Addis Ababa's water crisis: challenges and opportunities

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Birhanu, B., Kebede, S., Alamirew, T., Zeleke, G. and Charles, K. (2022). Addis Ababa's water crisis: challenges and opportunities. Policy Brief: REACH Programme.

Summary

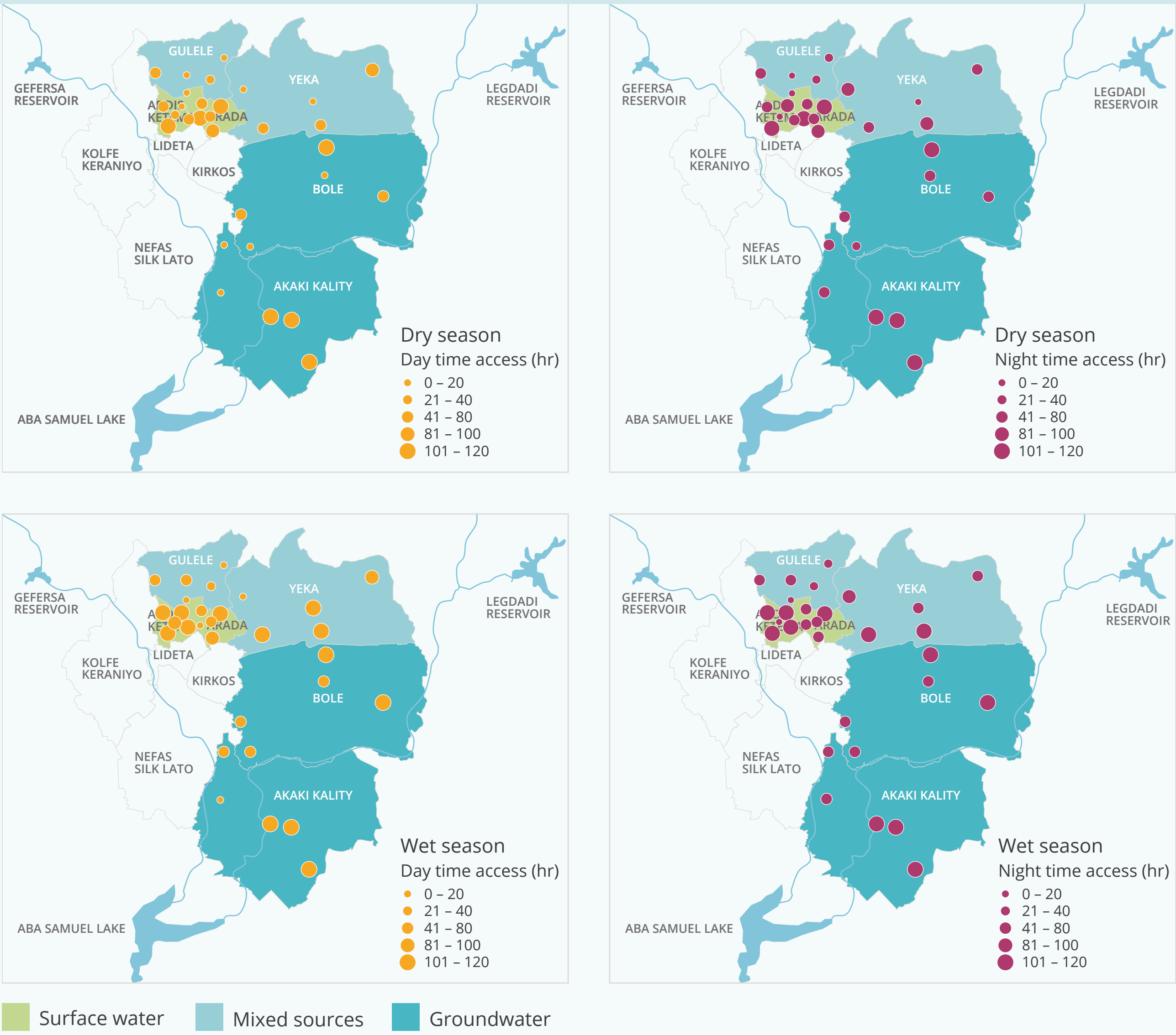
- Addis Ababa's water supply is insufficient to meet current needs, leading to intermittent water supplies which are increasing inequalities in water access depending on access to household storage and finances to develop private wells.
- Proposals to expand surface water storage will not fully meet the growing demand from the population and expanding industries.
- Groundwater depletion, land for expanding reservoir storage, water quality and unreliable energy supplies limit opportunities for increasing water provision.
- Action is needed now to better monitor and manage groundwater use, and to improve the conjunctive use of surface and groundwater to support sustainability for Addis Ababa's water supplies.

