for WASH (Water, Sanitation and Hygiene) across Ethiopia have been implemented since the turn of the millennium. Perhaps, the most current and influential of these is the WASH Implementation Framework (WIF) and its underlying concept of the One WASH National Programme (FDRE, 2011a). The WIF is an all-encompassing, national governance standard for WASH that envisaged an abundance of projects across a multi-institutional landscape integrated into one harmonious and co-ordinated effort (FDRE, 2011a). The One WASH national programme aims to enact this vision by bringing together four key ministries and associated sectors with the goal of advancing and streamlining WASH service delivery.

The highest priority of the Ethiopian government for water management is drinking water supply. The multiple demands on water resources within the country have been prioritised as follows in the national water resource management policy (FDRE, 1999): (1) safe drinking water supply; (2) water for irrigation and (3) for industrial use and hydropower. There are multiple drivers for these priorities (Grasham, 2016). Internationally, Ethiopia is committed to the SDGs which have a target of safe and affordable water for all as well as targets for food security. Nationally, Ethiopia is implementing the Growth and Transformation Plan II (GTP II), which identifies a water-intensive agricultural development-led industrialisation strategy for national economic development. Also, Ethiopia's 85% dependency on hydropower is expected to rise closer to 95% upon the completion of the dams currently under construction (Yewhalaw *et al.*, 2009), and industrial water use is growing. Access to potable water for vulnerable and underserved citizens remains key, however, and central to its flagship programmes and funding.

Responsibility for urban water security is fractured across a number of key stakeholders. These include water user communities; district, regional and federal levels of government; public enterprises; government-run urban water utilities; donors; and local and international NGOs. Each of these stakeholders have various roles, relatively well-defined under a comprehensive memorandum of understanding,

which aims to promote good governance and inter-sectoral cooperation between the water, education, health and finance ministries (Neville, 2017). The small-scale private (or informal) sector remains illegal.

Despite the favourable policy arrangements, difficulties in achieving urban water security are set against the backdrop of Ethiopia's tumultuous recent political history. Development has been severely hindered by a military dictatorship; civil war; the Eritrean War of Independence; multiple famines and droughts; and IMF-imposed structural adjustment all since the 1970s (Marcus, 1994; Bigsten *et al.*, 2005). More recently, there has been intermittent social unrest across the country since 2018 which has had considerable impact on water service provision in some urban areas.

Overall improvements in safe access to drinking water in urban areas in Ethiopia have been slow. Ethiopia was purportedly one of the only African countries to meet the MDG target to half the population without access by 2015. This was largely achieved due to improvements in urban areas, as the WHO and UNICEF Joint Monitoring Programme (JMP, 2014) estimated that piped water directly to premises and alternative sources of improved water together served 97% of the nation's urban residents in 2012. However, in the context of monitoring for the UN's SDGs, there has only been a small increase in safely managed urban drinking water services from 30.7% in 2000 to 38.5% in 2017, the first category that can be seen in Figure 1.

Climate resilience is a concept that is gaining momentum in the WASH sector in Ethiopia. In 2011, the national government of Ethiopia launched a Climate Resilient Green Economy Strategy to guide the country towards middle-income, carbon neutral economy by 2025 (FDRE, 2011b). Since then, sectoral policies across the country have been brought into alignment with ideas of resilience, including the water sector. There are large internationally funded climate-resilient WASH programmes operating in Ethiopia (DfID, 2020) and as previously mentioned, the One WASH National Programme will continue with climate-resilient water systems as a central component.

Research design

Our research design centres on a comparative case study methodology of three urban areas in Ethiopia: Wenji, a small town with a population of around 50,000; Harar, a larger town with around 150,000

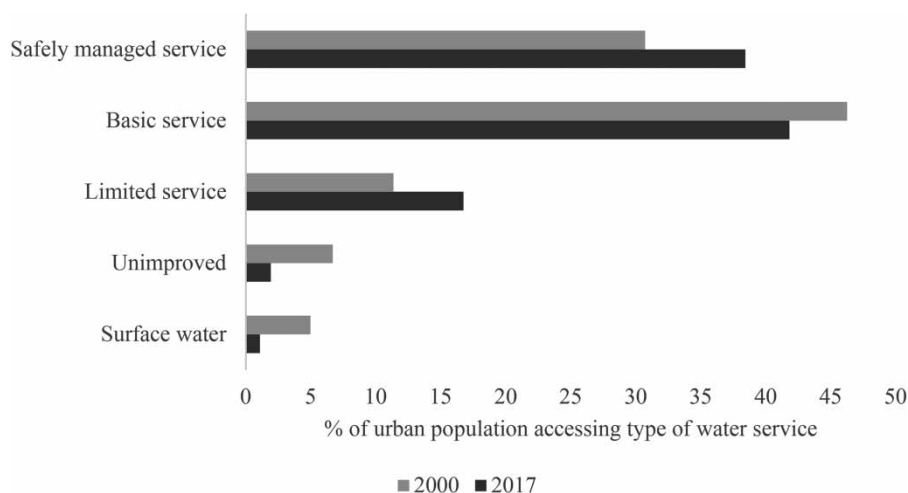


Fig. 1. Chart to show changes in urban drinking water service coverage (%) in Ethiopia from 2000 to 2017 (data source and for definitions of water services: JMP, 2019).

