

Urban Water Scarcity in Sana'a, Yemen

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This essay is based on Aliza Herzberg's final paper for the CRP Department's Cities in a Global World taught by Dr. Laura Tate in the Winter quarter of 2018. Open to all majors, the class explores the social and economic implications of urbanization and the international political economy on global cities, such as authenticity, gentrification, migration, social and environmental justice, and urban security. Students also assess global challenges through specific case studies, such as the one discussed by Aliza in this essay.

The world's urban population is growing at an unprecedented rate; one half of the world's population is already living in urban areas (Emmerij, 1997, p. 104). Urban life often draws people from rural areas due to its "better quality and more choice in education, material comforts, medical care, employment opportunities, and self-expression. It [the urban setting] provides a wide variety of skills, services, cultures, delivery systems, and so on" (Emmerij 1997: 105). The benefits of the urban setting are especially attractive to impoverished rural dwellers who aspire for a better quality of life. While the growth of megacities often benefits the respective national economy and incorporates the country into the global world system, there are many social and environmental consequences associated with urban growth.

Urban life and increasing urbanization shares and exacerbates its own host of social issues, including "poverty, housing, unemployment and underemployment, slums, crime, drugs, and street children" (Emmerij, 1997, p. 105). These issues are a consequence of the "growing urban [economic] dualism and informalization," a phenomenon that emerges with increasing economic inequality, creating an inevitable divide among the powerful and wealthy elite and the impoverished masses. Poverty and marginalization are embedded as an inevitable aspect of the social structure of the megacity (Emmerij, 1997, p. 104). This paradox manifests itself in most urban spaces and is further intensified in periphery countries due to the lack of social services that would mitigate inequality.

Yemen's geopolitical and economic circumstances put the country in a disadvantaged position in a highly contested region of the world, Southwest Asia and North Africa (also known as the Middle East). Yemen has one of the highest populations in the Middle East, yet it has the lowest Gross Domestic Product in the entire region and lacks adequate infrastructure and

political control to sustain the growing needs of the country. The country's arid environmental conditions strain the available environmental resources, especially water, leading the entire region into an era of constant drought and insecurity. The constant arid climate is magnified by climate changes and desertification, making freshwater access a constant challenge for Yemeni people.

Urban areas are particularly vulnerable to water shortages because of high population density. Sana'a, Yemen's capital and the densest urban area in the country, faces constant water scarcity and issues of poor management. The country has a relatively weak central government system, preventing enforcement of policy measures to aid in public water management (Hovden, 2015). Yemen's inadequate and unsustainable water infrastructure, including the reliance on depleting groundwater aquifers and infiltration of contaminated water, dramatically contributes to Sana'a's water insecurity. Social and political conditions within Yemen, such as the localized social power structure, civil unrest and violence, and the national addiction to the water-intensive stimulant "Khat," all further worsen the water scarcity and threaten the stability of the region.

Yemen's Social Organization

Specifically related to public water law and management in Yemen, responsibility and power is considered a region-specific issue due to the "tribal social structure" that shapes the political landscape "based on the collective responsibility and accountability of tribal leaders (sheikhs) to their communities" (Al-Sabahi & De Santis, 2016, p. 56). Experts in Yemen water management find that this local "tribal" organization is an important variable which may cause a group to either defy or accept broader water management laws, further complicating efforts towards political stabilization and achieving peace (Mis, 2015).

This regional water organization is intertwined with traditional principles of the Islamic system, also known as *ala'ala-fa-ala'ala*, a principle that gives “upstream land senior irrigation rights over downstream land” (Al-Hamdi, 2000, p. 3). This principle is applicable when managing fresh surface water, including rivers, lakes, and streams. However, due to Yemen’s arid physical geography and climate, Yemen relies on groundwater aquifers for 70% of the water supply, in which cases *ala'ala-fa-ala'ala* would not apply (Al-Weshali, et al., 2015, p. 216). Groundwater is an equally distributed resource because it is below ground and any successful well can reach the aquifer, whereas surface water makes access unequally distributed due to geography proximity near the water source. “Islamic principles treat [groundwater] as a communal property with a possibility of private ownership under special circumstances,” according to Yemen water expert Mohamed Al-Hamdi’s dissertation titled “Competition for Scarce Groundwater in the Sana’a Plain, Yemen: A study of the incentives for urban and agricultural water use.” Spatial constraints regarding water access and distribution are reified by the localized system of power and social structure, challenging any potential national policy reform regarding water management.