1 Current situation: chronic water interruptions in Addis Ababa

Addis Ababa's existing water supply infrastructure only meets 50% to 60% of the city's water demand leaving much of the population underserved and restricting productivity. Currently, a maximum of about 630,000 m3 of water is produced daily from both surface (225,000 m3) and groundwater (404,000 m3) supply sources. This falls short of the domestic daily water demand of more than 1 million m3. This water supply is further threatened by changing weather patterns with climate change, and changes in land use affecting groundwater recharge.

Population increases and industrial development are accelerating water demand. Addis Ababa, the capital city of Ethiopia and the diplomatic centre of Africa, is one of the fastest-growing cities on the continent. Its population is increasing rapidly: currently estimated between 4 and 7 million, it has nearly doubled every decade and is estimated to reach 12 million in 2024 (UN-HABITAT, 2008). Rural to urban migration and temporary or fluctuant residents contributed to the high population in the city. Additionally, there is high water demand from industry, with more than 60% of industries in the country located in the Awash River basin, in or near Addis Ababa (ABA, 2017).

Figure 1: A snapshot survey of dry (May 2020) and wet (August 2020) seasons of water interruption in six selected Addis Ababa sub-cities; (a) dry season daytime access to water, (b) dry season nighttime access to water, (c) wet season daytime access to water, (d) wet season nighttime access to water.



Households are experiencing significant water supply interruptions. Recent research[1] highlighted that there are hours of water supply interruption across Addis Ababa. Interruptions in the dry and wet seasons are consistent, indicating no significant variation in the amount of total water produced in the dry and wet seasons (figures 1a, b, c, and d). A significant number of households are connected mostly during the nighttime.

Electricity interruptions may be exacerbating water interruptions. Addis Ababa water is sourced from groundwater and surface water in different areas, with limited mixing of water sources in the piped systems, leaving different areas of the city effectively served by either surface water or groundwater.

The houses connected to only groundwater supply sources seem to suffer in water supply intermittency than those connected to only surface water supply sources. This may be attributed to a continuous interruption of electricity to abstract water from the boreholes. A subsection is served by a combination of groundwater and surface water, with variability strongly linked to seasonality; these areas have the least reliable water supply.

Water provision in Addis Ababa

Addis Ababa's location at the top of the Awash River basin (figure 2) limits the catchment area available for surface water. Addis Ababa has relied on groundwater since it was established in the 1870s. Initially reliant on springs and shallow wells, the city now draws its water from deep groundwater and surface water from the Awash River basin.

