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Water at the intersection of human rights and conflict: a case study of Palestine

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The global water crisis presents a multifaceted challenge intersecting with human rights and conflict, particularly evident in regions like Palestine. This study delves into the intricate dynamics of water scarcity in Palestine, with a specific focus on the Gaza Strip. The scarcity of water resources has a profound impact on agriculture and the economy, leading to increased food insecurity as a result of insufficient water availability for irrigation. Furthermore, the unequal distribution of water resources between Israel and Palestine perpetuates the crisis, with Israeli settlements consuming a disproportionate share compared to Palestinians. This research also highlights the widespread issue of water discrimination, where Israeli policies systematically restrict Palestinian access to water resources, thereby exacerbating existing disparities. In the Gaza Strip, the challenges are particularly severe, with a staggering 89% of the population lacking access to safely managed drinking water services. Addressing the water crisis in Palestine necessitates concerted efforts to enhance water security, safeguard water quality, and uphold the fundamental rights of the population. Collaborative initiatives are essential to alleviate the plight of communities in Gaza and across Palestine, ensuring equitable access to this vital resource and fostering sustainable development.

KEYWORDS

water scarcity, human rights, Gaza, Palestine, hydropolitics, water quality, water discrimination, sociohydrology

1 Introduction

Water does not adhere to administrative boundaries or political rules but instead obeys the laws of nature, such as the hydrologic water cycle and hydraulic principles. While these natural principles govern water movement, access to water has become a fundamental human right and critical global challenge. Modern world is confronted with significant water challenges that arise from the unjust and inequitable distribution of water resources. This inequitable distribution has severe humanitarian implications, as unsafe drinking water and inadequate sanitation facilities lead to water-related diseases that account for a significant number of deaths in the developing world (Salman, 2014). The right to water, explicitly recognized by the United Nations General Assembly in Resolution 64/292 (2010), emphasizes the fundamental importance of equitable access to clean and safe water for all individuals, regardless of political boundaries. The UN defines safely managed water as a continuous supply of uncontaminated water delivered directly to every household. This includes improved sources such as piped water, protected groundwater sources, rainwater harvesting, and packaged or delivered water that are accessible on premises, available when needed, and free from contamination (Bain et al., 2020; Humphrey et al., 2020).

Water structures have played a vital role in the history of Palestine. A publication predating the formation of Israel notes that Jerusalem possesses numerous ancient channels and subterranean passages, with origins tracing back to periods preceding the reign of Alexander the Great (Simpson, 1891). The significant labor invested throughout the ages becomes evident when observing the multitude of preserved structures, including ancient aqueducts, tunnels, pools, and cisterns, found throughout the Holy City of Jerusalem and its vicinity (Masterman, 1902).

The Palestinian water crisis exemplifies and exceeds global challenges in enforcing water rights, particularly in conflict-affected regions. While 71% of the world population has access to safely managed water services, only 59% of Palestinians have similar access. This disparity is particularly acute in Gaza, where just 11% of the population has basic water access, compared to 95% in the West Bank. This crisis is further underscored by the global context: approximately 2.2 billion people worldwide lack access to safely managed drinking water services, with fragile states averaging 26% lacking such access. Yet Gaza's situation is significantly worse, with 89% of its population deprived with safely managed water (UN, 2020). This stark disparity highlights how political conflicts exacerbate water security challenges beyond typical global patterns, making Palestine's case a critical example for understanding the intersection of water rights violations and geopolitical constraints worldwide. This intersection is particularly evident in Palestine, where historical water infrastructure reflects centuries of development.

The current water crisis in Palestine exemplifies the profound impact of political conflict on water rights and access. Since the occupation began, Palestine has faced severe consequences, including resources scarcity, contamination, rapid population growth and limited job opportunities. These factors have created significant environmental hazards, with water scarcity and declining water quality posing major challenges to Palestine's economic development (Shomar, 2011). The complexity of water challenges extends beyond basic scarcity.

Palestine, particularly Gaza, contends with groundwater depletion due to overextraction, seawater intrusion exacerbated by rising sea levels, and contamination from untreated wastewater and agricultural runoff. Today, Israel exerts complete control over all transboundary water resources in Palestine, denying Palestinian sovereignty and perpetuating water insecurity. This control has led to severe disparities in water access. While the total Palestinian population is roughly half that of the Israeli population, Palestinian water consumption is only 10–15% of that of Israeli settlers (UNDP, 2006). On average, Palestinians consume approximately 82 liters of water per day, compared to 320 liters per day for Israelis (PWA, 2023). This unequal distribution of resources has been described as hydrologic apartheid or hydro-hegemony (Zeitoun, 2008, p. 2). It significantly impacts domestic water consumption, public health, agriculture, and food sovereignty in Palestine (Al-Shalalfeh et al., 2018).

The water challenges in Palestine vary significantly across its geographical regions, with Gaza and the West Bank facing distinct issues. The Gaza Strip confronts particularly severe challenges, with 89% of its population lacking access to safely managed drinking water services, making it the most challenging region in the Middle East for water accessibility (UN, 2020). While the West Bank physically borders the Jordan River, Palestinians are denied access to this vital water source. In Gaza, geographically isolated from the Jordan River system, the population relies entirely on its coastal aquifer, which faces severe over extraction and seawater intrusion. The West Bank's water challenges primarily arise from restricted access to aquifers and springs, while Gaza's crisis is exacerbated by its isolation, high population density, and deteriorating infrastructure. These regional distinctions profoundly shape both the nature of water scarcity and the potential solutions required to address the crisis in each area.

The implementation of water rights in Palestine faces significant obstacles under the current political conditions. Land and water disputes are central to the ongoing conflict between Palestine, other Arab nations, and Israel (Kuttab and Ishaq, 1994). These disputes manifest in specific restrictions. Palestinians face limitations on drilling new water wells, installing pumps, and deepening existing wells. Additionally, they are denied access to the Jordan River and freshwater springs. Israel exercises authority over rainwater collection in most of the West Bank, often leading to the destruction of rainwater harvesting cisterns owned by Palestinian communities (Amnesty, 2017).

The impact of water access restrictions is particularly severe in Gaza, where population density compounds the challenges. Gaza is recognized as one of the most densely populated regions in the world with approximately 6,019 individuals per square kilometer as of the end of 2022. This density is significantly higher than the population density in the West Bank, which stands at around 569 individuals per square kilometer (PCBS, 2023b). The majority of Gaza's population consists of refugees displaced from other occupied territories in Palestine. This intense population concentration has given rise to numerous social, economic, and political difficulties, along with environmental degradation, inadequate infrastructure, and health-related concerns (Shomar, 2011).

Previous research has documented various aspects of this water crisis and its human rights implications. Many studies have reported Israel's interference with Palestine's surface and groundwater resources, as well as the severe implications of conflicts on water quality. Nijim (1990) explored the historical dimensions of the Palestine-Israel conflict and its influence on the availability of water resources in the area. Elmusa (1998) conducted an analysis of the Johnston Plan, evaluating its shortcomings, and offering recommendations for the plan to move toward a unified management system in the Jordan Basin. Isaac (2000) focused on the management of water resources in Palestine and Israel, shedding light on the unequal distribution of water consumption and the importance of addressing Palestinian water rights. Abu Zahra (2001) conducted an analysis of the water crisis in Palestine, specifically focusing on quantifying the total and per capita water shares of various countries within the Jordan River Basin (JRB) area. The study also considered factors such as surface and groundwater reserves and the overall water demand. Allan (2002) concentrated on the water resources of JRB, with a specific emphasis on the region's water scarcity and historical conflicts. The findings highlighted the potential politicization of water resources in cases where there is an unequal distribution of power, such as in Israeli water management. Shomar (2011) shed light on the consequences of Israeli aggression on the surface and groundwater resources in the Gaza Strip, addressing the associated challenges of water quality, quantity, and other humanitarian issues. Khoury (2013) conducted a comprehensive study on the water resources and infrastructure in Area C and the West Bank, examining the governance, legal frameworks, and regulations pertaining to water

Abbreviations: Mm^3, Million meter cubes; lcd, liters per capita per day.

structures. Niksic et al. (2014) investigated the connection between Area C and the economic development of the West Bank, exploring the possible direct and indirect benefits related to sectors such as agriculture, minerals, mining, construction, tourism, telecommunications, and cosmetics. Beltrán and Kallis (2018) emphasized the necessity of further exploring the interconnection between water, trade, and agriculture, highlighting how Israel's trade control resulted in its dominance over the virtual flow of water. Their research delved into the virtual water movement in the agricultural sector of Palestine after the Oslo Period, revealing the Israeli hegemony in managing Palestinian agricultural virtual water. World Bank Group (2018) emphasized the marginalized and vulnerable state of water security in the West Bank and Gaza, underscoring the need to prioritize water security in the region. Amnesty (2009) provided a detailed analysis of the water crisis in the Occupied Palestinian Territories, emphasizing the unequal distribution of water resources, Israel's enforcement of military edicts to obstruct Palestinian access to water, and the deliberate targeting of water facilities by Israel in the conflict-ridden region.

Building on this research foundation, this study provides an integrated analysis of water rights, resource management, and human security in Palestine. While extensive research has examined water scarcity in various regions, the complex intersection of water rights, geopolitical constraints, and human security in Palestine presents a unique case requiring detailed analysis. Recent global studies have highlighted how climate change impacts water security differently across arid and semi-arid regions (Jain et al., 2024). This study advances current understanding by providing comprehensive analysis of water accessibility under complex geopolitical constraints, extending beyond typical climate change and resource management frameworks. Unlike other regional analyses, our research examines the unique intersection of water rights violations and human security in Palestine, where over 79% of surface and groundwater resources are under external control. Furthermore, this study examines the intricate network of water-related issues, notably by uncovering the correlation between water resources and the geopolitical influence wielded by affluent nations over less privileged regions.

This study addresses three fundamental research questions that guide our analysis: How do geopolitical constraints impact water accessibility and management in Palestine, particularly in Gaza? What are the relationships between water rights violations and human security outcomes in the region? And how do current water management practices affect socioeconomic development and public health in Palestinian territories? By examining these questions, the study offers an integrated analysis of water rights, resource management, and human security in Palestine.

This study adopts a comprehensive analytical framework utilizing authoritative data sources such as the Palestinian Central Bureau of Statistics (PCBS), Palestinian Water Authority (PWA), and Palestinian Meteorological Authority (PMA) databases. Complementary data from international organizations like the World Bank, United Nations Development Programme, and various humanitarian agencies enriche the analysis. Maps were created using ArcGIS 10.8.While these datasets are publicly available, our study's novelty lies in their systematic integration to examine the intersection of water rights violations, resource management, and human security implications. The study employs a descriptive analytical approach, examining water security challenges through three main focus: historical documentation of water access and control, empirical analysis of current water availability and consumption patterns, and assessment of human rights implications. The analysis draws on established principles of water rights as defined by UN frameworks and international humanitarian law to analyze how access to water intersects with human security and development in conflict-affected regions. This study integrates historical records, demographic data, hydrological measurements, and climate statistics to provide a multi-faceted examination of water security challenges. Contemporary water consumption patterns and resource allocation data are analyzed alongside historical trends to understand the evolution of water accessibility issues. Our analysis specifically focuses on the period from 1967 to 2023, capturing the critical timeframe when the current water crisis emerged and intensified following Israel's control of water resources from the Jordan River to the Mediterranean Sea. This period encompasses key developments including increased restrictions during the 1990s and the deterioration of conditions in Gaza after 2007 due to blockade conditions.