The tribal social structure, grounded in the power of the sheikh, is reified as “people lose faith in government institutions” from unstable national authority, control or services. Accordingly, 65% of Internally Displaced Persons within Yemen choose to find safety or conflict resolution through their local leader. When international aid organizations intervene to provide resources or

services to these displaced populations, these groups often rely on the regional social structure through “approval of sheikhs” before intervening in the local communities (Alsabahi & Desantis, 2016). However, this can lead to an uneven distribution of needed resources, as illuminated by a study undertaken by Oxfam and published by the Yemen Community Engagement Working Group. In the study, 48% of respondents felt that humanitarian aid in Yemen was not reaching the most vulnerable populations. Arguably the most vulnerable or marginalized populations, such as the elderly, mentally disabled, or illiterate people, have difficulties accessing information about humanitarian assistance and consequently accessing the direct assistance.

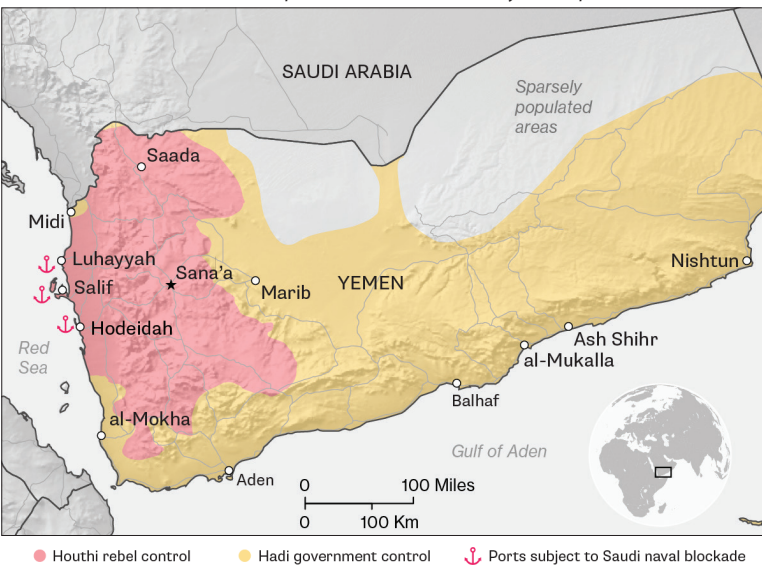
Identifying the most vulnerable groups in Yemeni society is even further complicated by continuous societal discrimination towards certain minority groups. These marginalized groups, which often do not belong to a more organized “tribe” or have a sheikh, are overlooked when aid organizations come into the country to offer humanitarian assistance. Because these minorities often have no organizational leader or group, either due to their informality or institutional discrimination against them, they have no credible or informed representative to advocate for them while navigating the international aid process (Alsabahi & Desantis, 2016). This further exacerbates social inequality and prevents aid from reaching the most at-risk groups in Yemen.

Yemen’s Civil War and Political Turmoil

Similar to many other countries in the region, Yemen is facing an intense water crisis with effects magnified by several political and cultural factors. The country is currently in the midst of a proxy civil war between Saudi Arabia and Iran being fought on Yemen soil. The Saudi forces support the current Yemeni President Hadi, while Iran supports Houthi rebels (Asia News Monitor, 2018). In addition to this regional political tension being fought in Yemen between Saudi Arabia and Iran, the al-Qaida in the Arabian Peninsula (AQAP) and Islamic State (IS) have manipulated the regional instability and established a haven for terrorist activity and deadly attacks (Asia News Monitor, 2018). These violent quarrels exacerbate social inequality and increase the vulnerability of environmental management on a local and national scale. Instability leads to the lack of distribution of resources/public facilities, which can lead to private entities taking advantage of the situation through privatization, public resource deprivation, and the black market. When these critical resources are taken away, civilians often turn to the violence out of desperation, necessity, and security.