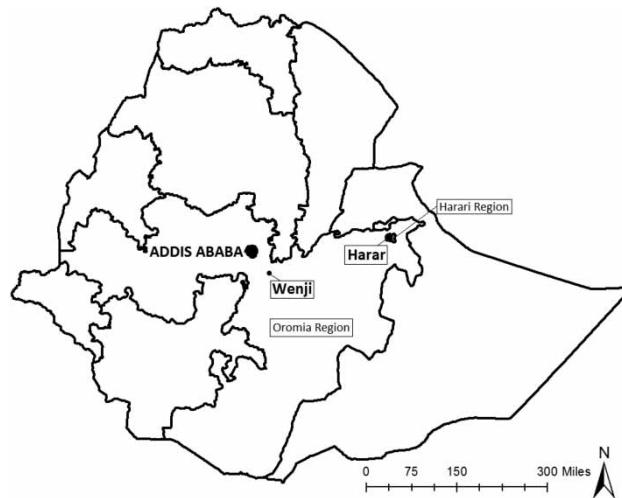


Fig. 2. Map to show the location of the three urban case studies in Ethiopia (Akaki Kality is a sub-city of Addis Ababa).

dwellers and Akaki Kality, a sub-city of Addis Ababa with more than 200,000 people. The location of the three study sites can be found below in Figure 2. The selection of case studies allows comparisons to be made across different urban contexts in Ethiopia and a continuum of population sizes. We believe that there are common socio-political challenges in the urban water sector in Ethiopia that can be revealed with a comparative approach while keeping in mind that different sized urban centres will need tailored approaches for assessing and monitoring urban water services (Adank *et al.*, 2018).

Case study sites

Akaki Kality was, until the turn of the millennium, classified as a series of villages located outside Addis Ababa. It became an official sub-city of the capital as a result of rapid urbanisation that accompanied industrial growth within the South-East area of the city. At the time of fieldwork, Akaki Kality was home to approximately 210,000 people, which equated to around 7% of the total population of Addis Ababa. Although a formal water infrastructure existed in places across Akaki Kality, including a piped network for domestic connections, community water tanks and standpipes, multiple barriers exist and reliable access to these services remains out of reach for many.

The cost of connecting a household to the formal piped network was high – unless no extension to the infrastructure was needed because the customer was located near to existing pipes – and the cost fell on the consumer. Those who did subscribe were experiencing an intermittent service due to blowouts and breakdown, seasonal shortages, as well as the rationing policy in place that systematically ‘switched off’ sections of Addis Ababa from the supply throughout the week to meet demand. Water quality was also an issue with contamination concerns from the increasing presence of metal, paint and food-processing industries. Rental housing comprised the predominant form of occupancy in Akaki Kality and landlords tended to have small regard for the water, sanitary and hygienic needs of tenants. Akaki Kality is divided into 11 *woredas*¹, of which two remain unserved by the formal water network.

¹ *Woreda* is the Amharic word for district which is the second-lowest government administrative unit in Ethiopia.

Harar is an ancient walled city that was home to around 150,000 people at the time of data collection. The city has a complex legacy of urban water supply that is well known across Ethiopia. In 1966, a water treatment plant was constructed on Haramaya Lake, a water body around 20 km from Harar, to supply the town with safe water. At that time, the lake was an important water source for surrounding communities and measured more around 4.9 km². In 2004, Lake Haramaya dried completely, as did Harar's water supply. Immediately afterwards, five boreholes were drilled in the lakebed in a state of emergency to temporarily supply water to Harar until a more long-term solution could be found. However, there remains a water supply gap.

To meet demand, water was being trucked in from a neighbouring city, Dire Dawa, and residents in Harar began buying bottled water to drink due to the poor quality of the water supply. In 2009, an inter-basin transfer project began construction to divert water from the Dire Jara well-field in the Awash River basin to Harar and was completed in 2012; water is pumped along a 72 km pipeline over an elevation of 1,000 m and this system is currently the formal water supply for Harar.

Wenji is a small town in the rift valley located around 7 km from Adama, a large, sprawling metropolis. The population of Wenji was around 50,000, whereas the population of Adama was more than 500,000. Wenji grew as a distinct urban area due to the construction of a sugarcane processing factory in that area in the 1950s. The town lies close to the banks of the Awash River and Wenji's urban water supply, at the time of fieldwork, was treated water from the Adama water supply system diverted and flowing from Adama to Wenji once per week, typically on a Friday.

The urban water supply was not meeting Wenji's demands and residents were accessing water through other means, including using shallow groundwater wells that contained dangerously high levels of fluoride. In response to this, a compacted water treatment system had been donated by a charity, and the Adama urban water utility had established a new water abstraction point from the Awash River, separated from the Adama abstraction, solely for Wenji. At the time of fieldwork, the infrastructure was nearly complete. With an abstraction rate of 10 l/s to deliver 7 l/s of clean water, the supply will likely remain insufficient to meet the water demand of Wenji's population.

Methods

Our study employed mixed methods to unpack the experiences of and explanations for water insecurity in these three urban areas. A household survey was conducted in Harar ($n = 95$) and Wenji ($n = 96$). For this survey, a spatial cluster sampling approach was used to select households. Households were proportionally and randomly selected from each of the urban *kebeles*² in the two study areas. Semi-structured interviews with household residents in *Woreda 7* ($n = 90$) and *Woreda 10* ($n = 90$) of Akaki Kality were conducted. These *woredas* were selected purposively in order to provide a direct comparison, with one site being served and the other entirely unserved by the formal water supply network. A cohort of research participants was built initially through gatekeepers who provided access to the communities, followed by a combination of purposive and snowball sampling, to ensure the experiences of households with varying levels of access to different water modalities were captured. Semi-structured interviews ($n = 19$) and participatory exercises with informal water vendors were also carried out in Akaki Kality. The cohort of vendors was established through immersive

² *Kebele* is the smallest administrative unit within the Ethiopian government.

stays within the target communities in order to establish trust, recognising the sensitivity of their work. Our findings have been triangulated with field observations as well as stakeholder interviews with urban water utilities and other government organisations involved in water governance at the woreda, zonal, regional and national levels.