2 Study area

2.1 Short history and conflict in the region

The Amalekites, considered the ancestors of the Arabs, were the earliest known settlers in the land of Palestine around 5,000 BC. They were followed by the Canaanites, Phoenicians, and Arameans who migrated to the region. Around 1,200 BC, the Jewish people led by Moses conquered a significant portion of the area, establishing their own state. This era witnessed remarkable periods of prosperity, particularly during the reigns of David and Solomon. However, in 63 BC, the Roman Empire took control of Palestine. From 395 onwards, Christianity began to spread throughout the region. In 629, Emperor Heraclius brought all Palestinian territories under Byzantine rule. From the time of Caliph Abu Bakr until 641, the entire region fell under Muslim rule. Subsequently, it became a province of the Abbasids, and in 1079, the Seljuk Sultanate of Syria-Palestine was established. The Crusaders gained dominance in 1099, but in 1187, Saladin restored Islamic rule. Finally, in 1516, the Ottoman Empire, under Sultan Selim, assumed authority over Palestine until 1917 (Karaman, 1996; Karaköse, 2018).

After 1917, the region came under the administration of the United Kingdom as the British Mandate, established by the League of Nations and lasting from 1917 to 1947 (UN, 2023). The issuance of the Balfour Declaration in 1917, advocating for the establishment of a national home for the Jewish people in Palestine, marked a significant milestone in the history of the Israel-Palestine conflict. Following this declaration, Jewish settlers, who had previously inhabited Palestine in scattered communities, began to assert their rights on the international stage and initiated organized migration activities within Palestinian territories. In 1947, the UN terminated the British Mandate and proposed the partition of Palestine into two separate independent states, for Arabs and Jews, respectively (UN, 2023). After 1948 Arab-Israeli war, the Jews has captured around 77% of Palestine, including large part of Jerusalem (UN, 2023). The day of May 15, 1948, holds great significance as it is remembered as Nakba (catastrophe) for the Palestinians and celebrated as Independence Day for Israel (Sokolower, 2023). Following the Nakba, the West Bank came under Jordanian

control, and Gaza was controlled by Egypt (Onion et al., 2023). In 1967 6 Day War, the Israeli forces occupied the overall Palestine including West Bank, Gaza and Jerusalem. After the war, the UN issued a call for the withdrawal of Israeli troops from the occupied territories of Palestine. The UN Security Council Resolution 242 declared the illegality of acquiring territory through war and emphasized the importance of striving for a fair and enduring peace in the Middle East, where all states in the region can live securely (UN, 1967).

The region witnessed the eruption of the First Intifada (Palestinian Uprising, 1987) as a response to Israel's prolonged oppression, sparking widespread protests and violence until 1991. In an effort to address the conflict, a peace conference was organized in Madrid with neighboring countries participating. However, between 2000 and 2005, the situation further escalated during the Second Intifada, overshadowing any prospects for peaceful dialogue (TRT World, 2019). In October 7th, 2023, the Israel-Hamas War erupted following the Al-Aqsa Flood Operation conducted by Hamas. This led to the Israeli occupation of Gaza and a planned genocide activity. The people residing in Gaza find themselves in an arduous struggle for survival, confined to refugee camps characterized by extremely poor health and hygiene conditions. This dire situation is primarily attributed to the persistent closure of Rafah, the only border crossing between Gaza and the Arab world, by Egypt, as well as Israel's prevention of international aid access to Gaza. Figure 1 presents the key historical time points that mark the conflict in the region during the last century.

2.2 Location

Situated in the eastern part of the Mediterranean Sea, Palestine serves as a pivotal link between the continents of Asia and Africa (Figure 2). Over the past century, the territorial expanse of Palestine has undergone significant reduction. Originally spanning approximately 27,000 square kilometers, historic Palestine witnessed a drastic reduction following the Arab-Israeli conflict in 1948, with Israel occupying approximately 78% of its landmass. Consequently, only remnants of the original territory remain, comprising the "West Bank" and the "Gaza Strip" with a combined area of <6,000 square kilometers (see Figure 2). The West Bank, positioned to the west of the Jordan River, covers an area of around 5,600 square kilometers. However, this region is heavily fragmented due to the presence of Israeli settlements, resulting in disjointed communities across various urban centers, villages, and refugee camps (Yousef, 2004). On the other hand, the Gaza Strip, situated along the Palestinian coastal plain, occupies an area of approximately 365 square kilometers. Bordered by Egypt to the south, the Green Line to the north, the Negev desert to the east, and the Mediterranean Sea to the west, Gaza's geographical coordinates lie between 34°2″ and 34°25″E longitude, and 31°16″ and 31°45″N latitude (Abualtayef et al., 2017).

2.3 Climate

Palestine's climate acts as a transition zone between the arid, desert climate of the Sinai Peninsula and the temperate, semi-humid climate of the Mediterranean (Yousef, 2004). The occupied Palestinian territory experiences distinct seasons, characterized by rainy winters and dry summers, with rainfall patterns varying across the region (Khoury, 2013). Average annual rainfall measures approximately 460 mm in the West Bank and 356 mm in the Gaza Strip (PWA, 2023). Notably, rainfall distribution across the West Bank exhibits significant diversity. Northern areas near Jenin and Tulkarm receive as much as 800 mm of rainfall, while southeastern regions bordering the Jordan River and Dead Sea receive as little as 100 mm. The varied climates within the occupied Palestinian territory have historically supported the cultivation of a diverse range of grains and fruits. This agricultural diversity has been sustained by the region's climatic heterogeneity. Figure 3 illustrates the annual average rainfall, temperature, and relative humidity distribution across several Palestinian districts for the year 2018.

2.4 Population

According to statistics from the World Bank (2023), the combined population of the West Bank and Gaza exceeds 5 million people. Since the 1850s, there has been a notable influx of Jewish immigrants into Palestine, predominantly from Eastern Europe (Figure 4). The migration of Russian Jews gained momentum starting from 1882, further accelerated by the rise of the Nazis in Germany in 1933. By the onset of World War I, approximately 120,000 Jews resided in Palestine, with Jerusalem serving as their primary hub (Karaköse, 2018). Between 1931 and 1940, the Jewish population in Palestine experienced a significant surge, soaring from 174,606 to 456,743 due to intense immigration (NPG, 1941). McCarthy (1990) indicates that the proportion of Jews in Palestinian lands was approximately 3–5% between 1850 and 1921, with a sharp increase observed after 1922, reaching 11.5%. Following the establishment of Israel in 1948, the Jewish population surpassed the

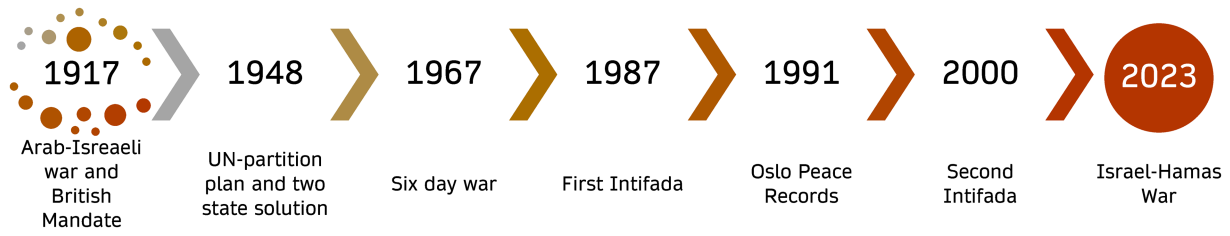

FIGURE 1
Key events in the Palestinian–Israeli conflict from 1917 to 2023.

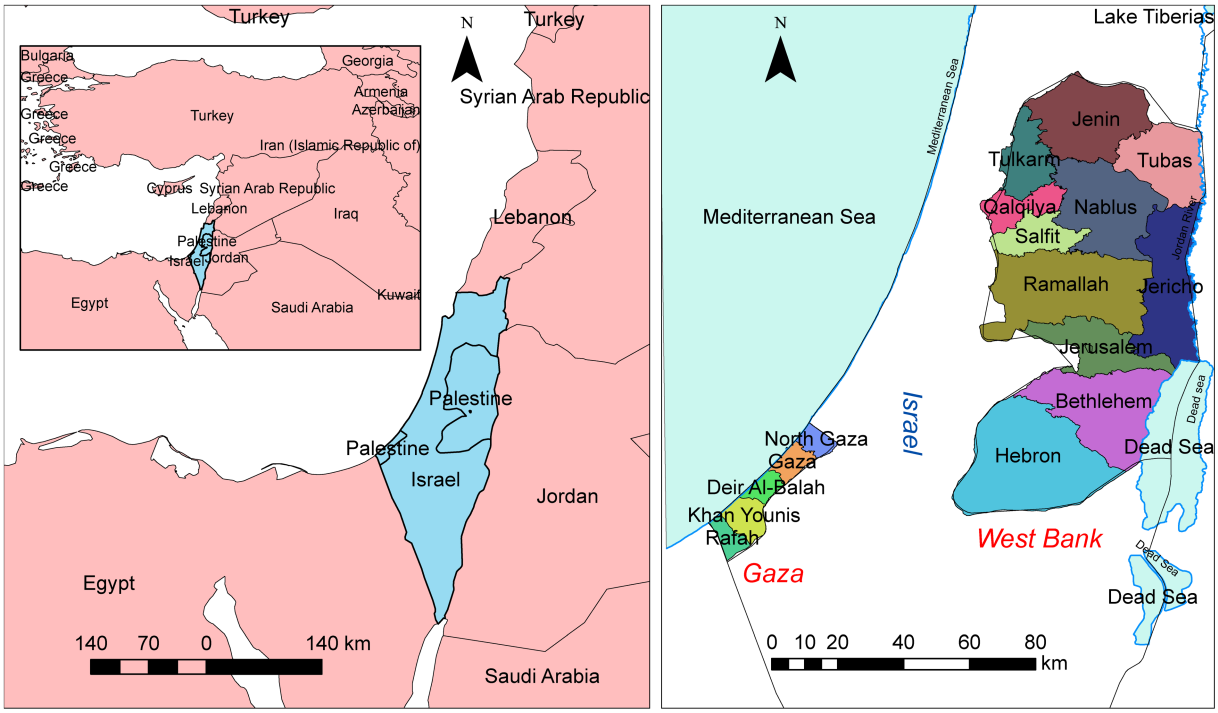

FIGURE 2
Location of the study area.

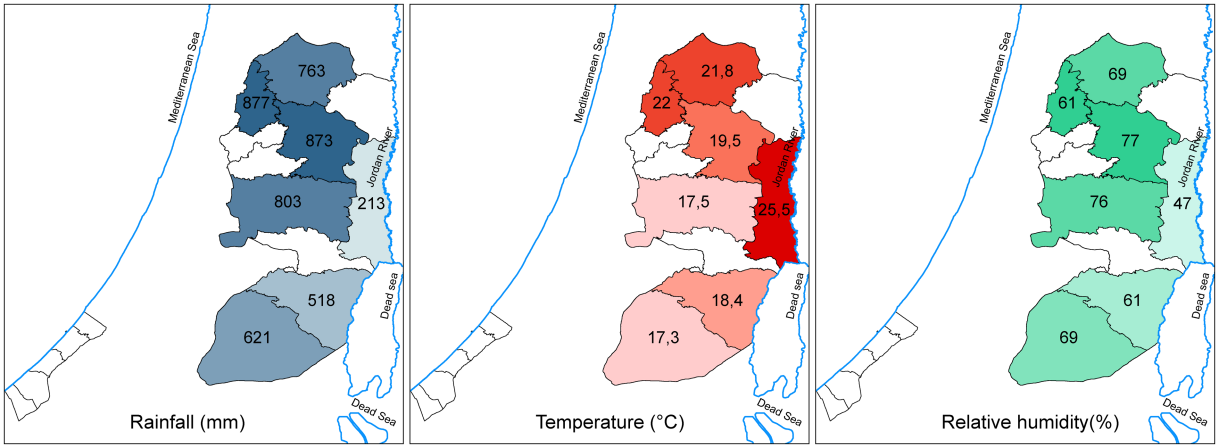

FIGURE 3
Annual average climate parameters of some Palestinian districts [Data is based on 2018 records by PMA (2018)]. In the figure areas with no color represent the absence of available data.

original Palestinian population, as reported by the UN (2023). The aftermath of the 1948 conflict resulted in the expulsion or displacement of over half of the population in occupied Palestine, according to UN records. Similarly, during the Arab-Israeli war in 1967, around half a million individuals were displaced from their lands. The Palestinian population has experienced natural growth as a primary factor contributing to its increase, while emigration activities have had a significant negative impact. In contrast, the Israeli population heavily relies on immigration. Data from the Palestinian Central Bureau of Statistics (PCBS) indicates a significant rise in the number of Israeli settlements in the West Bank (Figure 5). The quantity of settlements increased from one in 1967 to 151 settlements by 2022. As of 2022, the overall population of Israelis residing in the West Bank is estimated at approximately 745,000 (PCBS, 2023a). Additionally, the estimated number of Palestinians residing outside the Palestinian territories is approximately 6.43 million in Arab countries and 0.76 million in foreign countries (PCBS, 2023b). Notably, as of the end of 2022, only about half of the total Palestinian population resides in the West Bank and Gaza, primarily due to emigration (PCBS, 2023b).