Addis Ababa's piped water supply

Groundwater: capacity ~404, 000 m3/day

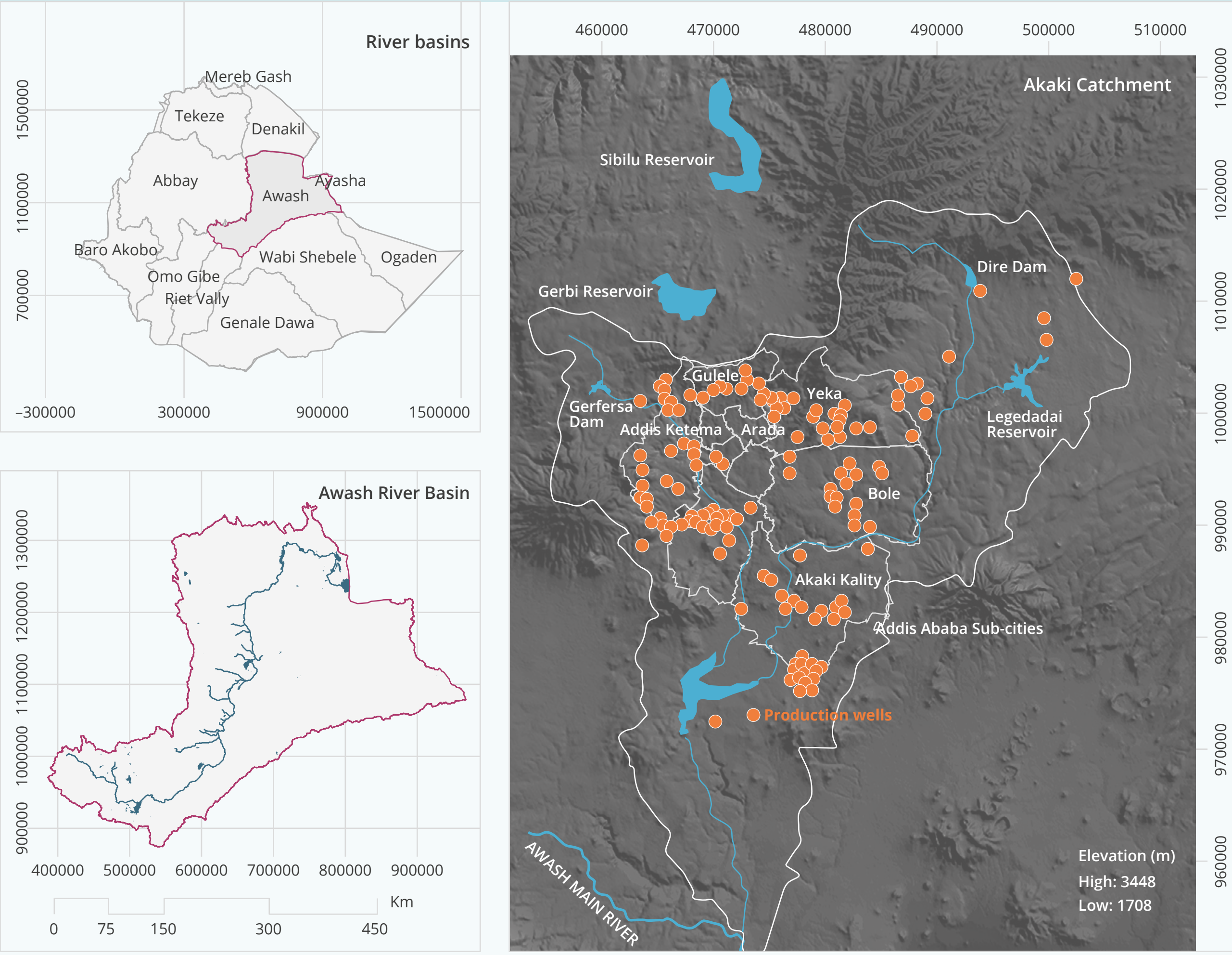
- As an option to reduce the water supply deficit in Addis Ababa, deep and shallow groundwater sources were provided by developing new wellfields in Akaki, Fenta, and Legedadi areas. The development of groundwater well fields was done in different phases. The current Addis is Ababa city groundwater production is 198, 000 m3/day from Akaki well field (Phase IIIA (35, 000 m3/day), Phase IIIB (65, 000 m3/day), Old city (5, 000 m3/day), New City (68, 000 m3/day), City 5 (Koye Feche) (25, 000 m3/day) and 206, 000 m3/day from scattered wells & protected springs (Pocket wells (90, 000 m3/day), Legdedadi well field (36, 000 m3/day), South Ayat (80, 000 m3/day).

Surface water sources: capacity ~225, 000m3/day treated water.

- **Gefersa Dam**: the oldest surface water supply source, situated northwest of Addis Ababa, was constructed in 1942. The dam was raised in 1955 providing an increased capacity of 6.2Mm3. The operation of the treatment plant was commissioned in 1960, with a design capacity of 30,000m3/day. To augment the Gefersa main reservoir, Gefersa III with an impoundment capacity of 1.2Mm3 was constructed in 1966. The Gefersa dam was fully rehabilitated in 2009 and the reservoir capacity was increased to 7.2Mm3 (AAWSA, 2002).
- **Legedadi & Dire Dams**: Legedadi and Dire dams (c. 1999) have impounding capacities of 44Mm3 and 19Mm3. This Legedadi treatment plant has a capacity of 165,000m3/day (AAWSA, 2011). A new treatment plant expansion was completed in 2014 to produce an additional 30,000 m3/day.

