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Improving Water Access to Areas That Lack Water

Lucia Carrol Zhou

Abstract:

Better water management practices and fairer water distribution systems are essential for a sustainable water supply. Currently, 844 million people lack access to safe drinking water, with the Middle East, North Africa, and South Asia having the highest water stress levels. Agriculture remains the largest consumer of water globally, further exacerbating water stress. Groundwater extraction often exceeds recharge rates, leading to problems like saltwater intrusion. Sustainable solutions involve efficient irrigation, advanced wastewater treatment, and technologies like drip irrigation and hydroponic agriculture. Case studies from regions like South Africa and California highlight the challenges and successes in addressing water scarcity. Efforts such as South Africa's Free Basic Water Access policy and California's adoption of sustainable agricultural practices demonstrate the importance of policy, technology, and stakeholder cooperation. Despite progress, achieving global water sustainability goals remains off-track, necessitating coordinated efforts and continued innovation to ensure equitable water access.

Keywords: Water scarcity, Sustainable water management, Water distribution, Water policy, Wastewater treatment, Water sustainability

1. current water situation

1.1 global water distribution

Today, 844 million people lack access to safe drinking water, especially in developing countries, and global water use is still growing [1]. Most regions now witness medium-high or low-medium water stress [5]. However, some countries in the Middle East, North Africa, and South Asia face high to extremely high water stress. In particular, "the most water-stressed regions are the Middle East and North Africa, where 83% of the population experiences extremely high water stress, and South Asia, where 74% is exposed" (Kuzma, Saccoccia, Chertock). Low supply and heavy demand from domestic, industrial, and agricultural uses cause water stress [5]. According to Figure 2, agriculture and livestock uses the most water—up to 60% of total water use. Industrial processes such as refining metal and making paper consume water [4]. For example, copper requires 440 liters of water per kilogram; aluminum requires 410 liters of water per kilogram; steel requires 260 liters of water per kilogram; and paper requires 125 liters per kilogram [4]. as developed countries tend to be more well-equipped with bathrooms [4], they tend to have higher water use per capita than developing countries, indicating that water use distribution is not even. Even within the United States, water use outdoors is not even among states due to different weather conditions [4]. The difference in water per capita shows that sustainable lifestyles may coexist with efficient and sustainable water use.

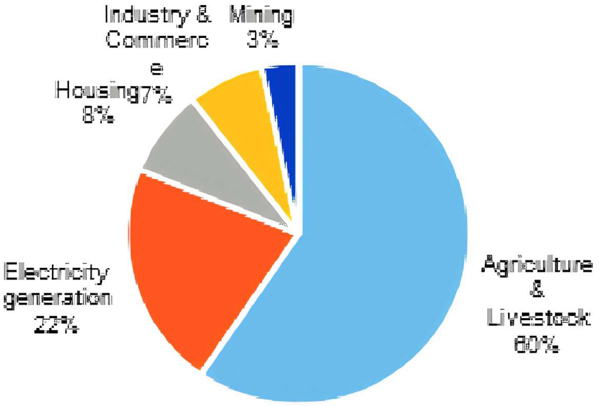

Fig. 2 water use across different sectors [6]

1.2 water sources

Freshwater sources include aquifers, springs, wells, streams, rivers, ponds, lakes, wetlands, reservoirs, and bottled water. Groundwater can be extracted through wells from permeable layers of sediment in aquifers [4]. Plants also use groundwater through root uptake. When precipitation occurs, water percolates down the soil, and the groundwater in the aquifer is recharged [4]. However, today, water extractions occur faster than recharge, such as the Ogallala aquifer, a significant water supply in the United States [4]. Excessive pumping of groundwater can also negatively affect the water quality in the aquifer,

especially near coastlines [4]; extracting water through a well first lowers the water table, then as the water pressure decreases, seawater contaminates the groundwater by mixing in [4]. Saltwater intrusion occurs when saltwater mixes in with groundwater [4]. Coastal areas are particularly vulnerable to saltwater intrusion. When an aquifer has an opening on the land surface, water flows out and forms a spring--an important source of freshwater and habitat for many organisms [4]. They are also the start of many streams and rivers [4]. In places where water infrastructure is mature, an array of pipes, canals, and pumping stations transport water to households [10].
Bottled water can be a potential water source and can be brought in from other countries for developing countries [2].