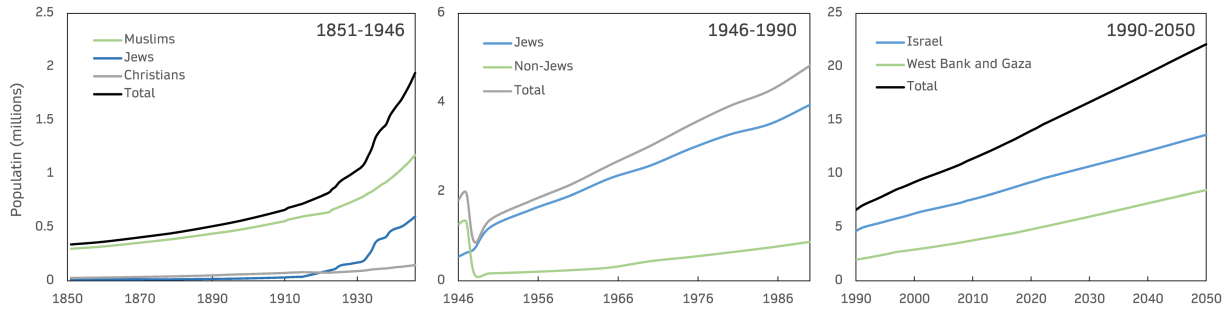

FIGURE 4
Historical population statistics in Occupied Palestine Territory and Israel [The 1851–1946 data is based on McCarthy (1990), the 1946–1990 data is based on JVL (2023), the 1990–2050 data is based on World Bank (2023)].

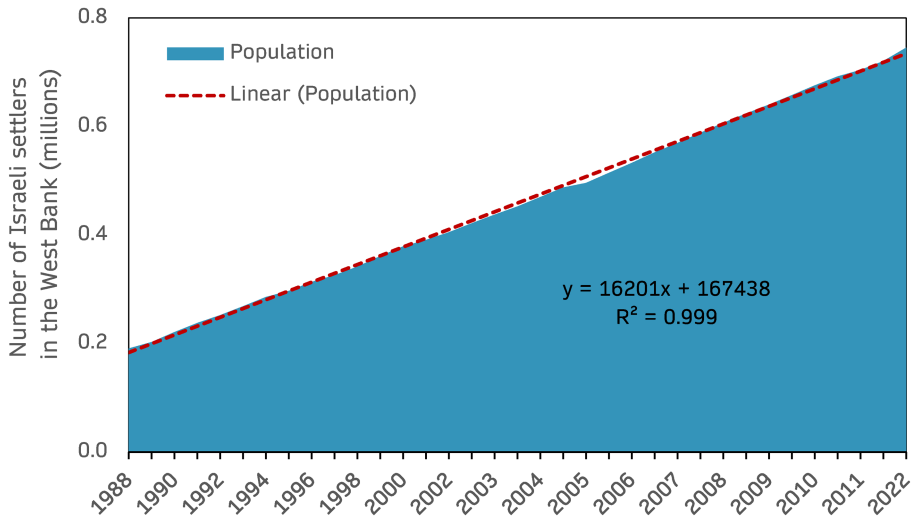

FIGURE 5
The number of settlers in the Israeli settlements in the West Bank [Data is based on PCBS (2023a)].

2.5 Water resources in the Jordan River basin

The Occupied Palestinian Territory is located in one of the most water-deprived areas globally (UNDP, 2006). The water requirements of Palestine and riparian countries are primarily met by the Jordan River Basin (Figure 6). This basin is a significant area for water-related conflicts involving Syria, Israel, Lebanon, Jordan, and Palestine (Fisher and Askari, 2001). While the West Bank physically borders the Jordan River, making Palestine a riparian state, Palestinians have been unable to access this water source. This restriction particularly affects the West Bank, where the Jordan River could serve as a vital surface water resource. Gaza, separated geographically from the Jordan River system, relies solely on its coastal aquifer. Among all nations in the basin, Palestine has the lowest per capita water allocation (Abu Zahra, 2001).

According to Isaac (2000), prior to 1967, only 3% of the Jordan River basin fell within the boundaries of Israel. However, after the occupation in 1967, Israel took control of all water resources in the newly acquired territories, establishing exclusive authority over the water resources stretching from the Jordan River to the Mediterranean Sea (B'Tselem, 2023). Additionally, Israel's occupation extended to the Golan Heights, a strategically significant region located upstream in the Jordan River Basin, characterized by its fertile land (Abu Zahra, 2001). The implementation of Israeli practices in the Jordan River Basin has resulted in a significant decline in the annual discharge of the river Jordan, dropping from 1.3 billion cubic meters to <30 million cubic meters (Al-Shalalfeh et al., 2018).

2.6 Water availability in Palestine

The overall water availability in Palestine is estimated to be around 448 Mm^3 (Figure 7), with groundwater contributing approximately 79% of the total supply (299.1 Mm^3), a percentage that remains consistent at around 80% across different years. Palestinians are forced to purchase 20% of their water needs from the Israeli water company (Mekorot) amounting to around 90 Mm^3 annually. The remaining water is obtained from springs (53.3 Mm^3) and through desalination (5.7 Mm^3).

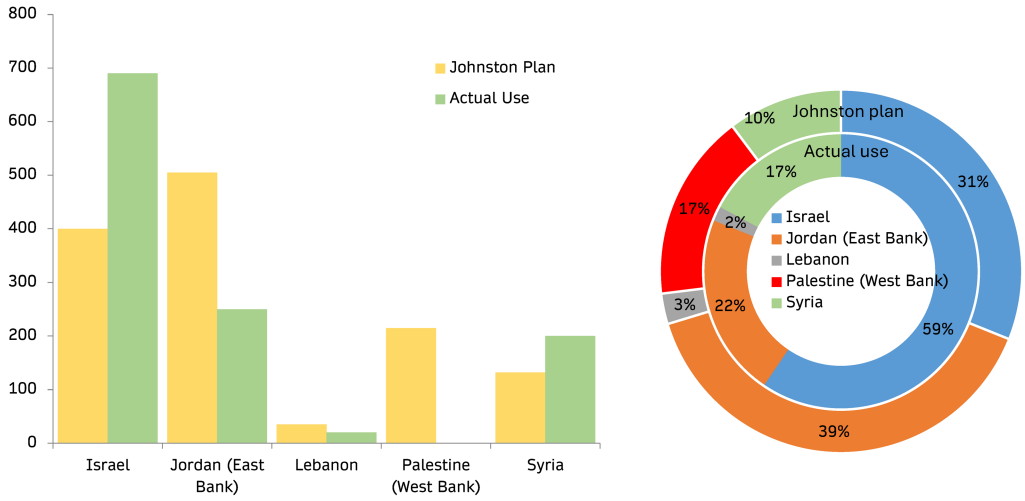

FIGURE 6
The allocation of water resources of JRB through the riparian countries [Data is based on Elmusa (1998)].

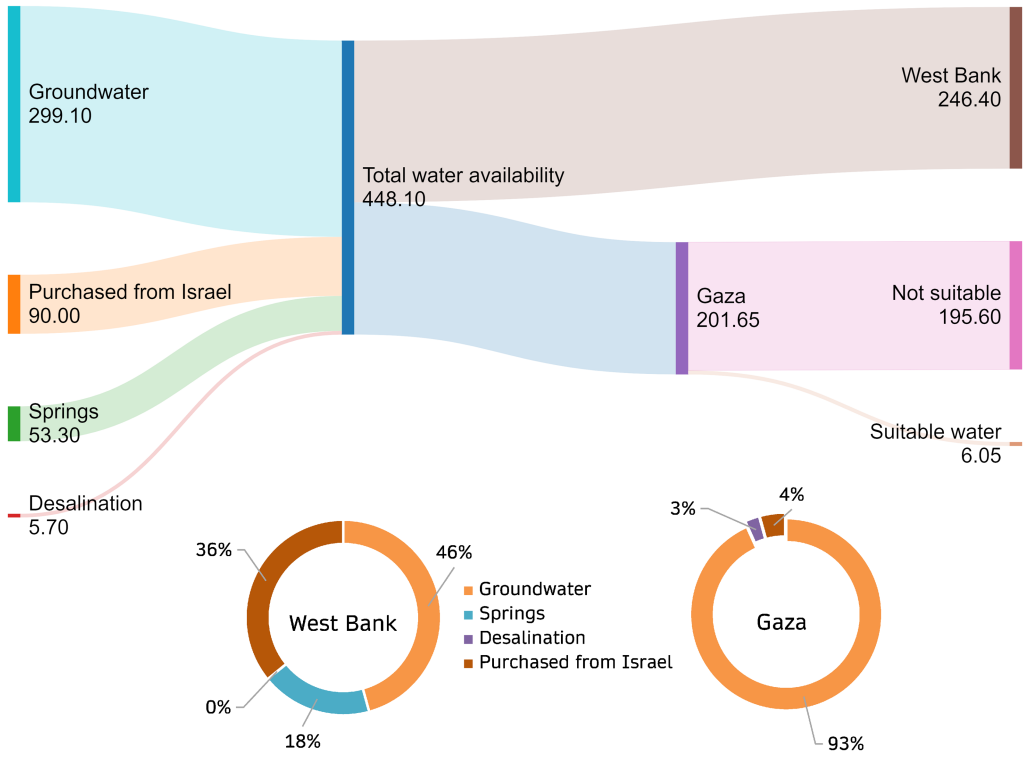

FIGURE 7
Water availability and allocation of Palestine (Mm^3) [Water availability data is based on PCBS (2022); Source share data is derived for 2010–2021 averages reported by PCBS (2021)].

Groundwater plays a crucial role in meeting the water needs of Palestinians. The main source of the groundwater is the Mountain Aquifer, which is primarily recharged by the mountainous regions in the West Bank (Isaac, 2000). However, Israel consumes a significant amount of this water resource through direct pumping from a considerable number of wells, exceeding 300 in total (Isaac, 2000). The UNDP (2006) states that roughly 13% of wells owned by Israeli settlers extract approximately 53% of the total groundwater.

The Mountain Aquifer is subdivided into three aquifers: the eastern, northern, and western. However, only 7.5% of the Western Aquifer System is utilized by Palestine, which heavily depends on precipitation in the West Bank (Isaac, 2000). In 2022, Palestinians in the West Bank extracted approximately 100.8 Mm^3 of water from

these aquifers (PCBS, 2022). In the Gaza strip, the coastal aquifer serves as the sole water source, with an estimated annual renewable capacity of 50–60 Mm^3/year (PCBS, 2022). However, the extraction rate from this aquifer is around 190.5 Mm^3/year (in 2022). Extensive documentation reveals a significant decline in the groundwater level of the Gaza coastal aquifer, leading to alarming sustainability issues. The rate of extraction from this aquifer exceeds its recharge rate by approximately threefold (Figure 8), thereby negatively impacting the 2 million Palestinians who rely on it for their water needs (Abualtayef et al., 2017).