1 To characterise the current situation of water supply intermittency in Addis Ababa city, we have recorded dry (May 2020) and wet (August 2020) seasons of water interruption in six selected sub-cities (Addis Ketema, Akaki, Arada, Bole, Gulele, and Yeka) (Figure 1a). The six sub-cities were selected to represent 1. Houses connected to only surface water supply sources, 2. Houses connected to only groundwater supply sources, and 3. Houses connected to mixed sources (Table 1). Five households were surveyed from each sub city. A citizen science approach was applied to record the water interruption for 240 hours (120 hour night time and 120 hour day time). 30 houses were covered in the snapshot of ten days' water interruption survey engaging 30 volunteers willing to record water interruption in their respective houses.

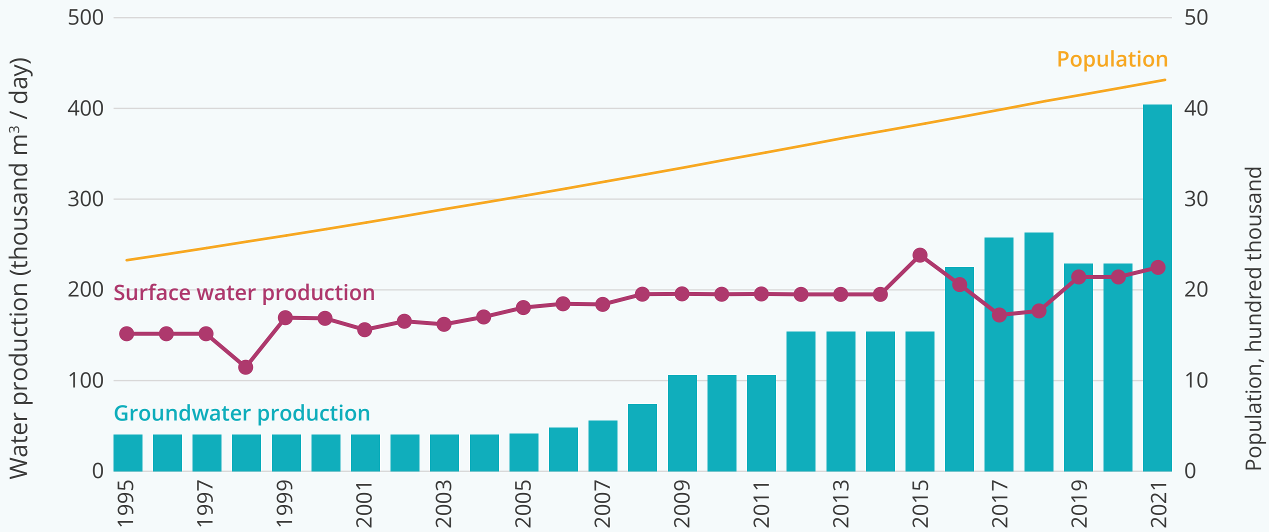
Figure 2: Location map of Addis Ababa city in the Upper Awash basin within the Akaki catchment. The existing (Gefersa, Legedadi-Dire) and planned (Gerbi and Sibilu) surface water supply reservoirs and boreholes are indicated.



After the construction of the three surface water supply reservoirs, Addis Ababa city water supply was dominated by surface water with more than 80% of the city water supply from surface sources (figure 3). Groundwater development has increased to meet more than half the supply in the past five years. Currently, more than 60% of Addis Ababa city water demand coverage is from groundwater (Birhanu et al., 2021).

The total available water from surface water and groundwater is not sufficient to meet the current Addis Ababa city water demand. Additionally, based on the production and billing collected from the users, leakage loss due to poor water supply distribution networks is estimated to be 20 to 40% (Welday Berhe, 2005; Daniel Elala, 2011; Berhanu Hailu, 2009; AASWA, 2015; references therein).

Figure 3: Daily surface and groundwater production to supply Addis Ababa city domestic water demand. The population projection is based on the 2007 CSA census.



2 Challenges to the expansion of water supplies

Five key areas are identified that are constraining the expansion of water supplies.