2. Making water supply more sustainable

2.1 why do people suffer water stress

2.1.1 Africa

One example of an area that lacks water is North and South Africa. Surprisingly, up to 9% of the world's drinking water sources are in Africa; while countries in Central Africa are experiencing low water stress, water stress is high in North and South Africa [4]. Reasons for limited water access mainly include climate, physical location, agriculture, and government [7]. Figure 3 shows the percentage of water each sector used in South Africa. Physical location affects how people get water. Water access is more convenient for cities due to more advanced infrastructure and sewage systems [7]. However, people living in the village travel a long distance to get water, limiting their room for personal development [7]. In South Africa, 60 percent of the 51 million people live in urban areas with updated infrastructure to transport water, while the rest live in rural settlements [9]. The water sources for South Africa include surface water (77 percent of total use), groundwater (9 percent of total use), and recycled water (14 percent of total use) [9]. Due to different distances from water sources, the primary water sources for citizens are different based on location. In rural settlements, 74 percent of people primarily rely on groundwater, such as local wells and pumps [9]. Urban residents get access to surface water, such as the Limpopo and Komati rivers [9]. The outdated pipes in rural areas will also contribute to water scarcity by wasting water; South Africa loses over 1.5 million cubic meters of water annually due to inefficient water infrastructure. In addition, crop productivity in South Africa is not efficient enough to meet the growing population. "Up to 95% of Sub-Saharan farmers rely on green water" for irrigation, which is water "caught in the soil by seasonal rainfall" [7]. However, the prevailing problem of global warming will further reduce precipitation in the sub-saharan climate, thus calling for more efficient forms of irrigation [7]. The unequal access to water between the cities and villages illustrates that a fairer and more advanced water distribution system is needed, which may include pipelines and sewers that could bring water directly to humans [7].

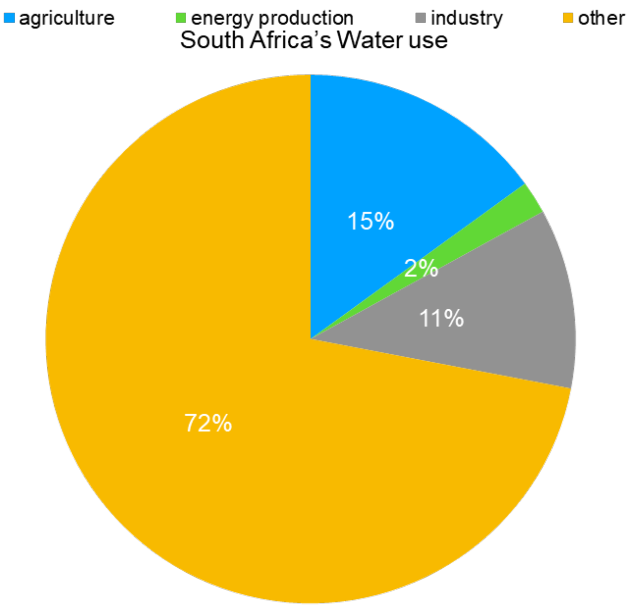

Fig. 3. The water use for industry is greater than 11 percent since the process of mining contaminates local water supplies [9].

2.1.2 South Asia

Climate change, water resource mismanagement, and water contamination are causes of severe water scarcity in South Asia. Climate change negatively affects water supply by disrupting weather patterns and rainfall, making water availability unpredictable [8]. In addition, water resource mismanagement includes poor water quality and over-pumping of aquifers [8], indicating the need for stricter water quality monitoring and sustainable resource management. Water contamination also negatively affects water accessibility by making the water unusable. Pollutants found in water include pathogens, harmful chemicals from anthropogenic activities, and chemicals and minerals from the natural environment [2]. For example, in Bangladesh, up to 1.4 million tube wells contain naturally occurring arsenic [2], which is commonly associated with cancers of the skin, lungs, kidneys, and bladder and poses a threat to human health [4]. Thus, to improve water accessibility, researchers need to identify wastewater sources and develop a corresponding treatment plan. Finally, conflict over ownership of a water source can negatively influence the water supply. Bangladesh and India share more than 200 rivers, making water ownership complex.