3 Water challenges in Palestine: the struggle for access and control

3.1 Historical water politics and management

Water resources have historically played a central role in regional politics and management strategies. Described in biblical texts as a land flowing with milk and honey, Palestine's water resources have played a pivotal role in territorial expansion and settlement (Nijim, 1990; Karaman, 1996).

Following the British capture of the Holy Land, led by General Allenby, efforts were made to secure water sources to support military operations. The American army, collaborating with engineering units, embarked on the task of tapping into the "Sweet Water Canal" originating from the Nile, after intense clashes with Turkish forces in Gaza. This endeavor involved laying pipelines over an 80-kilometer stretch from the Kantara pumping station to supply water to the troops stationed in Gaza. Interestingly, although these pipelines were initially intended for oil transportation, they were repurposed for water conveyance (Carson, 1919).

The establishment of water management systems in Palestine underwent several historical phases. With the establishment of the British mandate in 1922, Jewish settlers prioritized water management schemes to support agricultural development (Isaac, 2000). Notably, a comprehensive plan was devised to harness the water resources and irrigation potential of the Jordan River Basin, formulated by hydrologist M. Ionides under British auspices. This plan laid the groundwork for the United Nations Partition Plan for Palestine in 1939, underscoring the centrality of water in territorial delineation (Isaac, 2000).

Subsequent initiatives, such as the Johnston Plan, also known as the Jordan Valley Unified Plan, emerged in 1955 under the mediation of American special ambassador Eric Johnston. Aimed at resolving water conflicts among riparian states within the Jordan River Basin, this plan proposed water allocations, diversion schemes, and the establishment of a joint commission, reflecting efforts to address the intricate interplay of water resources and regional politics (Elmusa, 1998).

The dynamics of water governance shifted dramatically after the 1967 war, as Israel assumed control over the water and land resources of the West Bank and Gaza Strip. This transition led to the conversion of the West Bank Water Department (WBWD), initially established by Jordan in 1966, into a mechanism for distributing water to Palestinian settlements under Israeli authority (Khoury, 2013). Consequently, Israel gained full dominion over the water resources of the Jordan River Basin, with the natural assets of these territories falling under Israeli military control.

Despite the recognition of Palestinian water rights in the Oslo II agreement, the transfer of responsibility for water management to the Palestinian Authority failed to adequately address future population needs (Khoury, 2013). This failure stems from specific governance mechanisms that maintain Israeli control. A key instrument is Military Order 158, which requires Palestinians to obtain permits from Israeli military authorities for any water infrastructure development or maintenance, while exempting Israeli settlements from similar requirements. The Joint Water Committee, established under Oslo II, further institutionalizes these restrictions by giving Israel veto power over Palestinian water projects. Moreover, collaboration between Israel and the Palestinian Authority has been strained, resulting in a heavy reliance on Israel for water supply in the West Bank. Israeli control over shared water resources, including the coastal aquifer, persists, perpetuating disparities in water access between Israelis and Palestinians (Beltrán and Kallis, 2018). Contemporary studies on Israeli-Palestinian water relations emphasize the enduring challenges and inequities in water

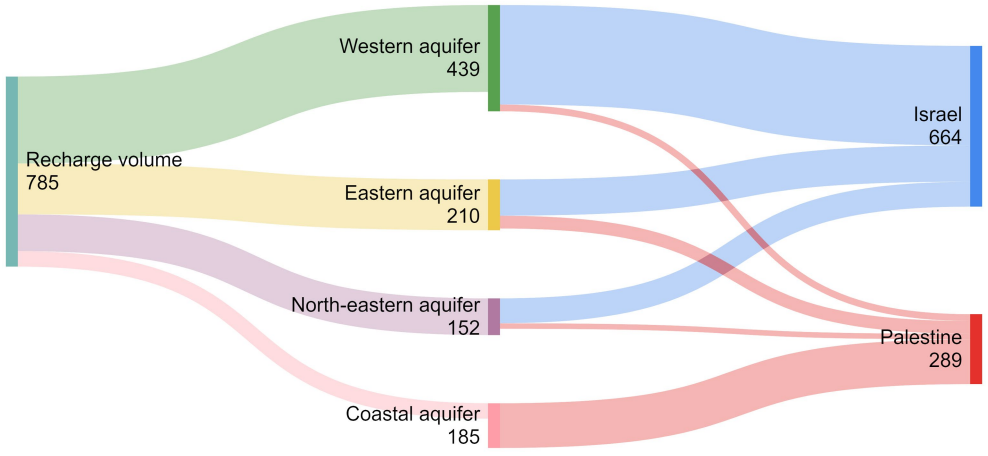

FIGURE 8
Water abstraction volumes (Mm^3) from the aquifers in the West Bank and Gaza by Israeli and Palestinian population [Data is based on PWA (2013)].

governance. Research by Beltrán and Kallis (2018) underscores the disproportionate power dynamics entrenched in the Oslo negotiations, consolidating Israel's hegemony over land and water resources in Palestine. The implementation of these control mechanisms involves a complex permit system where applications for Palestinian water infrastructure projects face lengthy delays or outright rejection. This bureaucratic framework effectively limits Palestinian water development capabilities while maintaining Israeli authority over resource allocation (FAOLEX, 2022). Similarly, Klawitter (2007) argues that the Oslo II agreement failed to substantially alter Israel's control over water resources, perpetuating disparities in access and allocation. Moreover, recent studies highlight Israel's restrictive policies, such as Military Order 158, which severely curtail Palestinian access to groundwater and impose bureaucratic hurdles on water management (FAOLEX, 2022).

The evolution of water governance in the region has significantly shaped current management challenges. Since 1990, Palestinian access to water has faced substantial restrictions imposed by Israel. Furthermore, Israel's dominance over water resources transitioned from direct physical control to a more pervasive hegemonic influence. This shift was accompanied by the delegation of authority over water management to the Palestinian Water Authority, albeit under Israeli supervision (Zeitoun, 2008; Al-Shalalfeh et al., 2018).

3.2 Current water consumption patterns

Water consumption in Palestine is characterized by significant regional variations and access limitations (Figure 9). Palestine struggles with a notable lack of access to safe drinking water services, with only 39.5% of the population having reliable access. Even among water-stressed Middle Eastern nations, this represents an exceptionally low rate of access. Neighboring countries like Jordan (84.0%) and Lebanon (77.0%) maintain significantly higher access rates despite facing similar regional water scarcity challenges. This disparity highlights how Palestine's unique political constraints compound natural resource limitations while other nations have been able to develop water infrastructure and management systems, Palestine's ability to implement similar solutions remains severely restricted by external control over water resources and infrastructure development (PCBS, 2023c). Furthermore, a stark contrast in water access exists between the populations of the West Bank and Gaza Strip. In the West Bank, 86.5% of the population enjoys the convenience of piped water directly into their homes. However, in Gaza, this percentage plummets significantly to just 4.1% (PCBS, 2023b). These comparisons emphasize the uniquely challenging situation in Palestine, where socio-political constraints, prolonged occupation, and environmental factors have compounded to create a water crisis more severe than in many similarly affected regions. This broader perspective highlights the critical need for targeted interventions in Palestine, drawing lessons from global experiences (World Bank, 2023).

The distribution of water consumption reflects broader regional disparities. The Gaza Strip confronts severe water challenges. Safely managed drinking water services are lacking for about 89% of the population, making the Gaza the most difficult region in the Middle East in terms of water accessibility (UN, 2020). Public taps provide water to only around 10.8% of the population, while a significant 69.7% population heavily rely on tanker trucks for their water supply (PCBS, 2023b). Bureaucratic barriers further compound water access challenges for vulnerable populations. The permit system for water infrastructure development particularly affects refugee camps, where maintenance and improvements face significant administrative hurdles. These restrictions, combined with reliance on private water vendors, create a disproportionate economic burden on refugee camp residents, especially women-headed households who often have the least resources to navigate both administrative and financial barriers.

Water demand projections through 2032 indicate increasing challenges (Figure 9), with consumption expected to rise approximately 8.4% every 5 years due to population growth and urbanization (Mukhairez and Al-Halees, 2018). These projections from the Palestinian Water Authority suggest that without significant changes in water access and management, the gap between availability and demand will widen, particularly in already water-stressed regions like Gaza Strip and refugee camps. These projections can guide policymakers in prioritizing investments and interventions to bridge the widening gap between water availability and demand. For example, early implementation of infrastructure development and sustainable water management practices could mitigate future water scarcity issues and ensure more equitable access across different regions.

Current consumption data reveals stark contrasts in water usage patterns. In 2020, the per capita daily water consumption was reported to be approximately 82.4 liters in the West Bank and 86.6 liters in the Gaza Strip (PCBS, 2022), while the average Israeli person consumes around 240–300 liters of water (UN, 2020). However, due to pollution and associated risks, the amount of freshwater suitable for human consumption in the Gaza Strip is reported to be only 26.8 liters per day (PCBS, 2022). These consumption patterns are directly influenced by water allocation policies. For instance, Jordan's advancements in wastewater reuse have significantly mitigated water scarcity, demonstrating the potential for similar approaches in Gaza, provided political barriers are addressed. Lebanon's community-led water projects exemplify how grassroots initiatives can strengthen local water governance, a model that could be adapted to Palestinian communities.

The distribution of water availability parameters in Palestine at the district level is depicted in Figure 10. The data shows that in several regions, including the densely populated area of Gaza, water consumption rates are significantly low, particularly in Hebron and Bethlehem. The lack of access to water and high water demand in these regions can be attributed to the high population, limited water supply, and absence of surface water resources. The average per capita water consumption rates in Bethlehem and Hebron are approximately 55 liters per day, which only covers the basic human needs such as drinking and sanitation, excluding food production.

In 2021, the municipal water supply was limited to 3 days a week, leading many residents to purchase drinking water from private suppliers, which imposes a financial burden to the inhabitants (Humaid, 2023; Salem and Ertz, 2023). Particularly during the summer months, approximately 2 million individuals residing in the Gaza Strip face a critical water deficit (Salem and Ertz, 2023).