Results and discussion

Experiences of urban water insecurity

Urban populations in our three study sites had similar experiences of water insecurity. In all three areas, Akaki Kality, Harar and Wenji, formal urban water supplies were found to be intermittent and of poor quality resulting in financial, health and time burdens for urban residents. The quantity and quality of water that was available for the urban communities was below the national government standards laid out in the government's national GTPII (FDRE, 2015). Urban water access targets in the GTPII include five categories of urban areas based on different water demand categories: 100 lpcd for category 1, 80 lpcd for category 2, 60 lpcd for category 3, 50 lpcd for category 4, and 40 lpcd for category 5 (towns/cities). The water demand categories for our case study sites are given in Table 1.

There were also differences across the study sites where urban residents were adapting by accessing water from a range of informal sources of unknown quality. In Akaki Kality and Harar, the main water challenge reported was the high price of water. Differently, in Wenji, water quality and the resultant health burden were the highest concern highlighted by 40% of the urban community. In this section, we will uncover the lived experiences of water insecurity in the three urban areas by looking at water access in terms of quantity and quality in the context of intermittent formal water supplies. We will then uncover coping and adaptation strategies employed by urban residents to access sufficient water and the role of informal water vendors within this.

Intermittency of formal urban water supplies. Urban water supplies in Ethiopia are managed by an urban water utility that is guided by national policies. Urban water supply in Akaki Kality was being managed by the Akaki Kality Water and Sewerage Authority (AKWSA), acting as a local subsidiary to the Addis Ababa Water and Sewerage Authority (AAWSA). The task of trying to create new water supply modalities at a rate that exceeded or at least kept pace with population growth in the region – and with limited resources – was acute. In Harar, the urban water supply was being managed by the Harar Town Water Supply and Sewerage Services Authority (HTWSSSA) and had been since the first water treatment plant was constructed in 1966 on Lake Haramaya. In 2004, Lake Haramaya dried completely. Between 2004 and 2012, the utility faced stark challenges in supplying water to Harar until

Table 1. Populations and national urban water demand categories, according to the Government of Ethiopia's GTP-2, of the three case study sites.

	Akaki Kality	Harar	Wenji
Population	200,000	150,000	50,000
National urban water demand category	1	2	4

a new water supply came online. In Wenji, the urban water supply was being managed by Adama Town Water Supply and Sewerage Service Enterprise (AWSSSE). The Adama (city) water supply system was not designed to deliver water to Wenji but was being used to bridge the gap in supply until a donated, compacted treatment plant became operational.

Across all three urban areas, formal government water supplies were intermittent. In Akaki Kality, residents in *woreda* 10 were technically residing within an ‘unserved’ area until the final few weeks of fieldwork when the utility erected a new water tank. There was no piped network to which households could connect and, even after the tank installation, residents were experiencing up to 2 days each week without water waiting for the tank to be refilled. Residents in the ‘served’ *woreda* 7 were able to access water from the utility-provided water tank and NGO-supplied standpipes in the community. However, these water points could only be accessed for an average of around 3 days per week due to breakdown or intermittent supply. Households connected to the piped network in *woreda* 7 also experienced outages for days, weeks and, in some cases, months on end.

Similarly, in Harar and Wenji, water supplies were intermittent and unreliable. In Harar, 92% of households had access to a tap in their household or yard. Despite this high level of piped water infrastructure, huge inequities were reported in regularity of supply (see Figure 3). Water was available for every household at least once per month, with only a third of households reporting that water was available more than once per week. In Wenji, due to the nature of the water supply management model, there was never water in the tap on more than 1 day per week, and typically, water would arrive in the town on a Friday. Only 20% of households had access to their own tap.

There was a city-wide water rationing policy in Addis Ababa – an initiative that has long been implemented by the urban water authority and on a continual basis – that emerged as a key point of contention in interviews in Akaki Kality. This system of rotational water rationing is applied across the whole of Addis Ababa, whereby supply was alternated throughout areas of the city during the week. It was designed to satisfy the growing demand-supply imbalance, as demand increased (with rapid urban population growth) while supply remained somewhat stagnant. Specific sub-cities and areas were therefore without piped water on certain days. While most residents were aware of this, it became problematic when a scheduled rationing period merged with a pipe blowout or functionality

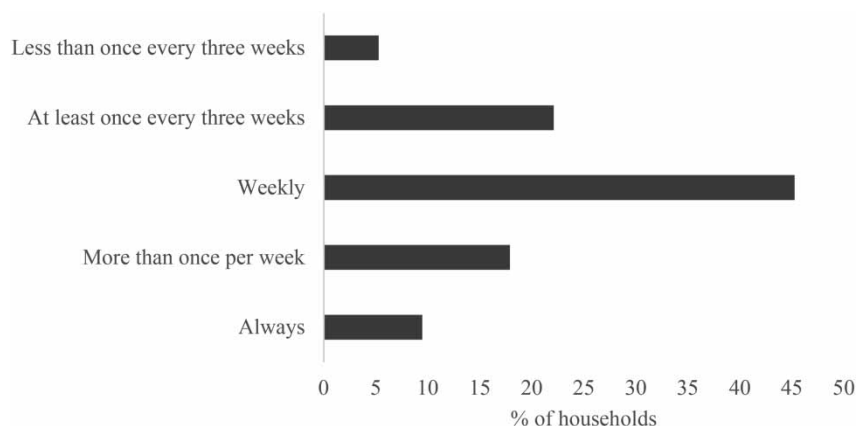


Fig. 3. Chart to show reported variation in tap water availability across Harar.

issue causing outages to last for days. This was a common occurrence, and the consensus among respondents who had invested and connected their homes to the piped network was that it was untenable and not cost-effective. It was estimated by residents that piped water was typically unavailable on just over 3 days a week, but at the time of interviews in one *kebele* there had been no water from household taps for 1 month.