The tribal organization of Yemen is also influential when dealing with land and water disputes, which contributes to regional, smaller, and more frequent spurts of violence. The

Figure 1: Map of Yemen showing the front lines of the war. (by the American Enterprise Institute’s Critical Threats Project as of 01/02/2018; source: <https://www.bloomberg.com/news/articles/2018-02-22/who-s-to-blame-for-pestilence-near-famine-in-yemen-quicktake>)



Government of Yemen estimates that this type of violence “results in deaths of some 4,000 people each year,” and probably contributes to “more [fatalities] than the secessionist violence in the south, the armed rebellion in the north, and Yemeni al-Qaeda terrorism combined” (Hales, 2010, p. 2). These conflicts have historically catalyzed collective, more organized violence, threatening stability in the greater public arena. In the context of Yemen urban areas, especially areas where new land developments are taking place, “disputes over ownership of, or access to, natural resources such as land and water” have become the “most prevalent type of social violence” (Hales, 2010, p. 2).

The conflict over water is strongly associated with land issues, due to control over sources of surface water and particular territory that accesses upstream water. “Dam construction... channel ‘improvements’” and other man-made alterations of the water infrastructure can “interfere with delicate social balances” due to the fragility of the diverse communities and their interrelationships (Hales, 2010, p. 3). Pre-existing environmental conditions like low levels of rainfall and lack of permanent rivers intensify these concerns even further.

However, due to the increase in groundwater withdrawal over the last thirty years, access to the underground aquifer has become a more critical territorial resource. Property owners, including domestic, industrial, and agriculture users, have continued to dig deeper wells in order to ensure their own share of the aquifer’s water (Al-Hamdi, 2000). Yemen’s constitution “declares all natural resources to be a state property” but “the absence of a detailed legal framework, the lack of proper institutional setup to administer and manage water resources, and the weak capacity of the government to implement and en-

force water-related policies” prevent further action from being taken (Al-Hamdi, 2000, p. 72). This has contributed to a conflict “among well owners drawing water from the same aquifer... lead[ing] to a ‘race to the bottom,’” contributing to rapid land subsistence and threatening the potential for renewable recharge of the aquifer (Hales, 2010, p. 4). These factors related to competition and conflict over water resources are further detailed in Table 1 below. These cumulative factors, including a weak political system and a tribal social organization, constant regional violence, and arid climatic conditions make Yemen’s current situation “the worst humanitarian crisis in the world” (Asia News Monitor 2018), the United Nations claims.

Sana’a Current Water Supply and Public Infrastructure

Yemen is one of the most water-scarce countries, compared both to other countries in Southwest Asia and also on a global scale. “The annual per capita availability of freshwater is 120 m³, which is only about 10 percent of the regional [Middle East] average” of available freshwater, meaning Yemen’s freshwater is only 10% of the national average of other surrounding neighbor countries like Saudi Arabia and Oman. Internationally, this water availability is “less than 2 percent of the global average” (Hales, 2010, p. 3). Yemen also has no permanent rivers, making water availability continually fluctuating with the season and resultantly inconsistent.