3.3 Water quality challenges and public health

The dire water situation in Gaza poses a significant threat to the health and wellbeing of its population, particularly children. Many studies aim to shed light on the alarming state of water quality in

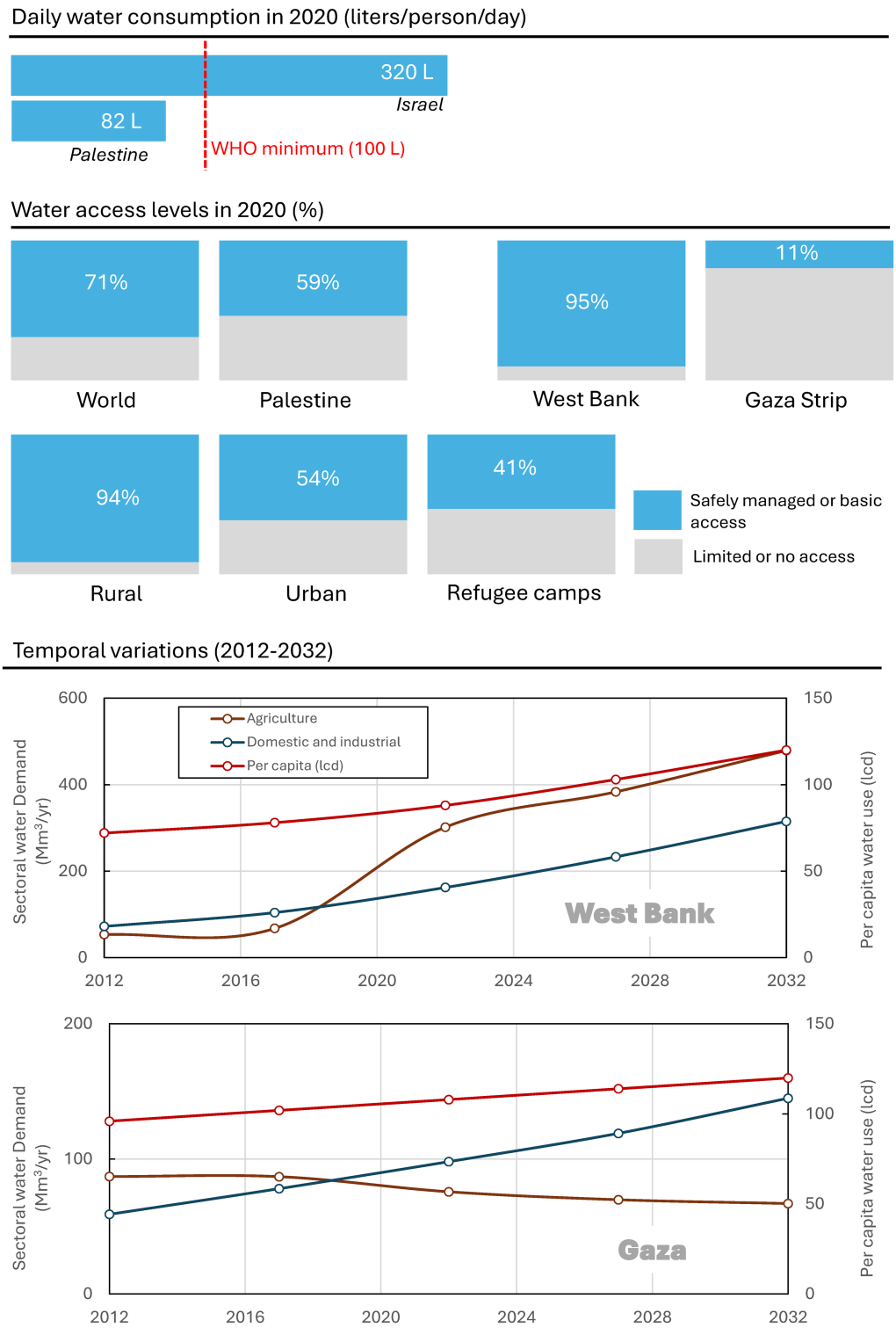

FIGURE 9
Water access and consumption disparities in Palestine [Daily per capita water consumption comparison between Israeli settlements and Palestinians against WHO recommended minimum (PCBS, 2023a); multi-level comparison of water access: global vs. Palestine (World Bank Group, 2018), regional disparities between West Bank and Gaza Strip, and access variations by settlement type (PCBS, 2023b). The safely managed water access indicates continuous supply of uncontaminated water delivered directly to households (WHO standards). The temporal variations and future projections are based on PWA (2012)].

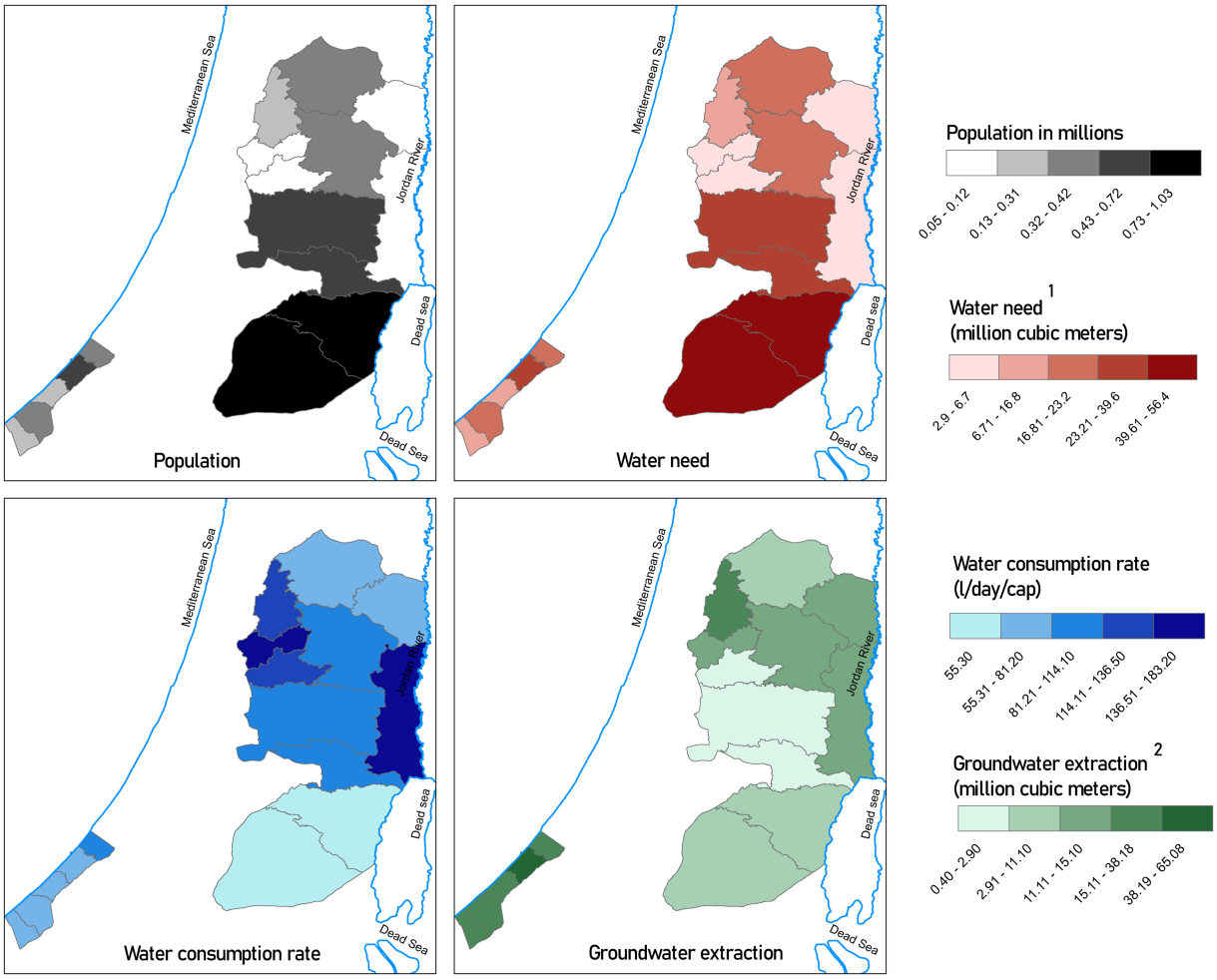

FIGURE 10
District based annual water availability and consumption patterns in Palestine [The data is based on 2021 statistics by PCBS (2021)]; [1]The water need is determined by the per capita water supply of 150 liters per day, following the standards set by the WHO; [2]Groundwater extraction to the Gaza Strip is estimated based on the population share.

Gaza, a crisis that demands urgent attention. Shomar (2011) has underscored the inherent vulnerability of Gaza's groundwater quality due to its permeable soil structure, making it highly susceptible to surface contamination. Reports indicate that tap water in Gaza contains alarmingly high levels of salinity, nitrate, and chloride (Salem and Ertz, 2023), rendering it unfit for consumption according to the classification by the World Bank Group (2018). Moreover, the majority of extracted groundwater fails to meet the acceptable standards set by the WHO (Abualtayef et al., 2017), with a staggering 97% of the water in the Gaza Strip considered unsuitable for human consumption (PCBS, 2022). Consequently, waterborne diseases stemming from low water quality standards have been detected, further exacerbating the health challenges faced by the population (AbuQamar et al., 2023). Hospital records corroborate the link between water scarcity in Gaza and issues of sanitation, chemical contamination, and the presence of microbial pathogens (Shomar, 2011). In refugee camps, where water supply is inadequate and intermittent, water quality deteriorates further, leading to the presence of *E. coli* bacteria (Alazzeh et al., 2019). Shockingly, waterborne diseases account for nearly a quarter of child morbidity cases in Gaza (UN, 2020). These distressing statistics underscore the urgent need for immediate action to address the water crisis in Gaza and the broader Palestinian territories. Collaboration among policymakers, researchers, and relevant stakeholders is imperative to devise and implement sustainable solutions to ensure the wellbeing of the population.

3.4 Socioeconomic impacts of water scarcity

The Middle East is globally acknowledged as a region experiencing acute water scarcity, marked by significant deficits in both freshwater resources and soil moisture. Consequently, the economies in this area rely heavily on freshwater resources to sustain their agricultural practices, resulting in a significant inflow of virtual water through the global trade of staple food, which is similar in magnitude to the annual discharge of the River Nile (Allan, 2002).

Given the prevailing climatic conditions, irrigation plays a crucial role in agricultural production, which holds significant prominence within the Palestinian economy. The Gaza Strip and the West Bank, both identified as low-middle-income areas, face difficult geopolitical challenges that obstruct their socio-economic progress, with their economic activities heavily reliant on water resources (World Bank Group, 2018). The irrigation system remains underdeveloped, with Palestinians irrigating less than one third of the fertile land (UNDP, 2006). Hence, water security directly affects food security in the area. However, the limited availability of water resources imposes constraints on irrigation practices, thereby hindering extensive agricultural activities among Palestinians (Klawitter, 2007). Food insecurity poses a significant challenge in Gaza, making it one of the world's most food insecure regions. In the majority of areas in Gaza, the Food Insecurity Experience Scale (FIES) exceeds 50%, indicating that approximately half of the population faces moderate to severe food insecurity (UN, 2020).

Water scarcity in Palestine has profound sectoral impacts, particularly affecting agriculture, industry, and public health. High irrigation water costs and limited access to quality water resources significantly impact farming feasibility and profitability, particularly in regions like the Tulkarm district (Abu-Madi, 2009). Specific agricultural subsectors show varying vulnerabilities. The citrus sector is notable for its water use, contributing to virtual water exports, which is unsustainable given the current water crisis (Nassar, 2007). The introduction of large date palm plantations by agri-business interests has diverted water supplies from traditional sharecropping farmers, affecting their livelihoods and food security (Brooks et al., 2019). To mitigate these challenges, agricultural rainwater harvesting (ARWH) has emerged as a potential solution, with 53% of agricultural lands in the West Bank identified as highly suitable for such practices, particularly significant given that 61% of the West Bank experiences high agricultural water poverty (Shadeed et al., 2020).

Industrial development faces similar constraints. While water reallocation from agriculture to industry could offer economic benefits, such policy shifts risk further straining the already vulnerable agricultural sector (Abu-Madi, 2009). The limited reuse of treated wastewater for industrial purposes, due to inadequate infrastructure and management systems, represents a missed opportunity for alleviating water stress (Salem, 2023).

The public health implications are equally severe. Many Palestinian households receive water that fails to meet international health standards, leading to adverse health effects (Mousa, 1994; Zohud and Alam, 2022). With average per capita water consumption significantly below WHO minimum standards, these water quality and quantity issues directly impact community wellbeing (Abu Zahra, 2001).

Beltrán and Kallis (2018) shed light on the consequences of trade relations between Israel and Palestine, citing a decline in Palestine's agricultural productivity and a subsequent reduction in the agricultural sector's contribution to the overall economy. Poverty rates in Palestine paint a stark picture, with approximately 29.2% of the population living below the poverty line, according to 2017 data. The Gaza Strip bears the brunt of this economic hardship, with a poverty rate of 53%, while the West Bank exhibits a comparatively lower poverty rate of 13.9% (UN, 2020). Additionally, unemployment rates in Gaza and the West Bank stood at approximately 45.3 and 13.1%, respectively, by the end of 2022 (PCBS, 2023b).