The intermittency of urban water supply was being affected by seasonality – dry season increases in water demand and reductions in supply. Across Addis Ababa, water scarcity intensifies in the dry season; we found that urban water demand was higher in the dry season and supply decreased. In Wenji, for example, 20% of residents reported less available water in the dry season. In Akaki Kaliti, the water pressure and available volume from most formal water points improved in the wet season and the dry season was characterised by periods of prolonged non-functionality. Residents reported a negligible seasonal difference in the rate at which water tanks were manually replenished despite the increase in demand for water in the dry season. Demand increased due to changes in water user behaviour resulting in higher water use such as more frequent showering and/or using water to dampen dry dust on the ground as well as the lack of rainwater sources.

Quantity. Households were accessing vastly different amounts of water across and within the study sites. The differences between Harar and Wenji, for example, were found to be quite extreme. On average, households in Harar were using 1.5 times the amount of water per capita than households in Wenji. In both cases, quantities were below national standards. Harar is a category 2 urban area, meaning that the GTP-2 water access target is 80 lpcd. However, in Harar, those households with a tap reported using, on average, 18 lpcd with a range of 65 lpcd. Wenji is a category 4 urban area, with a water access target of 50 lpcd. However, residents reported using 9 lpcd, with an average of 6 lpcd and a range of 36 lpcd from household resellers or informal vendors.

The quantity of water used by residents in Akaki Kaliti varied markedly between the served and unserved woredas, as well as between those with access to multiple sources compared with those with fewer. Many respondents found it difficult to quantify given the diversity of water sources they simultaneously used as well as their fluctuating functionality, but estimates varied from 7 to 25 lpcd, well below the target of 100 lpcd for the city.

Quality. Urban communities had uncertainties about the quality of their water supplies, based on their perceptions, not water quality tests. In Akaki Kaliti, 90% of households perceived no quality issues with water from household taps, but 60% of respondents noted a current or previous quality issue with water from community taps and water tanks. In Harar, 80% of households perceived no water quality issues with their tap water. In Wenji, 22% of households did not report water quality issues. The most common organoleptic properties reported by 78% of households in Wenji were related to sight – the colour of the water, the presence of sediment or visible worms. Intermittent changes in the taste of the water supply were also reported such as metallic and salty. There were also reported experiences of the impact of poor water quality on health from personal or familial experiences of illness and, in Wenji, the presence and impact of high levels of fluoride in the water.

Table 2. Different categories of water sources being accessed by urban residents in the three case study sites.

Water source category	Akaki Kality	Harar	Wenji
Informal			
Rainwater harvesting	✓	✓	✓
Household resellers	✓	✓	✓
Broken pipes/outlets	✓		
Raw water sources	✓	✓	✓
Water kiosk operators	✓	✓	✓
Mobile water vendors	✓	✓	✓
Private household wells			✓
Private companies			✓
Formal			
Community boreholes or waterpoints	✓	✓	✓
Household/yard connections	✓	✓	✓
Community tanks	✓		

Community adaptation

In order to cope with the shortfalls in formal urban water supplies, residents were accessing multiple sources to meet their water needs. In Akaki Kality, 100% of households confirmed the use of more than just a single water source, instead alluding to the regular use of multiple sources simultaneously, or at the very least, a main source with several other identified backups. A handful of residents reported infrequently collecting water from broken or leaking public utility pipes that emerge due to the deteriorating infrastructure, as there were no quality concerns about this water and it is otherwise wasted.

There were nine identified categories of water source being accessed across the two studied *woredas* (see Table 2) in Akaki Kality, within which there was sometimes more than one option. For example, water users would not always go to the same household reseller³ or the water kiosk operator but would move around to find one available. In Harar, households reported accessing water from 10 different sources and 55% of households had accessed between two and four per household in the week before the survey.

Households in Wenji reported accessing water from 12 different sources in nine categories within a 1-week recall period. Most households (73%) had their own shallow, hand-dug wells that they were using to supplement the intermittent formal water supply. The water from these wells was high in fluoride and usually only used for washing clothes, cleaning, flushing the toilet and personal hygiene. For drinking and cooking, water was predominantly being accessed by household resellers (77% of households). When water was supplied to the town on a Friday, residents with taps and storage tanks would fill them and sell to neighbours for the rest of the week. Households were also collecting untreated groundwater, high in fluoride, from factories in the vicinity free of charge.

Rainwater harvesting practices varied significantly across the three case study sites for which we have limited explanation. Rainwater offers a relatively substantial source for domestic water in urban areas of Africa but remains relatively under-researched (Campisano *et al.*, 2017). Rainwater harvesting was quite

³ A household reseller is a household with a tap that sells water, normally with a large storage capacity, to households that may not have a tap or sufficient storage to buffer their demand with the intermittent supply.

uncommon in Akaki Kaliti, with only a handful of households, suggesting that it was a technique they were using. Similarly, relatively few households reported harvesting and using rainwater in Wenji (38%), with reports that it was culturally unacceptable to do so. This could also be partly explained by the fact that most households in Wenji had their own wells. In Harar, however, nearly all households (97%) were harvesting rainwater in the wet season; we observed that the majority of houses had rainwater harvesting infrastructure and hence were well equipped to do so.

Informal vendors and household resellers. Informal water vending was present across all three of our case study sites and was found to be operating in different ways. Informal vendors are crucial for enabling urban residents to adapt to unsafe, intermittent formal urban water supplies (Neville, 2017). In Akaki Kaliti, informal water activity dominates the local waterscape. Similarly, in Wenji, 72% of households were using vendors or household resellers as their primary water source (and an additional 5% as a secondary water source). However, in Harar, informal water activity was not found to be prevalent with only 14% of households accessing water from vendors.