Due to lack of available surface water, groundwater aquifers are the primary source of water for urban areas and agricultural irrigation in Yemen, which together make up 70% of the total water use (Al-Weshali, et al., 2015; p. 216). The national rate of depletion of groundwater is twice the recharge, meaning that

Table 1: Factors transforming water competition into conflict. (Hales, Muggah & LeBrun, 2010)

Factor	Explanation
Predictability of flow	More predictable flow creates the conditions for consensus about resource management; spate events give rise to intense stress and conflict.
Number of users	Large shared systems generate more potential for stress as individual control diminishes.
Visibility	Surface water flows are easier to measure and manage, but being visible may quickly give rise to conflict; groundwater sources are not.
‘Symmetry of cause and effect’	More direct competition between individuals is more likely to trigger conflict than, for example, depletion of groundwater affecting a broad community.
Power relations	Large power imbalances between winners and losers tend to mitigate conflicts.
External interference	The state, donors, and others can trigger conflict when they interfere with existing water management practices or ignore the management and maintenance implications of new infrastructure projects.



Figure 2: A woman carries jerrycans to fill with water from a charity tap in Sana'a. (CCTV/Facebook; source: <https://www.middleeastmonitor.com/20171121-2-5m-lack-access-to-fresh-clean-water-in-yemen-says-red-cross/>)

the groundwater supply is not being renewed at a sustainably sufficient rate and will have significant long-term environmental consequences once the groundwater depletes to the point of no recharge.

Yemen established a domestic infrastructure to aid water management by founding the National Water Resources Authority (NWRA), the Ministry of Agriculture and Irrigation, and the Ministry of Electricity and Water (Al-Hamdi, 200, p. 3-4). In 2002, the Sana'a Water Basin was "designated as one of the five critical basins" within Yemen. The National Water Resources Authority even established a Sana'a Branch in 2003 to directly implement water resources management for the Sana'a Basin region (JICA, 2007, p. 1). Although the establishment of these government-backed water and water-associated institutions was a great improvement for Yemen's water infrastructure, their execution is limited and generally unsuccessful. These companies "only supply some households in the major cities and 70% of Yemenis live in rural areas" (Whitehead, 2015); however, with a growing global trend towards urbanization, these demographics will shift towards growing urban populations.

Insecurity is even more magnified in Sana'a, the country's capital city and the most stressed water basin in the country. Because of the lack of surface water, the basin's reliance on groundwater (especially in the last several decades) has increased exponentially. The city's growing population places extra strain on the water supply, with a predicted basin population of 6.06 million by 2025 (Al-Hamdi, 2000, p. 4). The Tawilah aquifer provides all water needs for the Sana'a basin. Water usage in the city increased rapidly "after the identification of the Tawilah aquifer in 1972 and the establishment of the NWRA" (Al-Hamdi, 2000,

p. 6). This trend was illustrated by the following; "the number of wells in the basin went up from a few hundred in 1973 to around 6000 wells in 2001, and 8000 wells in 2009... the water balance of the Sana'a Basin indicates [extractions] to be five times higher than recharge" (Al-Weshali, et al., 2015, p. 221). If the region continues to extract water at a constant rate, predictions state that the "total usable storage would be depleted within 32 years" (Al-Hamdi, 2000, p. 5).

This dramatic and concerning reality in Sana'a, due to the public infrastructure's financial limitations, lack of sufficient water supply, and the high demand for a water municipal system within the urban area, have led the National Water and Sanitation Authority and other government agencies to agree to provide an "intermittent" water system to "maximize its coverage and implement a policy of equitable access to water" (Al-Hamdi, 2000, p. 30). However, even with these efforts towards improvement, only 40-50% of houses in Sana'a are connected to the public water supply (Al-Hamdi, 2000). The existing pipe network is estimated to lose up to 60% of the water due to leaks (Whitehead, 2015), and the "systematic low pressure in the system...and the local topography" contribute to a system that fails to accomplish its goal of equally supplying every part of each zone of the city (Al-Hamdi, 2000, p. 30). The weak central government in Yemen prevents any substantial improvement of urban water management, infrastructure, or policy.