2.2 risks of wastewater

Combatting water scarcity and providing sanitation for everyone is a significant problem. Pathogens in wastewater expose drinkers and users to waterborne diseases such as cholera, hepatitis, gastrointestinal illness, and diarrhea [4]. Cholera is primarily found in raw sewage and takes thousands of lives away annually in developing countries [4]. Hepatitis A is becoming more common in the United States, with 1000 cases annually [4]. The bacterium Cryptosporidium is responsible for causing gastrointestinal illness [4]. Although the risk of diseases from poor quality water and sanitation practices also exists in developed countries like the United States, developing countries are most vulnerable. To make the water supply sustainable, treatments for sources of waterborne diseases and strict checking of water quality are needed.

2.2.1 sources of wastewater

Water becomes wastewater when pollutants enter. Wastewater is further classified into black water and grey water [11]. Black water is from sewers that contain high concentrations of organic content, nitrogen, and phosphorus [11]. Grey water is from baths, showers, bathroom sinks, and washing machines [4]. Point sources release pollutants from specific locations, such as factories, power plants, municipal wastewater treatment plants, and drainpipes [3]. Non-point sources include runoff from agricultural fields [4], runoff from rainwater [3], and airborne pollutants [3]. Also, human activities, such as producing electricity, mining, oil spills, deforestation, and household increase the amount of wastewater. Coolant water with radiation could flow into rivers or oceans and cause thermal pollution. Mining can leave trace metals in nearby water. In the house, laundry, bathing, the toilet, and cooking require water. To prevent human activities from negatively affecting the water supply, a solution to recycle wastewater, such as purifying wastewater and returning it to its natural source, could involve connecting the water source with a treatment plant. For mining, setting policies to clean up the location after mining could restore it to its state before mining. If the water becomes polluted and remains untreated, the amount of wastewater will accumulate.

2.3 current efforts to conserve water

2.3.1 agriculture

In agriculture, more efficient irrigation methods, such as drip irrigation in China, can reduce water use and prevent excess runoff. Currently applied in Indiana, precision agriculture utilizes the technologies of assessing variation between crops on the same field and the Global Positioning System (GPS), maximizing efficiency in applying fertilizers and irrigating [4]. Satellite photos can differentiate between areas with high fertility from those with low fertility [4]. Then, GPS-equipped tractors can steer themselves across fields to apply the needed amount of fertilizers, reducing excess nitrogen or phosphorus runoff [4]. However, both drip irrigation and precision agriculture pose the challenge of high costs to developing countries. With more financial investment directed towards conserving water and economic incentives, improving the agriculture system can be possible. In the long run, greater crop productivity, reduced fertilizer use, and reduced fuel costs reduce net costs [4].

Another way of reducing water demand in agriculture is through hydroponic agriculture, which cultivates crop plants in greenhouse conditions by immersing the roots in a nutrient-rich solution without soil [4]. Currently applied in Georgia, hydroponic agriculture uses 95 percent less water than traditional irrigation techniques [4]. Water not taken by plants could also be reused [4]. Although hydroponic agriculture has high initial costs, it can reduce costs in many other areas, such as water, and more flexible growing conditions make fulfilling consumers' demands more convenient.

2.3.2 technology

Some regions purify wastewater in a treatment plant before returning it to its water source, which improves water flow. Common ways of advanced wastewater treatment include septic systems and sewage treatment plants. Recycling wastewater may involve connecting a treatment plant with a natural water source, such as a river. Finally, the Middle East is currently employing desalinization to extract water from the ocean. Ways to desalinize water include reverse osmosis and distillation.