The socioeconomic impacts of water scarcity in Palestine are not unique; similar challenges are evident in other conflict-affected regions such as Syria and Yemen. In these areas, water scarcity exacerbates existing vulnerabilities, contributing to reduced agricultural productivity, economic stagnation, and heightened food insecurity. For instance, in Syria, prolonged conflict has disrupted water management systems, leading to severe water shortages that impact agriculture and public health, much like the situation in Palestine (Gleick, 1996). Similarly, Yemen faces one of the world's most severe water crises, where decades of conflict have significantly hindered access to clean water and strained resources, resulting in high levels of poverty and poor health outcomes (Krakow, 2020). These examples highlight that while Palestine's water scarcity issues are deeply rooted in political and historical contexts, they mirror the broader patterns seen in other conflict regions. The challenge of implementing international human rights frameworks to address water inequities is evident in all these regions, where political barriers and limited infrastructure hinder effective solutions.

3.5 Water access disparities and management issues

Israel's water management practices include extraction from deep groundwater wells in the West Bank beyond the pre-1967 Armistice border (OCHA, 2015). This extracted water is then allocated (being sold) between Israeli settlements and Palestinian communities, with significant disparities in distribution. In certain regions, Palestinians lack access to water network and depend on expensive tanker water. Palestinians face restrictions on drilling wells within their own territories (Klawitter, 2007). The matter of unequal water sharing and the issue of severe water scarcity in the Occupied Palestinian Territories have also been underscored by the United Nations Development Programme (UNDP). According to UNDP (2006), water distribution from West Bank aquifers shows marked disparities: Israeli settlers consume approximately nine times more water than Palestinians (620 m^3 compared to <100 m^3) (UNDP, 2006). Current data indicates that more than 79% of Palestine's surface and groundwater resources are under external control (Yaqoub, 2023). The average per capita water availability of Palestinians is one fourth of the Israelis while the agricultural water consumption is one fifth (Khoury, 2013). This control includes consistently restricting Palestinian access to water infrastructure, tanks, wells, requiring Palestinians to purchase water (Khoury, 2013). Amnesty (2009) reports that prior to 2009, 450,000 Israeli settlers in the West Bank consumed as much or even more water than the Palestinian population of 2.3 million. Currently, certain areas in Palestine have daily water consumption as minimal as 20 liters per person, whereas Israeli settlements benefit from considerably higher water allocations, reaching up to 1,475 liters per person for domestic and agricultural needs (Al-Shalalfeh et al., 2018).

4 Water as a human right

The recognition of water as a human right draws upon integrated theoretical frameworks combining international law and environmental justice perspectives. The Inter-American Court of Human Rights (IACtHR) has played a pivotal role in this evolution,

integrating environmental protection with the human right to water. This integration provides a new normative perspective in both domestic and international human rights law, emphasizing the interconnection between human rights promotion and water resource protection (Bahia and Lima, 2022).

Environmental justice (EJ) theories further strengthen this framework by emphasizing that water justice extends beyond distribution to include cultural recognition and political participation. Water justice is deeply embedded in historical and socio-cultural contexts and inherently linked to ecosystem integrity (Zwarteveen and Boelens, 2014). The global environmental justice (GEJ) approach particularly addresses challenges of universal access to safe water, especially in areas where environmental pollution and lack of formal water provision are prevalent (Mehta et al., 2014).

The intersection of international law and environmental justice theories provides a comprehensive framework for understanding water as a human right. This integration enables new legal bases for redress and shifts discourse toward more socially just and environmentally sustainable water futures (Harris et al., 2015). Moreover, a new conceptual framework in water law that integrates environmental and human rights law is crucial for addressing global water issues while ensuring local access (Cullet, 2011). The international recognition of the human right to water necessitates that states fulfill their commitments through a human-oriented approach to water security (Avila-Garcia, 2017).

The intersection of international law and environmental justice theories in Palestine reveals unique challenges in implementation. While other water-scarce regions primarily face resource limitations, Palestine confronts additional layers of complexity where external control over resources creates barriers to applying standard water rights frameworks. This intersection of political control and resource access requires innovative approaches to water justice that go beyond traditional resource management solutions.

4.1 The role of water as a fundamental right in global agreements

The recognition of access to water as a fundamental right has evolved through complex international legal frameworks, revealing both progress and limitations in water rights protection. While the Universal Declaration of Human Rights (UDHR) did not explicitly mention water rights its inclusion of the right to an adequate standard of living implicitly acknowledged water's fundamental role in human dignity. This implicit recognition in Article 25 encompassing rights to adequate food, clothing, housing, and health established a foundation for water rights but also highlighted a critical limitation: the absence of explicit water rights protection. As Gleick (1998) argues, this indirect approach to water rights created challenges in practical implementation, particularly in regions where water access faces political constraints. Nevertheless, meeting these basic rights standards requires the provision of sufficient clean water in terms of quality and quantity to individuals.

The evolution of water rights recognition through international conferences since 1970 reveals a gradual strengthening of legal frameworks, though implementation challenges persist. The Stockholm Declaration (1972) marked a significant shift by highlighting water's intergenerational importance, expanding the temporal scope of water rights consideration. This was followed by a more concrete step in the 1977 UN Conference on Water in Argentina, where the action plan explicitly acknowledged individual rights to adequate drinking water - a crucial progression from previous implicit recognitions. The Dublin Statement (1992) further advanced this evolution by emphasizing affordability alongside access, though its practical implementation remained limited. The UN General Assembly's 1999 recognition and the subsequent Millennium Development Goals attempted to transform these theoretical rights into measurable targets, yet achieving universal access remained elusive (Hansén, 2018). This progression demonstrates how international frameworks have grown more comprehensive in principle while struggling with practical enforcement, particularly in regions facing political conflicts.

The incorporation of water rights into specialized human rights conventions demonstrates both progress and persistent gaps in protection frameworks. The "Convention on the Elimination of All Forms of Discrimination against Women" (1979, Article 14–2) and the "International Convention on the Rights of the Child" (Article 24) significantly advanced water rights by recognizing specific vulnerabilities of women and children (Arden, 2016). These targeted protections acknowledge how water access intersects with gender and age-based discrimination, though enforcement mechanisms remain weak. The 1997 UN Watercourse Convention (UNWC) attempted to address transboundary water issues by establishing guidelines for equitable allocation (Ahmad, 2020), yet its effectiveness in conflict zones where power asymmetries exist has been limited. These conventions, while expanding legal protections, highlight the challenge of translating international principles into practical access in politically complex situations.

The late 1990s and early 2000s marked a critical shift in water rights frameworks, though implementation challenges persisted. The UN (1999) "Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes" represented an ambitious attempt to universalize water access, explicitly mandating drinking water and sanitation for all (Article 6–1) (UN, 1999). However, this universal approach, while theoretically comprehensive, often proved insufficient in addressing region-specific challenges. The 2002 UN "International Covenant on Economic, Social and Cultural Rights" further refined water rights by incorporating specific criteria - adequacy, safety, affordability, and physical accessibility (Klawitter, 2007). This more detailed framework better acknowledged the multidimensional nature of water rights, yet its effectiveness remained limited in regions where political conflicts override international obligations.

The 2030 Agenda for Sustainable Development, adopted by all 193 UN member countries in 2015, represents the most comprehensive attempt yet to integrate water rights into global development frameworks. While previous agreements focused primarily on legal recognition, SDG 6 marks a shift toward measurable targets and practical implementation. This evolution acknowledges that water rights extend beyond basic access to encompass quality, management, efficiency, and integrated resource approaches (Sadoff et al., 2020). The ambitious deadline of 2030 highlights the tension between global aspirations and local realities, especially in regions where political conflicts impede progress toward water security.

The 2016 resolution "International Decade for Action—Water for Sustainable Development" (2018–2028) represents an attempt to bridge the implementation gap in global water rights frameworks. While international frameworks like the UN Watercourse Convention

and SDG 6 emphasize equitable and sustainable water management, their effectiveness is often limited by political realities in conflict zones. In Palestine, systemic restrictions on water access imposed through occupation highlight the inadequacy of these frameworks in addressing power asymmetries. Environmental justice theories advocate for culturally and politically inclusive approaches to water governance, yet their implementation remains constrained by the lack of enforceable mechanisms in international law. For instance, the Joint Water Committee established under the Oslo Accords institutionalizes inequities rather than resolving them, illustrating the disconnection between normative principles and practical realities. Comparatively, the EU Water Framework Directive's heritage-based approach offers a stronger institutional framework, yet its applicability is restricted to politically stable contexts, underscoring the need for conflict-sensitive water governance models.

The EU Water Framework Directive of 2000 offers a contrasting approach by conceptualizing water as heritage rather than commodity, establishing more rigorous protection mechanisms. Its objective is to attain high-quality water and ensure the availability of safe drinking water for the population. The directive stipulates a 15-year timeframe from its implementation to achieve good surface water status. Member States are obligated to implement necessary measures to prevent or restrict the introduction of pollutants into groundwater and prevent any deterioration of the condition of all groundwater bodies (EU, 2000). Its success in EU member states demonstrates how effective water rights implementation requires robust institutional frameworks and political stability - conditions often absent in conflict-affected regions.

The application of international water rights conventions in Palestine reveals significant systemic limitations. Despite incorporating principles of International Water Law (IWL) through agreements like the Oslo Accords, including equitable utilization and cooperation requirements, these frameworks have failed to protect Palestinian water rights effectively (Beshtawi and Cuadrado-Quesada, 2022). While the UN's general comment no. 15 establishes clear standards for the human right to water, Palestine's institutional structures struggle to meet these requirements due to political and structural barriers (Klawitter, 2007). Traditional trans-boundary water agreements prove particularly inadequate in this context, highlighting the need for joint management structures that enable continuous conflict resolution and de-nationalized water use approaches (Brooks and Trottier, 2010).

The legal framework's effectiveness is further compromised by fragmentation, where International Human Rights Law (IHRL) sometimes inadvertently legitimizes breaches of Palestinian water rights, particularly in agricultural water use (Tamarin, 2018). This situation is especially critical for stateless and displaced persons, whose water rights receive insufficient protection under current international law despite their heightened vulnerability (Krakow, 2020).

These limitations suggest the need for reformed approaches: strengthening legal protections specifically for conflict zones, implementing continuous joint management structures, and developing regional plans that expand available water resources rather than merely reallocating existing supplies (Shuval, 1992). Such reforms could help bridge the gap between theoretical rights and practical access in conflict-affected regions like Palestine.

The enforcement of Palestinian water rights through international legal instruments, while theoretically possible, faces significant practical limitations. Although mechanisms exist through the UN Watercourse Convention, human rights treaty bodies, and international humanitarian law, their effectiveness is constrained by lack of binding enforcement power. While the Fourth Geneva Convention provides for protecting civilian infrastructure and the UN Human Rights Council can issue recommendations, these instruments lack direct enforcement capability over water access restrictions or infrastructure destruction. The International Court of Justice could theoretically address water rights violations, but its jurisdiction requires state consent, making enforcement problematic in occupied territories. This gap between legal frameworks and practical enforcement demonstrates how international law, while providing normative standards, often fails to ensure water rights in situations of prolonged conflict (Brooks and Trottier, 2010; Tamarin, 2018; Krakow, 2020).

4.2 Basic requirements of humans to water

The standard recommendation for daily water intake for human beings is typically set at 3 liters. However, anything <5 liters per day is considered unsafe. It is important to acknowledge that the specific water requirements can vary depending on geographical factors and other circumstances. According to experts in the field of nutrition, adult men should aim to consume a minimum of 3.7 liters of clean water each day, while adult women should strive for at least 2.7 liters (Sawka et al., 2005). In regions with hot climates and particularly arid environments, these requirements may increase. Lactating women have a higher minimum requirement of 7.5 liters of water per day (Ahmad, 2020). The USA National Academy of Sciences predicts a range of 2–4.5 liters per day, correlating an individual's energy intake from food (Gleick, 1996).