Consequently, the city is reliant on private suppliers to provide the remaining water demand. The most common and predominant form of private water is "tanker supplies." The process consists of a tank owner, who is also the middleman and profit-maker, purchasing water from a well-owner. The tank owner sells the water for a much higher price, which is often defended by "the high cost of operation and maintenance of the truck and... the long hours of waiting to sell a tanker load" (Al-Hamdi, 2000, p. 30). The water is stored in household ground tanks to "bridge the unreliable 24 hour-cycle supply," although this water is presumed by consumers' to be "poor contaminated quality," creating yet another commercial opportunity for clean drinking water in Sana'a (Al-Hamdi, 2000, p. 30).

In the Sana'a basin, the agricultural sector produces Khat, grapes, and vegetables, all of which require intensive irrigation, using 85% of the groundwater extraction in this specific water basin of Yemen (Al-Weshali et al., 2015, p. 221). Many Khat farmers use "expensive pipes and plastic tubes" to direct water from the underground aquifer to the Earth's surface, rather than earthen channels (Al-Hamdi 2000: 100). The farmer's expensive investments in more advanced and intensive infrastructure are "driven by the limited supply" given many shareholders may all be extracting water from a single well. Farmers justify this more "extensive use of pipes" by claiming to "minimize conveyance

losses associated with the use of earthen channels" (Al-Hamdi, 2000, p. 100).

Additionally, Sana'a's geography and environmental conditions pose challenges for water management. The city is located 2,300 meters above sea level, which complicates getting access to water from rural places considering Yemen's poor infrastructure and difficult geography (Hovden, 2015). William Cosgrove, a Middle East water resources expert and former World Bank specialist, claims that Sana'a's problems are more complicated than just an aquifer running out of water, "but also that the city is hundreds of kilometres from the sea and has no alternative water supply" (Mis, 2015). This geographic landlock puts the city at odds to find creative solutions to water scarcity.

Incorporating Global Water Management in Sana'a

Global water management schemes often target developing nations with extreme water insecurity. In this case, Sana'a received funding from the World Bank to "solve the groundwater problem in agriculture," also known as the Sana'a Basin Water Management Program (Ward, 2015, p. 98). By signing onto this project in 2003, Yemen "committed itself to a long-term process [to transition to] Integrated Water Resource Management" (Ward 2015: 98), an intersectional phenomenon of water management and globalization being pushed by many intergovernmental organizations, especially the World Bank. By signing onto this program, Yemen is taking substantial strides towards becoming a more globalized and incorporated city, for better or for worse.

Integrated Water Resource Management (IWRM) is touted as "arguably the most influential global paradigm in water governance" (Newig & Challies, 2013, p. 440). The program views "fragmented and disjointed" water management through sector agencies as the major barrier preventing sustainable water governance. IWRM acknowledges and incorporates "underlying social and environmental drivers of change in planning" which influence water sectors, such as agriculture, energy, industry, municipal supply, and ecosystem management and preservation (Newig & Challies, 2013, p. 440). The three pillars of sustainability, including social equity, economic growth, and the environment, are incorporated into the IWRM strategy. Critics of IWRM argue that these concepts are intertwined with debates regarding "public versus private governance" and water as a commodity versus public good and human right (Newig & Challies, 2013, p. 440). The overall global consensus regarding IWRM is that its impacts are "at best marginal," with a recorded 20 out of 95 countries reporting "formal implementation" of its principles (Newig & Challies, 2013, p. 440).

The Sana'a Basin Water Management Program was budgeted and financed for a full 15-year implementation. Phase 1, which

included testing technology, analyzing supply and demand approaches to management, and organizational infrastructure, lasted from 2003-2010. After this phase in the program, the national governance began to plan for and implement the program by setting up political infrastructure, assessing and monitoring water resources, managing public awareness campaigns, and implementing measures for regulation (Ward, 2015).