Technological advancements in household appliances can also conserve water. For example, toilets manufactured after 1994 must use at most 6 liters of water per flush, compared to 27 liters in the United States [4]. Dual-flushing toilets have two buttons: one that uses 3 liters of water to remove liquid waste and another that uses 6 liters of water to remove solid waste [4]. Front-loading machines, which are more efficient than conventional washing machines, are now available, although they cost more [4]. Federal standards now require shower heads to use at most 95 liters of water for a 10-minute wash [4]. Other than household equipment, using water-conserving materials in constructing buildings can also prevent runoff, especially in urban areas. For instance, a gutter system can collect rainwater and channel it into rain barrels or store it in a large underground water tank [4].

Solar energy and wind energy sources are becoming more important as they minimize water use in the electricity sector. In regions experiencing water shortages, electricity production that requires water can lead to industrial interruptions. For example, in India, from 2017 to 2021, due to the lack of coolant water in the powerplant, India lasts 8.2 terawatt-hours of energy [4].

In conclusion, reducing water demand can aid us in adapting to water-scarce conditions.

2.3.3 nature

As discussed in 1.1, outdoor water use includes watering lawns. To reduce water demand in watering lawns, some regions in the United States require homeowners to practice xeriscaping, a style of landscaping that removes water-intensive vegetation and replaces it with more water-efficient native landscaping [4]. This practice can save up to 2000 liters of water annually [4]. Growing crops that require less water can also reduce water demand. Examples of water-intensive crops include alfalfa. Less water-intensive crops include potatoes, tomatoes, and broccoli; those crops also have higher resale value [4].

Natural means involve using natural ecosystems to filter water. Wetlands [4] such as salt marshes, mangroves, swamps, and forests act as natural filterers of water and buffer zones for floods. Thus, protecting these natural ecosystems is necessary. Other than ecosystems, biodiversity could also regulate water quality. Using natural means is a cost-effective way to manage the water supply.

2.3.4 In South Africa

In South Africa, mission 2017 aims to reduce water scarcity, transport water to those who need it, and identify sustainable water sources [9]. Currently, South Africa is initiating a policy called Free Basic Water Access, which sets the maximum amount of water each household can use; each household can only use 6000 liters a month. Households that use excess amounts would pay a fee [9]. With this policy, households will be more conscious of their water use. Challenges of this policy include monitoring water usage and deciding on how much to charge if a household uses too much [9]. In response, the South African Department of Water Affairs and Forestry (SADWAF), which is the organization in charge of water allocation in South Africa, installed water meters--a device that measures water flow--in households [9]. The water meter could monitor water usage in a household and detect whether tap lines for transporting water are broken [9]. To solve the long-term issue of water scarcity in South Africa, a communal tap water system with regular monitoring, which includes pipes and other infrastructure, is needed [9]. To ensure regular monitoring of pipe quality, the government assigns this duty to different private companies and offers incentives [9]. As a result, pipe replacements are quick to ensure a continuous water supply. The short-term solution is to have trucks transport water to households monthly with a fixed amount for each household [9]. One challenge that this long-term goal faces is cost distribution and investment sources. In response, the money could come from families or Private-Public Partnerships (PPPs), partnerships between private companies and the local or national government [9]. South Africa's approach to solving water scarcity, including using an assigned amount of water and working on long-term solutions, shows the importance of communication in solving a problem.

2.3.5 In California

Constantly experiencing droughts, California also experiences water stress, although it is responsible for nearly half of all fruits, nuts, and vegetables grown in the United States [4]. An advanced system of aqueducts transports water to the agricultural lands in Central Valley and municipalities that need drinking water [4]. Despite the success in agriculture, tensions arise as residents and businesses compete for water [4]. Diverting water from a river also negatively affects wildlife and the habitat by increasing water salinity and decreasing water capacity. For example, the salmon in the Sacramento-San Joaquin River Delta is experiencing a population decline due to excessive water pumping.