In Akaki Kaliti, between served *woreda* 7 and unserved *woreda* 10, households reported having an 87% average weekly dependence and 93% average monthly dependence on the informal market. In other words, the shortfall from formal water outlets was such that these households could not go about everyday life or complete basic household tasks without vended water. Informal modes of supply came in various forms in Akaki Kaliti; mobile vending was by far the most prevalent, operating with a variety of mechanisms including pushcarts, donkey-drawn carts, tanker trucks, wheelbarrows and even carrying by hand. Household resellers, as in Wenji, were also common where there was a piped network in place. This is like point source or kiosk operators who installed taps at their local business premises or outside of their home.

There were various informal water vending mechanisms that were playing out in Wenji. Informally, residents within Wenji were selling water from their own taps and using storage tanks (11% of households were operating as water vendors – which was more than half of the households with a tap). Households were typically purchasing water from neighbours with tanks on their premises with 87% of buyers collecting the water themselves. Someone from within the household would collect water from the vendor and transport it back to the household on foot. The gender of the collector was predominantly reported as mixed. Field observations triangulate this finding and suggest that collectors were mostly children, with boys and girls both seen transporting water. Water was also transported into Wenji from external sources (factories, Adama city, Awash River) normally with horse and cart, but this water was more commonly accessed by small businesses than households.

Unlike the sometimes negative or sceptical perception towards the quality of water from formal urban water supplies, opinions towards the quality of informally supplied water were overwhelmingly positive. This was particularly the case in Akaki Kaliti, where mobile informal water vendors were notifying consumers of any quality concerns and some were offering treatment options. Such a service is crucial in an environment where marginal cost decision-making is key to everyday life, as consumers were sometimes able to buy lower-grade batches of water at a cheaper price for household tasks that do not involve ingestion, such as laundry. Residents also did not report any quality concerns about the water that was purchased from informal vendors for human consumption. While the formal piped network and therefore informal household water resellers were identified as providing good quality water, several respondents had experienced ill-health using water from the formal water tanks and standpipes.

Similarly, in Wenji, respondents reported that water transported into the town from external water sources – in particular, from Adama – was safer than water from formal outlets.

Urban communities across the three case study sites were adapting to the intermittent formal water supplies as much as possible within their means. Informal vendors had an important role in allowing residents to adapt to intermittency and poor water quality. Any improvements in urban water supplies in Ethiopia are likely to have negative financial impacts for water vendors, and there is an argument that policies should work to mitigate these negative effects (Smiley, 2019). In some cases, urban residents were forced to adapt in ways that had negative consequences for their financial stability, health and use of their time. This will be explored further in the following section on the implications of urban water insecurity.

Implications of urban water insecurity

Urban water insecurity has wide-reaching implications for economic and social development (Hoekstra *et al.*, 2018). In particular, there are financial, health and time burdens associated with water fetching (Geere & Cortobius, 2017). There are also broader spill-over impacts of poor water access on the ability of people to meet other basic needs such as food security (Brewis *et al.*, 2019). Urban residents are constantly making trade-off decisions between health, money and time when it comes to choosing how to access water. We do not offer complete explanations for why these decisions are made but offer some insights into behaviour patterns based on the three key water burdens that we have identified.

The financial burden. There is a critical relationship between urban water access and money; water access poses a financial burden, particularly for poorer urban households. Across urban areas of sub-Saharan Africa, water access is unequal and wealthier households typically have better access to water (Grasham *et al.*, 2019). The poorer pay a higher proportion of their income to access water (Water-Aid, 2016) and the cost of water has been shown to be a predictor for emotional distress and stress (Thomas & Godfrey, 2018; Stoler *et al.*, 2020). The findings across our study sites offer three insights into this relationship according to water vending, household water infrastructure and the purchasing of bottled water.

We have found that there is an increased financial burden for households accessing water from water vendors and household resellers resulting from the poor management of formal urban water supply systems. For example, in Wenji, households were paying 0.5 ETB (0.015 USD) for 20 litres of water from the central community waterpoint. To access safer water, some were paying 10 ETB (0.31 USD) to have 20 litres of water transported to Wenji from Adama (~7 km), usually in jerrycans by horse and cart or auto rickshaw. In this case, the cost of water per litre from informal water vendors was 20 times higher than water from the formal government water supply system. However, some households were prepared to pay this to mitigate the health and time risks from accessing water from other sources.

Household water infrastructure has a key role to play in urban water security. However, connection to the formal piped network, household wells and water storage tanks each come with high initial investment costs. In Akaki Kality, the one-off cost to connect to the formal piped network was based on geography in relation to the existing infrastructure. In Harar, the volume of household water storage capacity ranged from 20 to 10,000 l, and there was a moderate correlation between the average per capita water use and the volume of household water storage ($p < 0.01$). This suggests that those

households with greater storage capacity had access to a greater quantity of water resources. In Wenji, households constructed their own household wells which would have required an initial investment. These different types of infrastructure were not available to every household, predominantly due to the financial barrier.

Intermittent, unsafe urban water supplies foster a legacy of buying water in plastic bottles, for those financially capable of doing so. In 2004, when Haramaya Lake dried, along with the urban water supply to Harar, residents began buying 20 litres of water in sealed plastic bottles as a response to the poor quality of the water available to them at that time. In 2015, the cost of this was 38 ETB (1.16 USD), 76 times the price from a public waterpoint. This was 3 years after the new urban water supply system had begun operation in Harar, providing better quality water more regularly and when only 7% of households reported water quality as a challenge. However, two in five households were still buying this water in plastic bottles at high cost and with far-reaching environmental implications.