Particularly regarding infrastructure, efforts towards enhancing water supply included improving structures for groundwater recharge, education on sustainable water management and improving the efficiency of water usage within agricultural "Water Users Associations," and investing in better technology like regional water pipelines and drip irrigation systems (Ward, 2015). Besides, technical support regarding water efficiency and irrigation productivity were provided to farmers. Results proved that these strategies towards limiting water use pumped 40% less water yet still increased incomes by 10 percent (Ward, 2015). This first phase of the program, which piloted IWRM approaches in Sana'a, demonstrated their success. Unfortunately, continuation and progress towards expanding the program have been put at a halt (possibly due to the political instability), which has prevented the transition to the official "2nd and 3rd phases" (Ward, 2015), despite the expired 15-year time frame of the program. Integrated Water Resource Management through the Sana'a Basin Water Management Program was limitedly successful in its preliminary efforts, but its lack of complete execution leaves Sana'a in an interim and uncompleted status of development.

Groundwater Contamination in Sana'a

Sana'a is faced with issues of water scarcity, distribution, and contamination regarding surface and groundwater. The latter issue is one that directly threatens all water resources, both above and below ground, which the urban area of Sana'a is reliant on. This is in large part due to the poor or completely lacking public waste infrastructure in Sana'a. It is not simple to "remediate" or re-clean water to its original state once it has been polluted. The consequences of contaminated water are far-reaching, creating "health problems for human beings and animals, deterioration of farmland (e.g. lowering the yields of crops), and adverse impact on the environment" (JICA, 200, p.: 13). Water contamination is even more threatening in developing countries, as "outbreaks of waterborne diseases usually associated with gastrointestinal symptoms and increasing carcinogenicity created by certain organic chemicals" enters the main water supply, having widespread implications in public and environmental health (Al-Hamdi, 2000, p. 52).

Sana'a's current waste management is limited and poorly run; a public sewage system covers 29% of the population in urban

areas. This sewage system utilizes a wastewater treatment facility, which “drained directly to an open channel.” Unfortunately, many uneducated farmers use this waste discharge for irrigation purposes, which poses a health risk and threatens the produce and fresh vegetables grown for Sana’a’s urban population. As a consequence, the National Water and Resource Authority of Sana’a Basin has “started to raise awareness among farmers not to use the drained water.” Unused water has “infiltrated into the ground...and the quality of groundwater downstream of the treatment plant has become worse” (JICA, 2007, p. 3). Domestic wastewater can also contaminate groundwater through “widespread use of on-site disposal facilities, leakage from sewer lines or infiltration from treatment facilities such as oxidation ponds” (Al-Hamdi, 2000, p. 50).

Approximately 75% of the population does not reach the public sewage network and relies on the cesspit, an underground pit that holds liquid waste and sewage, as their primary form of waste disposal (Al-Hamdi, 2000; p.50). In the case of heavy rain flow, rainwater overflows the cesspit and spreads contaminated water in previously clean areas. Cesspits have also proven to pollute the groundwater by infiltration through the soil, which threatens the safety and hygiene of the entire reliable water supply that Sana’a depends on. In Sana’a, “several hundred private wells” were proven to be affected by sewage contamination (JICA, 200, p. 12). This contaminated water in Sana’a’s central inner city area has a nitrate concentration two to three times higher than the “permissible limit for drinking water” according to the World Health Organization’s health standards (JICA, 2007, p. 13). Cesspits also threaten to disturb the pre-existing National Water and Sanitation Authority distribution network of sewage, particularly in identifiable areas more vulnerable to cesspit clogging and collection of wastewater in ponds (Al-Hamdi, 2000).

There is also concern regarding inadequate waste disposal in petrol stations, car service shops, medical units, and industry, mostly due to the lack of wastewater treatment facilities for these establishments. The disposal of wastewater from these sites is assumed to be uncontrolled, unregulated, and within the discretion of individual stakeholders (JICA, 2007, p. 13). This potential contamination poses a public health risk for those exposed to or in proximity to these establishments.

Government Subsidies and Limited Groundwater Supply

The Yemen government has little control over managing the extraction of groundwater. Government policy incentives, such as diesel subsidies, encourage well extraction, effectively stimulating inefficient and unsustainable water use for irrigation. These incentives are still prevalent and continue to magnify the consequences of poor water management (Al-Weshali et al., 2015).