Despite experiencing droughts, California also has high water demand compared to other states due to agriculture in the Central Valley region—as much as 144 trillion liters per day [4]. The government initiated the Central Valley Project in 1935, which diverted 8.6 trillion liters of water from rivers and lakes [4]. Other than diverting water, farmers also pumped groundwater at a rate past the rate of recharge [4]. In this project, one major challenge is cost. The government provided water for the farmers at a subsidized price—only 5 percent to 10 percent of the amount paid by cities. The price was so low that it did not cover the cost of electricity to transport the water [4]. If water prices increase, switching to less water-intensive crops and more efficient irrigation techniques will become more profitable [4]. However, some farmers cannot afford the costs and are forced out of business, reducing the amount of food grown [4]. The water stress fueled tensions between different stakeholders for opinions on water use.

Finally, excessive water diversion led to droughts from 2013 to 2016, which motivated farmers to switch to more sustainable agricultural practices [4]. The drought heavily influenced farmers who plant hay and rice--water-intensive crops [4]. Allowing around 200,000 hectares of land to become fallow, farmers started practicing drip irrigation and planting less water-intensive crops and crops that are suitable to the local climate, spending 300 million dollars in pumping groundwater as the aqueducts are not delivering enough [4]. Due to increased crop prices, overall farm revenues ultimately increased [4]. The case in California shows the significance of long-term development, even at the expense of personal or short-term economic benefits.

To achieve sustainability, understanding the benefits of different stakeholders is significant. In the water crisis in California, stakeholders include municipalities that need water, farmers that need to irrigate, and endangered species, such as local fish populations, that rely on the water habitat [4].

Climate change and water shortage are the primary causes of droughts in California. To make the water supply sustainable in California, stakeholders need to know the environmental impacts of water use and the recharge rate. Constant communication between residents, farmers, and the government is crucial to achieving agreement. Conflicts over water use result in insufficient water for everyone and environmental degradation. Another example of a case in which water demand between stakeholders conflict occurs at the Klamath River, which witnessed a die-off of up to 30,000 salmon [4]. The 1967 Arab-Israeli War and the 1980s Iran-Iraq War in the Middle East are also examples of political tensions that resulted from insufficient water supplies.

2.4 current progress

According to the United Nations Water Development Report 2023, achieving the sixth sustainable development goal by 2030 is still off-track [12] due to a lack of data from certain countries and coordination. The report concludes that cooperation among different communicates is necessary [12]. According to predictions, Water demand will increase by 1% per year over the next 30 years, primarily from the industrial and agricultural sectors [12]. The increase in water demand is especially apparent in emerging economies and middle- and lower-income countries [12].

2.5 water management

A plan for allocating water to different users and their corresponding sources is needed, which requires communication between various stakeholders, especially in cases where the owner of the water is ambiguous, such as in India and Bangladesh. They share about 250 rivers originating in the Himalayas and flowing into Bangladesh [4]. One way of distributing water implemented in Chile in 1981 is through a free market system [4]. In this way, interested parties have to pay for water [4], which will encourage more efficient water use and resource distribution. Government regulation, which is weak in Chile, is also significant to ensure that those who get water most need it. Another method to regulate water distribution is through tiered water-pricing systems [4]. A baseline amount of water is provided to all households to ensure basic needs [4]. Water use that exceeds the baseline level will require higher rates [4]. Both of the discussed methods require users to pay for their water use. However, water quantity is limited, so regulation of water use is necessary to prevent environmental degradation.

Regular monitoring of the water delivery system is significant. Water quality should also periodically be measured by taking samples. Some measures include BOD (biochemical oxygen demand), indicator species such as fecal coliform bacteria, nitrogen and phosphorus concentrations, and pollutants. In addition, periodic monitoring of the pipes and canals that deliver water is significant. Old, outdated pipes can have leaks that lose up to 55 percent of the water [4]. Finally, the water source, which can be a reservoir or groundwater, should receive monitor to prevent water table lowering and saltwater intrusion. With more attention and collaboration devoted to making the water supply sustainable, employment could increase due to increased job opportunities.

2.6 conclusion and potential solutions

Water stress is a growing concern in many regions, driven by increasing populations and limited resources. North Africa, South Asia, and the Middle East face the highest levels of water stress, but even developed regions like California are significantly affected. Freshwater sources such as aquifers, springs, wells, streams, rivers, ponds, lakes, wetlands, reservoirs, and bottled water are under pressure. Effective water management and monitoring are crucial to sustaining these supplies.