Groundwater depletion: Groundwater abstraction has significantly increased in the past couple of decades. Major water table reductions have been observed with the yield reduced either partially or fully, such as in the Akaki well field (Birhanu et al., 2021), especially for shallow wells. Increasingly, deeper wells are being developed (~500m) in the Akaki well field and other groundwater prospect sites supplying water for Addis Ababa city. Similar declines in the water table have been experienced elsewhere with severe implications for water security, such as in Mekelle, Axum, Harar, and Gondar (Kebede, 2013). This abstraction is not just for the city water supply but is developed separately by industry and private investors, often with abstraction weakly regulated, working in competition with city water supplies. If unmanaged abstraction continues, there is a risk that water tables drop further, compromising existing infrastructure. The shift from shallow to deeper wells addresses immediate demand but doesn't provide a long-term sustainable alternative without the management of abstraction rates.

The rapid land use land cover changes leading to increased urbanization and industrial coverages may also contribute to groundwater depletion by reducing potential recharge zones in the city. Not to mention, urban pollution and industrial effluents also add up to water quality concerns.

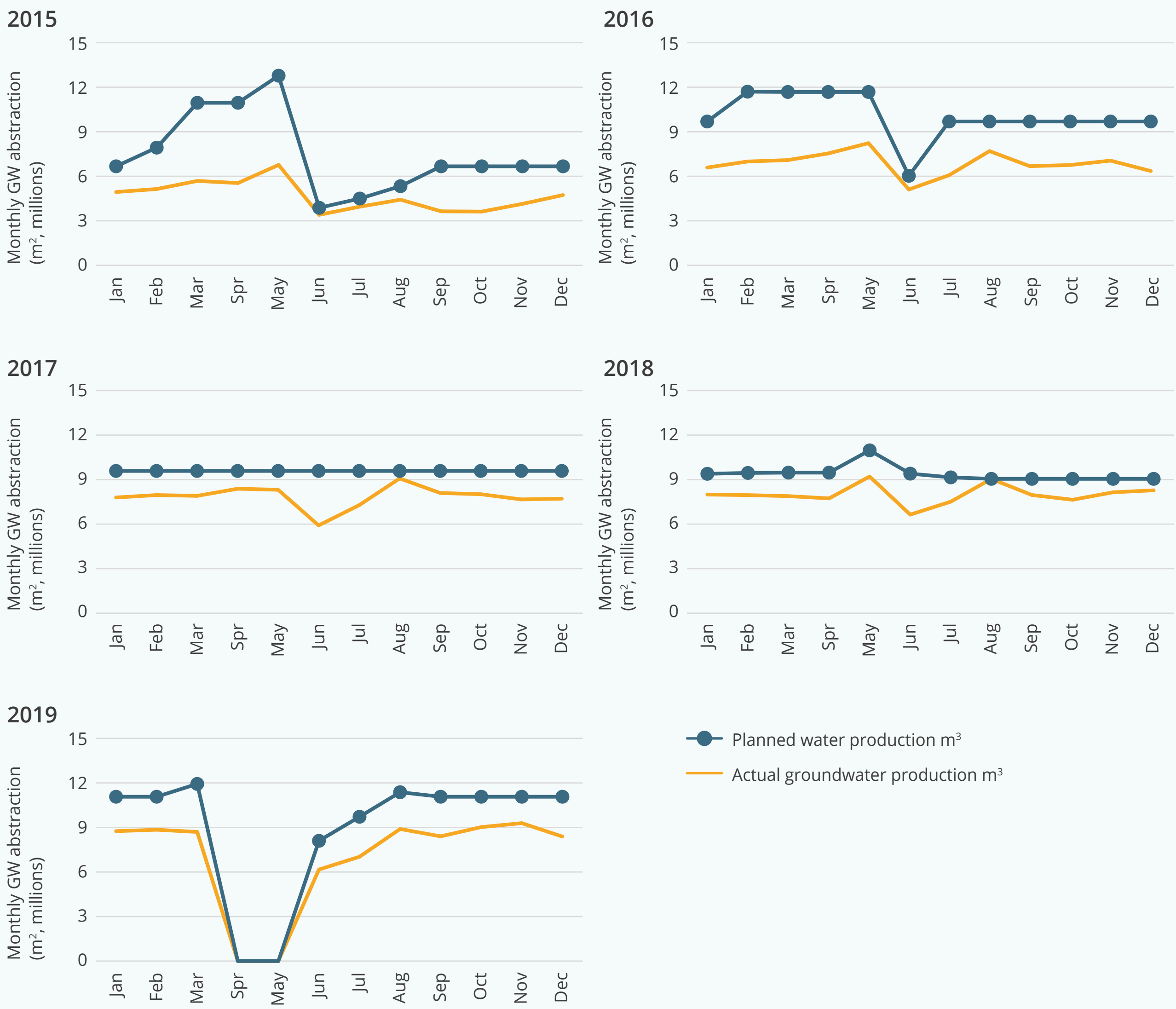
Land access for developing reservoirs: There are two planned surface water supply expansion projects to be located 30Km north of Addis Ababa city. Gerbi reservoir with a gross storage volume of 48.5Mm3 and Sibilu with a gross storage volume of 347.7Mm3. These projects were originally planned to be completed and supply Addis Ababa city with full capacity at the end of GTPII and GTP-III, respectively (AAWSA, 2015). The current Addis Ababa city administration announced that it will give a priority to resuming the delayed project.