The health burden. Lack of access to water negatively affects human health in different ways (WHO, 2019). Poor water quality has manifold impacts causing water-borne diseases (WHO, 2019) and can have longer term health implications with the accumulation of toxic elements in the body such as fluoride (Kabir *et al.*, 2020). We know that intermittent urban water supplies are closely linked to poor water quality and water-borne diseases (Galaiti *et al.*, 2016; Kumpel & Nelson, 2016). Additionally, there are health impacts of water carrying. A 20 l jerry weighs around 20 kg, and there is evidence that shows how carrying such a heavy weight long distances can cause long-term health problems (Geere *et al.*, 2010, 2018). We found water-related health burdens across all three of our urban study sites related to poor water quality and water collection.

Residents of Wenji were experiencing a large number of negative health impacts from poor quality water through the formal water supply and from drinking or cooking with water from household wells. Water-borne diseases were found to be rife, a direct result of drinking water that was only being supplied to the town once per week. The most commonly reported diseases were parasitic infections. Moreover, many community members were dealing with the health effects of fluorosis from consuming groundwater with dangerously high levels of fluoride over many years. The main health impacts were browning of the teeth and scoliosis of the spine. Despite the local awareness of high levels of fluoride in the shallow groundwater in Wenji, and the associated health risks, at times of severe water scarcity households reported that well water had been used for cooking and, in desperation, for drinking. Oftentimes, untreated groundwater was being used to prepare hot drinks and food in cafes, hotels and restaurants.

In order to mitigate the negative health impacts of poor water quality, some residents were employing household water treatment options to improve their water quality. A popular chlorine-based water treatment in Ethiopia is *wuha agar*; it is sold in individual sachets for household water purification. Residents in Akaki Kaliti reported no chlorine-based treatments, but 20% reported boiling certain batches of water for drinking as a form of treatment, either in the knowledge of a quality issue or just to be safe. In Harar, 27% of households were using chlorine-based treatments and/or boiling their water before drinking. In Wenji, household-level water treatment was incredibly rare; only 2% of households reported treating water and only occasionally.

In addition to poor quality issues with the formal water supply and groundwater resources, there were health implications of transporting and collecting water; in all three study sites, water was being transported in jerrycans to households. This increases the risk of contamination of the water (Wright *et al.*, 2004), and it was observed in our study sites that containers were not being kept in sterile conditions.

While the water quality in Akaki Kality was generally good, respondents did not want to clean their jerrycans – they spoke of the paradox of not wanting to waste water to clean a container for water that was in short supply. In general, jerrycans in the urban sites were observed being moved with a transportation device such as a bicycle or small trolley with wheels. Therefore, there were few impacts from carrying heavy water reported.

The time-use burden. Accessing water from multiple sources is time-consuming and unreliability is more difficult to manage than intermittency. Due to the dense urban space and large number of household resellers, we found that all those households collecting water could access it within a 30-min round trip. As seen in Akaki Kality, there was a planned water rationing system that residents could adapt to and issues only arose when there were infrastructure failings that interrupted the planned water schedule. In Wenji, even though water was only flowing through the town taps once per week, various coping mechanisms, as discussed above, were employed by households to address this. However, when the tap water was not supplied to the town for more than one week, residents would leave their jerrycans for hours, overnight and sometimes days with household resellers not knowing when they would get water; residents also reported long delays for delivery of water from informal vendors. While waiting for water, households reported not being able to fulfil their basic needs including delaying cooking and drinking.

Across our three case study sites, we found financial, health and time-use burdens of intermittent and unsafe formal urban water supplies. The predominant financial burden comes from the need to purchase water at high rates from alternative water sources when there is insufficient water in the formal system. In terms of health, there were cases of water-borne diseases across the study sites as well as a variety of site-specific health risks. The time taken to access water significantly increases at times of severe urban water scarcity, particularly when intermittency of supply becomes unreliable and urban water users are left unable to plan alternative modes of access. In the following section, we will unpack the socio-political explanations for these experiences and implications of urban water insecurity in Ethiopia.

Explanations for urban water insecurity

Our case studies show us that the experiences and implications of urban water insecurity in Ethiopia are far reaching and present across a range of different urban areas. In this section, we will offer some explanations for why urban water insecurity persists in Ethiopia, despite significant investment and a strong political commitment for change. The resolve of residents to adapt to water challenges goes some way to mitigate the poor management of urban water supplies but as we have seen, residents still experience financial, health and time burdens. Our explanations are grounded in socio-political findings and hence, are not complete, but contribute vital elements to our understanding of urban water insecurity in Ethiopia. Moreover, these findings present opportunities for contextualised, structural interventions to tackle the root causes of systemic urban water insecurity.

Poor and non-functionality of water supply systems. A key reason for continued water insecurity in urban Ethiopia is the issue of water system non-functionality, breakdown and therefore interrupted supply. It is in this area that we can explore some of the political and institutional arrangements that are constraining urban water security. WaterAid sought to explore the non-functionality of water systems by establishing the Post-Implementation Monitoring Survey (PIMS). This was an inventory-type survey that captured data on the effectiveness and sustainability of water infrastructure and

sanitation interventions carried out in both urban and rural areas in the Amhara, Oromia, SNNPR and Tigray regional states between 2006 and 2012. The principal findings were as follows:

‘Of the 103 pieces of water infrastructure surveyed, 80% were functional, 14% were partially functional and 6% were non-functional. There is an expected rise in the rate of functionality between 2007 and 2009, with an associated decline in non-functionality. However, between 2009 and 2011 this rate of functionality levelled off suggesting that those water points displaying partial functionality became non-functional.’ (WaterAid, 2012, 14)

This study revealed that as many as one-fifth of all water points was only partially functional at best. Manually drilled boreholes were found to have a 100% rate of failure, meaning that they would stop working at some point in time, while functionality rates ranged from 50 to 100% across the four regions.