Water is not just a necessity for drinking; its availability underpins multiple dimensions of human wellbeing, including sanitation, waste disposal, and food preparation. While Gleick (1996) identifies a minimum of 50 liters per day as a basic human requirement for essential needs, and WHO sets a higher threshold of 100 liters per day (UN, 2020), these benchmarks often fail to account for regional disparities in water availability and access. In water-scarce regions, such as Palestine, meeting even the minimum standard is an ongoing challenge due to systemic inequalities, geopolitical restrictions, and inadequate infrastructure. This highlights the inadequacy of global thresholds in addressing localized water security issues. The availability and quality of water have also significant indirect implications such as agricultural food production, energy generation, and industrial activities. The threshold for the primary water availability required for agriculture, industry, energy, and environmental purposes is assessed to be 1700 m^3/year per capita. A water scarcity threshold is breached when the per capita water availability diminishes to <1,000 cubic meters. Absolute water scarcity is defined as a per capita availability of only 500 m^3/year (UNDP, 2006). For instance, while the UNDP (2006) defines absolute water scarcity as <500 m^3/year per capita, this metric fails to consider the unequal distribution of water resources within and between countries. Such oversights disproportionately impact developing regions where agriculture consumes over 80% of available water resources, often at the expense of domestic and industrial needs. This misallocation is further exacerbated by water-intensive cash crops, which prioritize export markets over local food security.

The agricultural sector stands out as the most water-intensive industry, consuming over 80% of the world's water resources. This high demand is primarily driven by the evapotranspiration requirements of plants. In recent years, the concepts of virtual water and water footprints have shed light on the hidden relationship between food production and water availability (Figure 11). These analyses have revealed significant associations between the water content of various staple foods and their production processes (Muratoglu, 2020). Hoekstra and Mekonnen (2012) evaluated the global per capita average water footprint as 1,385 m^3/year. Despite potential variations across countries, it remains essential to establish and enforce effective administrative measures to secure an ample water supply for stakeholders involved in the agricultural sector. However, these frameworks largely emphasize water use efficiency without adequately addressing equity issues. For example, the global average water footprint of 1,385 m^3/year per capita masks significant regional disparities, where wealthy nations externalize their water demands through imports, further depleting water resources in poorer exporting countries. To address these challenges, an integrated approach that combines equitable resource allocation with sustainable water management is critical. Administrative measures such as localized water pricing, incentives for water-efficient agricultural practices, and investments in wastewater reuse technologies can mitigate these disparities. However, their success depends on robust governance structures and political will, which are often lacking in water-scarce regions.

5 Discussion

5.1 Current status

The analysis reveals critical challenges in Palestine's water security, particularly in Gaza where 39.5% of the population has access to safe drinking water services. The disparity in water access and consumption is evident: 86.5% of the West Bank population has piped water, whereas in Gaza, this figure is only 4.1%. In rural areas of the West Bank, daily water access falls below 50 liters per capita, compared to urban areas where it exceeds 120 liters per capita, highlighting stark regional disparities in distribution. Geographical differences in water scarcity are significant, with some districts experiencing much lower access rates than others. For example, areas in southern Gaza face more severe water shortages due to depleted aquifers and limited infrastructure. 89% of Gaza's residents lacking access to safely managed drinking water services, the region faces a dire water predicament. Palestine's water availability is estimated at approximately 448 Mm^3, with groundwater constituting roughly 79% of the total supply. Palestinians are compelled to procure 20% of their water requirements from the Israeli water company, Mekorot, totaling about 90 Mm^3 annually. Groundwater, primarily sourced from the Mountain Aquifer, plays a pivotal role in meeting Palestinians' water needs. However, Israel's substantial extraction from numerous wells severely depletes this vital resource.

The impact of water access disparities is particularly severe for vulnerable demographics. Women and children in Gaza bear a disproportionate burden, with waterborne diseases, including diarrhea and gastrointestinal infections. Approximately 64% of Palestinian households rely on water sources contaminated with nitrates and other pollutants, with nitrate levels exceeding WHO safety limits by up to six times (Palestinian Water Authority). These challenges are exacerbated by gender-specific issues, where women often bear the responsibility of water collection and distribution within households, limiting their time for education and economic activities. Girls, in particular, face higher risks of waterborne illnesses due to poor sanitation facilities and contaminated water sources in refugee camps. The burden on women and children in these communities further perpetuates cycles of poverty and reinforces existing gender inequalities.

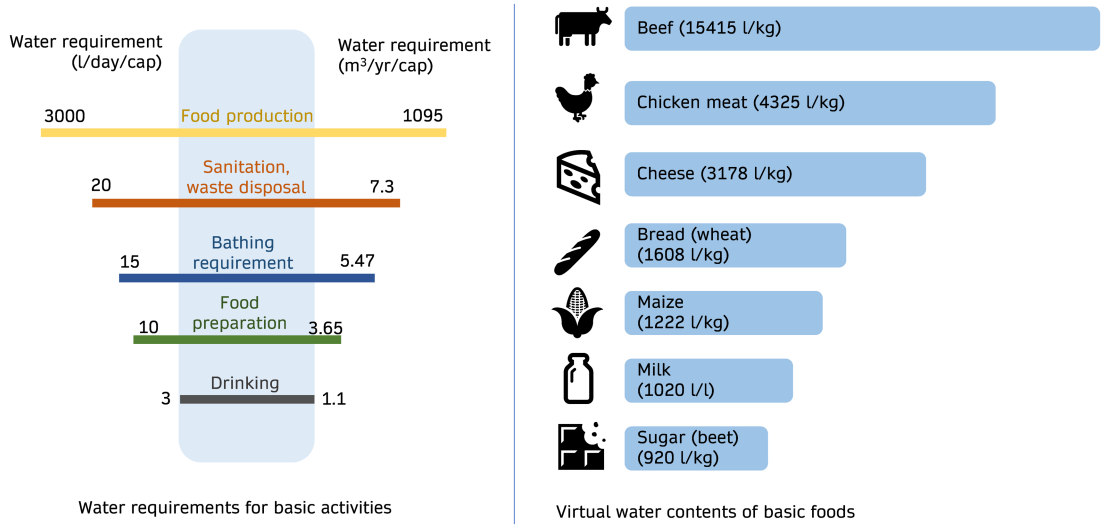

FIGURE 11
Water requirements for basic human activities and food [Basic activities are based on Gleick (1996); virtual water contents are based on WFN (2023)].

5.2 SWOT analysis of water resources in Palestine

We conducted a SWOT analysis to better identify key challenges and opportunities. This analysis reveals that while significant challenges exist, there are also opportunities for improving water security through targeted interventions and international cooperation (Table 1).

Based on our analysis of water access patterns and current challenges, we identify several actionable recommendations. International organizations should prioritize the development of independent water infrastructure in Palestine. For NGOs and local authorities, community-scale water projects should focus on West Bank regions where agricultural water harvesting shows high potential. The development of wastewater treatment facilities is crucial to address water quality issues, particularly in Gaza where waterborne diseases significantly impact public health. At the policy level, strengthening international oversight of water resource allocation is essential, especially considering the stark disparities in water consumption between Palestinians and Israelis. These recommendations stem directly from our findings on access limitations and current challenges. Implementation requires coordinated effort among international bodies, local authorities, and humanitarian organizations to ensure sustainable outcomes in both Gaza and the West Bank.

5.3 Infrastructure and management challenges

The current water management framework reveals significant structural limitations. Palestinian control extends to only 21% of total water resources, while access to the Jordan River remains restricted despite riparian status. The Gaza coastal aquifer faces particular challenges, where the extraction rate surpasses recharge by approximately threefold. Additionally, deteriorating infrastructure and limited maintenance opportunities have led to declining water quality, with notable public health implications. These challenges are compounded by restrictions on infrastructure development and rehabilitation.

TABLE 1 SWOT analysis of water resources in Palestine.

Strengths	Weaknesses
Existing international legal frameworks recognizing water rights	Limited control over water resources (79% under external control)
Available groundwater resources through aquifers	Deteriorating infrastructure and high network losses
Established water management institutions	Fragmented water governance systems
Public awareness of water scarcity issues	Limited wastewater treatment capacity

Opportunities	Threats
Potential for rainwater harvesting development	Increasing water demand due to population growth
Possibilities for wastewater reuse and treatment	Climate change impacts on water availability
International support for water rights enforcement	Continued restrictions on infrastructure development
Development of alternative water sources (e.g., desalination)	Deteriorating groundwater quality

5.4 Potential solutions and cooperation frameworks

The analysis suggests several potential approaches for enhancing water security. Technical cooperation could be advanced through joint monitoring of aquifer conditions, shared water quality assessment programs, and collaborative infrastructure maintenance. Resource management improvements could focus on developing sustainable extraction guidelines for shared aquifers, implementing water quality protection measures, and establishing equitable allocation mechanisms based on WHO standards. Infrastructure development priorities include the rehabilitation of existing water supply networks, enhancement of wastewater treatment capacity, and development of additional desalination facilities. International cooperation frameworks could support these efforts through UN-supported water management protocols, regional water-sharing agreements, and transparent monitoring mechanisms.

Modern digital technologies (Maity et al., 2024) could enhance water governance despite access restrictions. Remote sensing and GIS applications could improve monitoring of water resources and infrastructure conditions, while AI-driven systems could optimize distribution in areas with limited supply. These tools are particularly relevant for Palestine, where physical access to water infrastructure is often restricted—for instance, in monitoring Gaza's coastal aquifer depletion or managing water distribution in refugee camps. However, successful implementation would require addressing local infrastructure constraints.

5.5 Future implications

The findings indicate that sustainable water security requires a comprehensive approach encompassing several key elements. Recognition of water as a fundamental human right should be paired with practical implementation of WHO-recommended consumption standards. Critical water infrastructure requires protection as essential civilian facilities, while sustainable groundwater management practices need development and implementation. These integrated approaches could contribute to both immediate improvements in water security and long-term sustainable water management in the region. International organizations should prioritize the development of independent water infrastructure in Palestine, with particular emphasis on expanding desalination capacity in Gaza and rehabilitating existing water networks to reduce losses. The development of new groundwater wells in areas with sustainable aquifer conditions presents another crucial infrastructure priority. Non-governmental organizations can play a vital role by implementing community-scale water harvesting projects and supporting the development of wastewater treatment facilities. Additionally, establishing comprehensive water quality monitoring programs would

TABLE 2 Key recommendations for water security enhancement in Palestine.

Timeframe	Target group	Recommendation	Expected outcome
Immediate actions (1–2 years)	International organizations	Establishing emergency water supply systems in Gaza Strip. Rehabilitating existing water networks. Conducting rapid assessment of critical infrastructure.	Improving access to safe water. Reducing water losses. Understanding urgent infrastructure needs.
	NGOs	Developing community-scale water harvesting projects. Implementing household water treatment programs. Creating local water quality monitoring networks.	Enhancing local water security. Improving water quality. Achieving better health outcomes.
Medium-term solutions (2–5 years)	Policymakers	Implementing digital water monitoring systems. Developing integrated water management plans. Creating transparent water allocation mechanisms.	Enhancing resource management. Ensuring equitable distribution. Enabling better decision-making.
	Technical experts	Deploying remote sensing and GIS for aquifer monitoring. Designing AI-driven distribution systems. Creating sustainable groundwater extraction plans.	Improving resource monitoring. Optimizing distribution. Ensuring sustainable resource use.
Long-term strategies (5+ years)	International bodies	Building large-scale desalination facilities. Establishing regional water-sharing frameworks. Creating sustainable financing mechanisms.	Increasing water supply. Enhancing regional cooperation. Securing sustainable funding.
	Local authorities	Expanding wastewater treatment facilities. Implementing water-efficient agriculture. Developing drought management plans.	Improving water quality. Reducing agricultural water use. Strengthening drought resilience.

help track and address contamination issues. From a policy perspective, strengthening international oversight of water resource allocation and developing transparent mechanisms for water rights enforcement are essential steps. Creating and implementing emergency response protocols for water supply disruptions would help mitigate acute water access challenges. These recommendations align with international water rights frameworks while offering concrete steps toward improving water security in Palestine. Such interventions require coordinated effort among international bodies, local authorities, and humanitarian organizations to ensure effective implementation and sustainable outcomes. To provide clear guidance for various stakeholders, Table 2 presents a comprehensive framework of recommendations organized by timeframe and implementing group, with specific actions and expected outcomes.