One challenge for these developments is securing land access and compensation for resettlement. Given the two project sites are located outside of Addis Ababa city administration in the Oromia Reginal state, a negotiation should take place between Addis Ababa city administration and Oromia Regional Government on appropriate compensation and resettlement schemes for the community living on the site.

According to the Addis Ababa city administration, the two projects are expected to increase Addis Ababa city water demand coverage to 100 percent, with a capacity to supply 688, 500 cubic meters per day. However, considering up to 40% loss of water due to old water supply distribution networks, even the completion of the two planned surface water reservoirs together with the existing surface and groundwater supply sources may not satisfy the growing water demand (Birhanu et al., 2021).

Water quality: Surface water and groundwater are increasingly polluted by industrial and municipal wastewater, adding to the challenges posed by geogenic contamination (fluoride and salinity). Rapid population growth in Addis Ababa has put tremendous pressure on services, with the discharge of untreated domestic wastewater and dumping of up to 35 percent of solid waste (AAEPA, 2006) threatening water quality for users. Industrial pollution control is poorly enforced, with heavy loads of toxic elements (i.e., Cr, Pb, and Zn) (Dessie et al., 2022).

Figure 4. Comparison between monthly groundwater abstraction plan and actual abstraction amount for Addis Ababa city for the years from 2015 to 2019.



Records on the status of emerging contaminants in water supply sources (boreholes and surface water supply reservoirs) and tap waters showed that there are indications of pesticides, veterinary drugs, personal care products, and pharmaceutical drugs (Kidist et al., 2022, under review).

Unreliable energy supply: Unpublished reports show that groundwater points are not serving their design capacity because of regular power interruptions. The average water production period ranges only from 4 to 8hrs per day. Further development of groundwater resources will not resolve the water security problem unless energy production capacity is enhanced. Based on the five years (2015 to 2019) monthly groundwater abstraction plan and the actual groundwater abstraction data collected from the Addis Ababa Water Supply Sewerage Authority (AAWSA), the actual amount of water abstracted is always lower than what is planned to be produced (figure 4). Even though technical problems (i.e., pump failure) may contribute, this is mainly due to the interruption of electricity (personal communication with experts at AAWSA). The difference between the planned and the actual water production is even higher during the dry period because 1. There is higher water demand during the dry period and 2. Energy production is lower nationally due to the smaller water stored in the dams for hydropower generation.

Implications to downstream users; Traveling downstream of Addis Ababa in the Awash River basin, the rainfall decreases and variability increases, and vulnerability to drought increases. Many users rely on the river for water for drinking, agriculture, and industrial production. Over-abstraction of surface water and groundwater in the Upper Awash basin has implications for the water security of users downstream.

3 Impact of the current situation

Intermittent water supplies and water scarcity impact both economic and human development. Water scarcity impacts the health of users if there is insufficient water for hygiene, impacts time available for work and school when water collection duties and impacts finances as local water markets form and inflate prices in response to demand. Uncertainty in the availability of water from intermittent services further impacts on time available, often interrupting sleep or other activities to ensure water collection when available. Mostly, women and girls are responsible to store water for the family.

Inequalities in intermittent systems are further exacerbated by the capacity of the household to afford or access coping mechanisms, such as buying water from vendors and suitable storage containers to balance availability and demand (Grasham et al. 2022). Lack of effective oversight on the development of groundwater creates further inequalities as industry and private investors can develop deeper well, or invest in stronger pumps to access scarce water resources more readily (Grasham et al., 2022).