The situation is highly varied and inequitable between regions, and those in disadvantaged areas are likely to experience worse water access. Such problems were similarly apparent in our study, where pipe blowouts and standpipe malfunctioning went unfixed for prolonged periods leading to their non-functionality and disruption to people’s water access. In rapidly urbanising areas, particularly Akaki Kality, there is a strong willingness to try and extend urban water supply coverage quickly to meet the demands of increasing numbers on paper. This has meant that already ‘covered’ areas were not being properly monitored and experienced functionality issues related to a lack of maintenance. Including our three case studies, Akaki Kality, Harar and Wenji, the impacts of intermittent functionality of urban water supply infrastructure on everyday life are expectedly quite severe across Ethiopia.

Urban water demand-supply gaps. Urban water demand far outstrips supply across Ethiopia because (1) demand is poorly understood by water managers; (2) stark increases in demand due to population growth are not accounted for and (3) the informal water supply sector is not acknowledged.

Future urban water demand was being considered in planning but insufficiently operationalised in urban water supply infrastructure. In Harar, a comprehensive water demand assessment was undertaken in the planning stages of the project. This included a population projection to 2022, household demand, public demand, commercial and industrial demands, changes in demand with seasonality and an assessment of water losses (FDRE, 2005). The daily water demand of Harar for 2012 was calculated as 7,209 m³ (83 l/s; around 50 lpcd) and projected to be 36,807 m³/day in 2,025 (426 l/s) (FDRE, 2005). However, despite this comprehensive demand estimate, the project was still only designed to deliver 300 l/s. Therefore, if the growth predictions are correct, the future water demands of Harar will remain unmet.

Water demand planning was constrained by the tools that local water managers had access to. In Wenji, the newly donated, compacted water treatment plant was a fixed size and not selected to serve the demands of the population. The water abstraction from the Awash River will be 10 l/s to supply around 7 l/s of clean water for a population of 50,000, resulting in a daily per capita supply of around 12 l. The scale of the Wenji project was dictated by the capacity of the donated infrastructure and water planners were relatively powerless to determine how much the urban water supply would be. A planning document for Wenji water supply outlined that the water demand for the town had been calculated using the population data for Wenji with population projections and recognised that further development of water resources would be required to meet urban demands (Oromia Water Minerals and

Energy Bureau, August 2015, *personal communication*). The small scale of this project was justified with the classification of the intervention as an ‘emergency’ project.

The informal water supply sector is not acknowledged across urban Ethiopia and remains illegal. Uncertainty surrounding the sources they use and therefore the quality of water they provide are two of the foremost concerns maintained by water authorities (in contrast to public trust in the quality of water from informal vendors), as well as an overarching lack of knowledge about modes of operations and wider significance of their role. In Akaki Kality, the party line adopted by the formal water utilities is somewhat discordant. It remains dismissive of the significance and sometimes the existence of vendors, even though there is an acceptance that alternative means of accessing water that does not come from the AKWSA is both crucial for household survival and even averting further water shortages. Municipal authorities believe that the water deficit will be solved with substantial projects and investment, but here we find that the complex planning and redistribution operations undertaken by informal providers are already functioning as part of the solution, although without regulation and at much higher cost to the customer.

Insufficient water financing. In Ethiopia, urban water utilities are semi-autonomous and designed to self-finance their operation and maintenance (O&M) costs with a graduated water tariff using national guidelines (FDRE, 2013). However, in line with the existing research (Gezahegn & Zhu, 2017), we argue that locally established urban water tariffs are too low to maintain and improve urban water services. Crucially, we were told that, in the case of Harar, the water fees were not covering the O&M costs. In response to this, there have been calls for higher water tariffs (Kayaga *et al.*, 2018). The cost of water from the formal, piped water supply was much cheaper than the cost of water from informal vendors. In addition to a mandatory 5 ETB (0.15 USD) charged each month for rental of a water meter, water was being charged per cubic metre and the fee increased the more a household or service was using.

Urban water utilities face multitudinous challenges in fulfilling their remit centring on a lack of financial and human capacity. In Harar and Wenji, the urban water utilities reported insufficient funding to retain skilled staff and invest in better water systems. A representative from the Adama urban water utility told us, ‘We have no money! That is why it is difficult for us to perform.’ (May 2015). As well as financing, a lack of other resources were reported including inadequate access to materials to repair or expand water supply infrastructure. There was also a critical absence of chemicals to treat water to safe drinking water standards. These factors were preventing urban water utilities from fulfilling their remit of delivering safe and reliable water supplies to their customers.

In addition to shortfalls in O&M cost recovery, water fees were also insufficient to repay investment loans for urban water supply projects. In Harar, for example, the water supply system required enough electricity to pump water along a 72 km pipeline over an elevation of 1,000 m. The electricity demand for the project was remaining unmet due to insufficient supply and unaffordable energy costs.

‘The money that we are paying for [electric] power is really very expensive which makes the project very complex and different to other projects in Ethiopia ... We are getting money from the federal government, a subsidy for power.’ (Interview with HTWSSSA, May 2015)

The project had been financed primarily with a loan from the African Development Bank (AfDB), and at the time of fieldwork, the loan was being repaid. However, the loan repayments were being

made from another source, not from the water fees. Overall, we found that the Dire Jara urban water supply project in Harar was financially unsustainable.

Historical infrastructure development. Historical legacies of infrastructure development were shaping water access in our case study sites. Such legacies have been shown to contribute to differentiated water access in other areas of sub-Saharan Africa (Grasham *et al.*, 2019). For example, Harar has had a formal water supply since 1966 when a water treatment plant was developed on Haramaya Lake; the water piping infrastructure had been developed over many years and 97% of households are connected. However, water access varied considerably due to topography and urban location. If a household was at higher altitude, it was more difficult to pump water to the house. There were also reports that powerful community members did not struggle with piped water access in the same way as other, less powerful, urban residents due to their urban location close to the main water pipelines.