For potential solutions, reusing contaminated water presents a significant potential to reuse water. Many developing nations lack the infrastructure to recycle water efficiently, leading to the discharge of wastewater into the environment, resulting in greenhouse gas emissions, health hazards, and environmental degradation [11]. High-income countries recycle up to 70% of their wastewater, while low-income countries recycle only 8% [11]. In Bangladesh, research has shown that wastewater can generate hydropower [11]; wastewater contains five to ten times the energy required for its treatment [11]. Harnessing renewable energy, or hydropower, from wastewater can prevent the need to divert freshwater from rivers. Some methods include biological processes and technologies such as up-flow anaerobic sludge blankets (USAB), anaerobic digestion (AD), and micro hydropower plants (MHP) [11]. However, to make harnessing hydropower from wastewater feasible, a “central inventory of wastewater” and the ability to analyze the type of wastewater are necessary [11].

Wastewater treatment involves three stages: primary, secondary, and tertiary treatment. Primary treatment involves water passing through filters, where solid waste settles into a sludge layer [4]. Secondary treatment uses aerobic bacteria to break down organic content, converting it into carbon dioxide and inorganic nutrients like nitrogen and phosphorus [4]. Tertiary treatment involves disinfection to remove remaining nitrogen and phosphorus through technologies like UV radiation, chlorination, and ozone. After treatment, the water reenters rivers, where its quality is continuously monitored and improved. Monitoring technology includes underwater biological filtering beds, submerged plants, and hydrodynamic technology. Although the initial setup costs of wastewater treatment systems are high--ranging from $200,000 to $700,000--selling treated wastewater and taxes generate revenue [11].

References

[1] National Academies of Sciences, Engineering, and Medicine. 2019. Environmental Engineering for the 21st Century: Addressing Grand Challenges. Washington, DC: The National Academies Press. https://doi.org/10.17226/25121.

[2] Treacy, J. (2019). Drinking Water Treatment and Challenges in Developing Countries. IntechOpen. doi: 10.5772/intechopen.80780

[3] National Geographic. (2023, October 19). Point Source and Nonpoint Sources of Pollution | National Geographic Society. Education.nationalgeographic.org. https://education.nationalgeographic.org/resource/point-source-and-nonpoint-sources-pollution/

[4] Relyea, A. (2019). Environmental science for the ap (r) course.

[5] World Resources Institute. (2023). 25 Countries, Housing One-quarter of the Population, Face Extremely High Water Stress. Www.wri.org. https://www.wri.org/insights/highest-water-stressed-countries

[6] The Integrated Economic-Environmental Modeling Platform: An Application to Guatemala’s Fuelwood and Forestry Sector - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Water-use-by-sector-total-and-use-permitted_fig8_317425651 [accessed 13 Jun, 2024]

[7] Holtz, L., & Golubski, C. (2021, July 23). Addressing Africa’s extreme water insecurity. Brookings. https://www.brookings.edu/articles/addressing-africas-extreme-water-insecurity/

[8] UNICEF, 2021, The UNICEF Extreme Water Vulnerability Index (EWVI) – Methodology Paper. TP/12/2021

[9] Water Access in South Africa | Water for all. (n.d.). 12.000. Scripts.mit.edu. http://12.000.scripts.mit.edu/mission2017/case-studies/water-access-in-south-africa/#:~:text=Due%20to%20a%20lack%20of%20water%20infrastructure%20in

[10] US EPA, O. (2017, January 16). How We Use Water. Www.epa.gov. https://www.epa.gov/watersense/how-we-use-water#:~:text=Nationally%2C%20outdoor%20water%20use%20accounts%20for%2030%20percent

[11] AKM Khabirul Islam, Domestic and industrial wastewater generation and its energy recovery potential in Bangladesh, Cleaner Energy Systems, Volume 6, 2023, 100092, ISSN 2772-7831, https://doi.org/10.1016/j.cles.2023.100092.

[12] WWDR 2023 PPT Script (Full Generic)_FINAL_0.pdf