Due to the Yemen government subsidization of fuel, private interests cheaply power water pumps (causing it to over-extract) and make a profit by selling it privately. Private entities drill new unregulated wells geographically near public ones, which threatens the groundwater supply and creates a privatized black market for water resources (Hovden, 2015). These private agencies are also well aware that the public infrastructure in Yemen is not able to support itself and its reinforcement and maintenance is lacking or non-existent. These private companies can manipulate the water prices due to their monopoly over the scarce resource and overcharge the impoverished and desperate urban Yemeni community.

The Yemen government has also placed a financial subsidy on “imported grains” which has pushed out the grain industry and creates a national reliance on outsourced cereal crops. This shift in cropping pattern has led to the more intensive cultivation of “water-demanding cash crops, particularly Khat, grapes, and vegetables” which depletes the domestic water supply faster than grain crops (Al-Hamdi, 2000, p. 109). This import subsidy also lowered the national market price of cereals in Yemen, resulting in grain cultivation that “covers less than 5% of the agricultural land in the basin” (Al-Hamdi, 2000, p. 85).

Environmental Consequences of Khat Addiction

Although there are natural constraints based on Yemen’s geography and physical environment, other factors such as cultural norms, government behaviors, political unrest, and policy decisions are escalating and magnifying the water shortage. The widespread habit of chewing low-stimulant “khat” is just one of these factors contributing to water scarcity in Sana’a (Hovden, 2015). The drug is a “full-blown national addiction” with “90% of men and 25% of women regularly chewing the leaves” (Butters, 2015). Chewing khat is considered the country’s primary form of socializing, given that the predominantly Muslim population is banned from consuming standard drugs or alcohol.

Culturally, Khat influences the Yemeni population in several ways. It encourages “complacency” about the government failings. Furthermore, Khat contributes to an unproductive work environment because it “keeps the country awake,” which enforces staying up late and sleeping in, and pushes establishments to open much later in the day (Butters, 2009). The effects of Khat delays the urgency that must be ignited to create widespread societal change. It also leads to exclusionary “khat ceremonies” which reinforces gender inequality. On the other hand, it can also be attributed to keeping people calm during situations of crisis, which happen quite frequently during a Civil War, and also “keeping them off the streets” (Butters, 2009). These unintended consequences of heavy Khat use could be a significant reason why the country is struggling in so many

ways, and staying away from the substance might be part of the solution towards shaping a positive future for Yemen.

A regular user's daily dose of Khat costs approximately five US dollars. Considering the extreme poverty and other more pressing needs of the growing population, it is quite astounding that so much of the population is still consistently purchasing and chewing khat. Most families spend more money on Khat than on food (Butters, 2009). The Khat market demand allows for cultivator's to spend excessive amounts of valuable water to grow the plant, and the profits make it worthwhile for the farmers. The standard "annual income of a Qat [Khat] farmer...is more than twice the national average of per capita income" (Al-Weshali et al., 2015, p. 223) and "certainly provides a steadier income than growing vegetables" (Butters 2009). Because this habit is widespread in Yemeni culture, its usage is uncontrolled and continually provides demand in the market.

Growing Khat, "a shrub whose young leaves contain a compound with effects similar to those of amphetamines," requires intensive and routine irrigation (Butters, 2009). The Sana'a Basin is environmentally optimal conditions for Khat cultivation. "The plant thrives in the high hill country" and "is easy to grow and harvest." To cultivate Khat fields successfully, they must be "flooded twice a month" and consequently consume approximately 30% of the national water supply (Butters, 2009). These agricultural techniques are sucking the limited water from Sana'a's Basin which could be used in other capacities to maximize the utility of the precious resource.