Conversely, Wenji only emerged as an urban centre in the 1960s and the first water infrastructure was installed much later by the Catholic Relief Service (CRS) as a supply for their church, a small number of neighbouring households and proximal rural communities. Since then, responsibility for urban water supply provision had shifted from the CRS to the Adama urban water utility. However, this infrastructure still exists and it is these connected households that have continued water access through the Adama water supply diversion. In this case, access to water in the urban area is shaped by a historical water supply infrastructure development, originally designed to serve the Catholic Church in the town.

Multi-sectoral challenges. Electricity shortages were found to be one of the biggest barriers to a safe, reliable urban water supply which presents a strong link between electricity and water provision in Ethiopia. In Harar, the Dire Jara water supply project was designed to deliver 300 litres of water per second. However, only an average of 90 l/s was travelling along the pipeline at the time of fieldwork as severe shortages in electricity were resulting in the project running at less than a third of capacity. Therefore, households and urban services in Harar were experiencing severe water shortages. In Akaki Kality and wider Addis Ababa, the recent introduction of a rotational system of electricity supply in 2019 followed on from the aforementioned water rationing policy, which will have further consequences on water security.

We found that there was inadequate co-ordination between water planners in the irrigation and infrastructure sectors with urban water supply managers, significantly constraining urban water security. This sectoral fracture is, in part, shaped by the institutional arrangements from the federal to the local level, where sectors have their own organisations and there is insufficient co-ordination between them. A key constraint to water insecurity in Harar was the presence of intensive irrigation that contributed to the drying of Lake Haramaya and the urban water supply in 2004 (Grasham, 2016). Akaki Kality became a designated zone for industrial growth in the corner of Addis Ababa that was already unable to meet its daily demand for water from existing urban water users. Industries moved to the region, along with an 80,000 strong labour force to fill the jobs, yet only a basic water infrastructure was in place to service surging demand. Akaki Kality was also considered rural until relatively recently, meaning that the competition for water between this new industry and nearby agriculture was both considerable and strained, in addition to the problem of effluent discharge into the Akaki River.

Overall, water pollution was found to be constraining urban water security. Irrigation upstream of the Adama urban water abstraction point was having a negative impact on the water quality in the Awash

River and, in turn, the urban water supply for Adama and Wenji. The Adama water supply treatment plant worked on a backwash system and because of the high turbidity of the water, more water was needed for backwash than had previously been required, hence less water was being delivered to Adama and Wenji, contributing to the intermittent urban water supply in Wenji. Little has also been done to protect water bodies and groundwater reserves from industrial pollution in Akaki Kality, despite its designation as a special zone for factories (Neville, 2017). The Akaki River has become the most polluted river system in the country – predominantly from heavy metal factory discharge but also sewage and agricultural waste – and the toxic trace elements far exceed permissible limits set out by the WHO (Yohannes & Elias, 2017; Amare, 2019).

Overall, the findings in this section highlight the underlying socio-political processes that reproduce urban water insecurity in Ethiopia. We also reveal some critical regulatory gaps in the governance and institutional arrangements for managing urban water insecurity in the country. There has been a call for bottom-linked and broader policy frameworks (Habtemariam *et al.*, 2018) and alternative urban water supply governance models (Godfrey *et al.*, 2019). We add to these calls for change by arguing that institutional and regulatory arrangements must be at the centre of interventions to improve urban water security in Ethiopia.

Conclusions

Urban water insecurity persists and is underpinned by deeply rooted social and political structures and uneven power relations. While unprecedented urbanisation and climate change pose concrete challenges to the sector, it is critical that the complex socio-political drivers of urban water insecurity remain in discourse. Urbanisation and climate change have explanatory power for why continued attention and investment in urban water security will be increasingly challenging in the future. However, current urban water insecurity can be predominantly explained by the historical and present institutional and regulatory arrangements that govern urban water security. We call for socio-political processes to continue to be a central component of future interventions that seek to improve urban water insecurity.

With a comparative case study of three urban areas in Ethiopia, we have offered novel insights into how urban water insecurity is manifesting across the country. From a small town to a large sub-city of Addis Ababa, we have found intermittent urban water supplies forcing urban residents to access water from multiple sources of differing quality. Unregulated and illegal water vendors play a critical role in filling the supply gap left by insufficient formal water supply systems. There are opportunities in policy and practice to recognise the essential role of informal vendors in the urban water security picture.

The intermittency and unreliability of formal urban water supplies present financial, health and time-use burdens for urban residents in Ethiopia; we found unreliability to be a greater challenge than intermittency of supply. With unreliable water services, household members were becoming unwell or waiting days for water, limiting the ability to meet basic needs including cooking and drinking. Urban residents were continually making trade-offs between monetary, health and time-use risks when seeking to secure their domestic water access. These trade-offs were easier to manage when intermittency of water supply was reliable. In some cases, households were spending up to 76 times more for drinking water in plastic bottles that was of safe quality, with potentially far-reaching environmental implications. Little is known on this and we call for a research agenda that explores the relationship between unreliable formal water supplies and plastic pollution.

Overall, we find five key explanations for the persistence of urban water insecurity in Ethiopia. There is (1) a high level of non-functioning water supply points or systems, (2) inadequate operation of water demand estimates in water supply infrastructure, (3) insufficient financing of urban water systems, (4) unaddressed historical legacies of urban water supply infrastructure and (5) multi-sectoral challenges including insufficient electricity supply and a lack of co-ordination between the irrigation, industrial and urban water supply sectors for co-ordinated water management. With this evidence in mind, we call for a continued focus and acknowledgement of the socio-political processes that reproduce urban water insecurity overtime.

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Data availability statement

All relevant data are included in the paper or its Supplementary Information.

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