4 Policy options

The following points summarize policy options to enhance the management of Addis Ababa's water supply to increase water security for the benefit of residents, businesses, and surrounding areas.

4.1 Do nothing

A 'do nothing' scenario will result in increasingly constrained water availability for the city, restricting economic and health development gains, and exacerbating inequalities between those who can afford coping mechanisms and those who can't. There is potential for severe water scarcity shocks from rapid changes in water availability due to climate variability and change, such as was experienced by Cape Town in 2018, with impacts on industry, agriculture, and the economy.

Green legacy

The Office of the Prime Minister is leading an initiative called the green legacy. The initiative aims for a greener and cleaner Ethiopia and helps the global effort to withstand the impact of climate change. The initiative is believed to raise the public's awareness about Ethiopia's frightening environmental degradation and educate society on the importance of adjusting to green behavior. Billions of trees have been planted by mobilizing millions of people from every part of the country.

4.2 Improved groundwater management

4.2.1 Conjunctive use of surface and groundwater

Conjunctive use of surface and groundwaters is the management of surface and groundwater resources in a coordinated operation so that the total yield of such a system exceeds the sum of the yields of the separate components of the system resulting from an uncoordinated operation (Coe, 1990). Where used effectively, groundwater can provide a buffer in drought years, compensating for low surface water supplies.

Addis Ababa city gets water both from surface water (less than 40%) and groundwater supply sources (greater than 60%). However, the resources are used spontaneously without proper conjunctive water management design related to the engineering water distribution system. Conjunctive use of surface water and groundwater can usually increase yields at lower costs than more dams and reservoirs operated separately. As indicated in the recent study (Birhanu et al., 2021), even the completion of the planned surface water reservoir projects (Gerbi and Sibilu) will not be sufficient to fill the water demand-supply gap in Addis Ababa city unless conjunctively used with the groundwater resources. For the efficient application of conjunctive use proper physical (engineering infrastructure), operational (optimization models), financial, and institutional arrangements should be in place.

4.2.2 Groundwater monitoring

The increasing reliance on groundwater, especially during drought, heightens the importance of proper management.

To understand how the water supply sources respond to stresses from abstraction, and impacts from land use change on recharge and quality, there must be appropriate longitudinal monitoring of groundwater level and water quality. At present, there is a good network of pumping wells across the area, but there is no available installation of loggers for groundwater data recording.

4.2.3 Managed Aquifer Recharge (MAR)

Addis Ababa city is characterized by dry and wet extremes. In such environments, the challenges can be converted into opportunities by properly managing urban floods and storms through Managed Aquifer Recharge (MAR) schemes. To apply such a water management approach, the suitability for different MAR applications within and outside the city should be identified and mapped first to guide decision-making on where MAR intervention could be applied effectively. Potential groundwater recharge zones should be identified and should be protected from pollution threats mainly from land use land cover changes. Addis Ababa City Rivers and River Side Development Project can be successfully integrated with MAR schemes. In addition to city beautification, Addis Ababa City Rivers and River Side Development Project aims to clean up the rivers. The clean river water can be channeled to a suitable groundwater recharging environment (MAR site) downstream to enhance the groundwater stock, which is under pressure due to continuous abstraction.

4.2.4 Regulations and enforcing mechanisms

There is a lack of legal frameworks guiding industry and private institutions on where they should drill boreholes, to what depth they should drill, and limiting the amount of water abstracted.

To have a fair distribution of the water resource and for its sustainability, regulations on groundwater use should be prepared with the appropriate enforcing mechanisms.

4.3 Demand management and reducing leakage

Engineering solutions (reservoirs, boreholes, etc.) focus on the supply-side perspective. However, unless engineering solutions are integrated with options to reduce demand from leakage and water users, it will create stress on the water supply sources, distrust of the environment, and Impact on the downstream community. All types of urban water use (drinking, gardening, car wash, firefighting, construction) tap water from the same source. To avoid unnecessary water completion, discouraging tariff schemes should be in place for water uses other than household purposes. Besides, treated water can be a better alternative water supply source option for non-domestic water users (gardening, firefighters, car wash, and construction). Decentralizing the urban economy to different parts of the country may contribute to minimizing the water demand by decreasing the rural migration to the city.

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