According to Al-Weshali et. al.'s article Diesel Subsidies and Yemen Politics: Post-2011 crises and their impact on groundwater use and agriculture, around "85% of [national] khat production comes from five governorates located only in the highlands region of the country" including Sana'a's greater water basin (Al-Weshali et al., 2015, p. 223). Khat agriculture "is estimated to cover around 1/3 of the total area" in Sana'a" (Al-Hamdi, 2000, p. 5). Groundwater extraction for Khat cultivation is often shared or split between many shareholders invested in one well. Although this "network of shareholding" may clash with the regional "tribal structures" which shape the social landscape, the possibility for "improve[d] awareness and facilitat[ed] collective action to reduce water abstraction" are potential areas of improvement regarding sustainable groundwater management (Al-Hamdi, 2000, p. 107). A hydrologist and local director of a German technical-assistance advising team for water management, argues that on a national level, quitting khat would double the amount of household water available, a remarkable potential improvement given the already-threatened water supply (Butters, 2009).

The national Khat addiction feeds into the increasing water scarcity in the region due to its high demand and costly irri-

gation requirement. The drug limits educational initiative to change the way things are in Yemen - and helps people mentally cope with their often violent or impoverished surroundings. Nonetheless, this tradition is creating widespread complacency for societal issues, creating a norm of unproductivity and unmotivation which hinders change, while also prioritizing water to go towards Khat irrigation instead of more necessary social needs like running water and food.

Looking Forward, Possible Solutions

Future water supply options for Sana'a will be organized into two categories, either in-basin water resources or out-of-basin alternatives. Regardless, Yemen's national government should clearly define water ownership and water use rights. This could be achieved through the "establishment and enforcement of both boundary and authority rules," which would clarify and identify access to groundwater (by halting the continuous increase in pumpers taking from the aquifer). Establishing authority rules would "reinforce [the political] boundary" and its scope in Yemeni society (Al-Hamdi, 2000).

Some in-basin options include "enhance[d] utilization of rain-water, intra-basin transfer... reallocation of water from agriculture to municipal use, and utilization of unconventional water resources" through wastewater reuse (Al-Hamdi, 2000, p. 45). Another proposed solution to addressing Sana'a's water crisis is for the local municipality to purchase well-water that would've gone towards agriculture or private companies. This would be a cheaper alternative compared to shipping water in from abroad. However, it would require political reform and changes to Yemen's constitution (Whitehead, 2015).

Out-of-basin or "imported water" options consist of inter-basin or regional transfers of surface water from various sources such as Surdud, Marib, or the Red Sea (Al-Hamdi, 2000). However, developing the infrastructure to execute this and the costs associated with inter-basin water transfer "face high costs that range from 1.7 to 6.4 times higher than the current expensive option of private tanker supply" (Al-Hamdi, 2000, p. 45). Specifically regarding out-of-basin alternatives, "political, social, legal and technical" barriers should also be taken into account.

Public education to promote lower water use in farming communities could also help reduce the risk of water insecurity in the future. "Better agricultural extension, introduction of water-saving technology, and information assistance to shift to other crops" are all valid and productive ways to reduce water use. Eventually, the Yemen government should "seek to invest in an alternative economic base" rather than relying on the current water-based economy (Al-Hamdi, 2000, p. 107).

Yemen has immense disadvantages. It is in a region of the world facing geopolitical conflict, lack of government control, and growing populations. These factors magnify the pre-existing regional water scarcity, which is impacting every country in the Middle East, but particularly Yemen. The capital of Yemen, Sana'a, is one mega-urban area threatened by water insecurity. Sana'a is currently reliant on a groundwater aquifer which is rapidly depleting and becoming contaminated. Cultural factors, such as tribal organization and national addiction to Khat, prevent policy initiatives from successfully mitigating future water shortages and obstacles. On a global scale, Yemen is a country in dire need of international support and guidance. While these issues facing Sana'a threaten regional stability, it also serves as an opportunity for potential productive change through positive Yemeni leadership and outside actors to help Yemen out of its humanitarian crisis.



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