5.6 Limitations

While this study draws from established institutional sources, certain data limitations must be critically addressed. Access to comprehensive water-related data in Palestine is affected by the political situation, which influences the availability and reliability of data collection. For instance, regions like Gaza face periods of limited or inconsistent data collection due to conflict conditions, leading to potential gaps in longitudinal studies. Additionally, there are variations in the measurement methodologies and reporting periods between different sources, which can introduce biases or discrepancies. The data provided by some international organizations may also be influenced by political agendas or access restrictions, potentially impacting the comprehensiveness and neutrality of the information.

Despite these limitations, the overall patterns and disparities identified in our analysis remain consistent across multiple authoritative sources, supporting the reliability of our main findings. We acknowledge that these limitations could affect the interpretation of specific data points, and future research should seek to incorporate more comprehensive and consistently collected data to further validate these patterns.

6 Conclusion

Palestine faces a severe water crisis, with the Gaza Strip experiencing the most critical conditions. Only 39.5% of Palestinians have access to safe drinking water, dropping to 4.1% in Gaza. Groundwater, the main water source, is overexploited, particularly in Gaza's coastal aquifer, which faces unsustainable extraction rates. This crisis impacts agriculture, economy, and social welfare, reducing food production, increasing poverty, and exacerbating unemployment. Unequal water distribution, intensified by Israeli-Palestinian disparities, highlights the urgency for equitable water access.

The crisis hinders progress toward Sustainable Development Goals (SDGs), especially SDG 6 (Clean Water and Sanitation). Gaza's low access to safe drinking water affects SDG 3 (Good Health and Wellbeing) by increasing waterborne diseases. Agricultural water shortages impact SDG 2 (Zero Hunger), while inequitable distribution worsens SDG 10 (Reduced Inequalities). SDG 1 (No Poverty) is also affected as limited water access burdens households financially.

Addressing the crisis requires strengthening international oversight, upgrading water infrastructure, investing in wastewater treatment, enforcing equitable management policies, and supporting community-led initiatives. Improved water systems, desalination facilities, and wastewater reuse projects are critical for sustainable

water management. Community involvement and partnerships with NGOs can foster local capacity in water conservation.

Further research is needed to assess the health impacts of restricted water access, analyze groundwater quality, and evaluate economic losses in agriculture and industry. Exploring alternative solutions, such as rainwater harvesting and wastewater reuse, is essential for equitable and sustainable water management. Coordinated efforts by international agencies, local governments, and humanitarian organizations are imperative to mitigate the crisis, ensure clean water access, and promote socio-economic development in Palestine, particularly Gaza.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Author contributions

AM: Conceptualization, Data curation, Formal analysis, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. FW: Supervision, Validation, Writing – original draft, Writing – review & editing.

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The district boundaries are delineated according to the map provided by OCHA (2023). Climate data, including temperature, rainfall, and humidity, is sourced from PMA (2018). This publication presents data tables, figures, maps, analyses, and technical notes compiled from diverse previous databases, reports, and publications. It is important to note that the inclusion of such materials does not indicate any expression of opinion regarding the legal status of any country, territory, city, or area, nor of its authorities, or the delineation of its frontiers or boundaries.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. Authors used Claude 3.5 Sonnet (Anthropic, October 2024) and ChatGPT (OpenAI, basic version) for language editing.

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References

Abu Zahra, B. A. A. (2001). Water crisis in Palestine. *Desalination* 136, 93–99. doi: 10.1016/S0011-9164(01)00169-2

Abualtayef, M., Rahman, G. A., Snounu, I., Qahman, K., Sirhan, H., and Seif, A. K. (2017). Evaluation of the effect of water management interventions on water level of Gaza coastal aquifer. *Arab. J. Geosci.* 10:555. doi: 10.1007/s12517-017-3329-x

Abu-Madi, M. (2009). Farm-level perspectives regarding irrigation water prices in the Tulkarm district, Palestine. *Agric. Water Manag.* 96, 1344–1350. doi: 10.1016/J.AGWAT.2009.04.007

AbuQamar, M., Tabash, M. I., Aish, A., Hasheesh, A.-R. A., and Sharaf, F. (2023). Health impact of drinking water quality on the occurrence of osteoporosis in Gaza strip, Palestine. *Ethiop. J. Health Sci.* 33, 814–850. doi: 10.4314/ejhs.v33i5.14

Ahmad, N. (2020). Human right to water under international law regime: an overview. *Commonw. Law Bull.* 46, 415–439. doi: 10.1080/03050718.2020.1770618

Alazzeh, S., Galaitsi, S. E., Bishara, A., Al-Azraq, N., and Durant, J. L. (2019). Impacts of intermittent water supply on water quality in two Palestinian refugee camps. *Water* 11:670. doi: 10.3390/w11040670

Allan, J. A. (2002). Hydro-peace in the Middle East: why no water wars? A case study of the Jordan River basin. *SAIS Rev.* 22, 255–272. doi: 10.1353/sais.2002.0027

Al-Shalalfeh, Z., Napier, F., and Scandrett, E. (2018). Water Nakba in Palestine: sustainable development goal 6 versus Israeli hydro-hegemony. *Local Environ.* 23, 117–124. doi: 10.1080/13549839.2017.1363728

Amnesty (2009). Troubled waters-Palestinians denied fair access to water, Israel occupied Palestinian territories. London: Amnesty International Publications.

Amnesty (2017). The occupation of water. London: Amnesty International.

Arden, J. (2016). Water for all? Developing a human right to water in national and international law. *Int. Comp. Law Q.* 65, 771–789. doi: 10.1017/S002058931600035X

Avila-Garcia, P. (2017). Water as a human right in the global south: ethical, legal and sociopolitical dimensions. *Human Face Water Security* 25, 71–94. doi: 10.1007/978-3-319-50161-1_4

B'Tselem (2023). Water crisis. Available at: https://www.btselem.org/topic/water (Accessed December 5, 2023).

Bahia, A. N. M., and Lima, L. C. (2022). The environmental perspective of the right to water in the case law of the inter-American court of human rights. *Chin. J. Environ. Law.* 6, 170–185. doi: 10.1163/24686042-12340083

Bain, R. E. S., Johnston, R., and Slaymaker, T. (2020). Drinking water quality and the SDGs. *NPJ Clean Water* 3, 1–3. doi: 10.1038/s41545-020-00085-z

Beltrán, M. J., and Kallis, G. (2018). How does virtual water flow in Palestine? A political ecology analysis. *Ecol. Econ.* 143, 17–26. doi: 10.1016/j.ecolecon.2017.06.036

Beshtawi, A., and Cuadrado-Quesada, G. (2022). Draining international water law: lessons from the Israel–occupied Palestinian territory context. *Arab Law Q.* 38, 310–333. doi: 10.1163/15730255-bja10110

Brooks, D., and Trottier, J. (2010). Confronting water in an Israeli-Palestinian peace agreement. *J. Hydrol.* 382, 103–114. doi: 10.1016/J.JHYDROL.2009.12.021

Brooks, D., Trottier, J., and Giordano, G. (2019). Supporting Palestinian agriculture. *Springer Briefs Case Stu. Sust. Dev.* 11, 63–70. doi: 10.1007/978-981-15-0252-1_5

Carson, H. Y. (1919). Some water supply problems in Palestine. *J. Am. Water Works Assoc.* 6, 439–443. doi: 10.1002/j.1551-8833.1919.tb13267.x

Cullet, P. (2011). Water law in a globalised World: the need for a new conceptual framework. *J. Environ. Law* 23, 233–254. doi: 10.1093/JEL/EQR003

Elmusa, S. S. (1998). Toward a unified management regime in the Jordan Basin: the Johnston plan revisited. *Yale F&ES Bulletin* 103, 297–313.

EU (2000). Directive 2000/60/EC of the European Parliament and of the council of 23 October 2000 establishing a framework for community action in the field of water policy. *EU Off. J.* 43, 1–73.

FAOLEX (2022). Military order no. 158. FAO. Rome: Food and Agriculture Organization of the UN, FAOLEX Database.

Fisher, F. M., and Askari, H. (2001). Optimal water management in the Middle East and Other Regions. *Financ. Dev. IMF* 38:52.

Gleick, P. H. (1996). Basic water requirements for human activities: meeting basic needs. *Water Int.* 21, 83–92. doi: 10.1080/02508069608686494

Gleick, P. H. (1998). The human right to water. *Water Policy* 1, 487–503. doi: 10.1016/S1366-7017(99)00008-2

Hansén, N. (2018). The human right to water and its status in international law. Stocholm: Stocholm University.

Harris, L. M., Rodina, L., and Morinville, C. (2015). Revisiting the human right to water from an environmental justice lens. *Politics, Groups Identities* 3, 660–665. doi: 10.1080/21565503.2015.1080619

Hoekstra, A. Y., and Mekonnen, M. M. (2012). The water footprint of humanity. *Proc. Natl. Acad. Sci.* 109, 3232–3237. doi: 10.1073/pnas.1109936109

Humaid, M. (2023). Gaza's Undrinkable Water 'Slowly Poisoning' Palestinians. Al Jazeera. Available at: https://www.aljazeera.com/news/2021/10/12/gaza-undrinkable-water-slowly-poisoning-people (Accessed December 5, 2023).

Humphrey, J., Brown, J., Cumming, O., Evans, B., Howard, G., Kulabako, R., et al. (2020). The potential for atmospheric water harvesting to accelerate household access to safe water. *Lancet Planetar. Health* 4, e91–e92. doi: 10.1016/S2542-5196(20)30034-6

Isaac, J. (2000). The essentials of sustainable water resource Management in Israel and Palestine. *Arab. Stud. Q.* 22, 13–31.

Jain, S., Srivastava, A., Khadke, L., Chatterjee, U., and Elbeltagi, A. (2024). Global-scale water security and desertification management amidst climate change. *Environ. Sci. Pollut. Res.* 31, 58720–58744. doi: 10.1007/s11356-024-34916-0

JVL (2023). Jewish & non-Jewish population of Israel/Palestine (1517-present). Available at: https://www.jewishvirtuallibrary.org/jewish-and-non-jewish-population-of-israel-palestine-1517-present (Accessed December 22, 2023).

Karaköse, H. (2018). An overview of the Palestine question (from the middle of the XIX to the XX century). *Ahi Evran Univ. J. Soc. Sci. Inst.* 4, 150–165. doi: 10.31592/aeusbed.475402

Karaman, M. L. (1996). Filistin. Available at: (https://islamansiklopedisi.org.tr/filistin).

Khoury, M. (2013). Construction and rehabilitation of water sources in area C: An overview of the applicable legal and permit regime. Oslo: Norwegian Refugee Council.

Klawitter, S. (2007). Water as a human right: the understanding of water rights in Palestine. *Int. J. Water Res. Dev.* 23, 303–327. doi: 10.1080/07900620601181697

Krakow, C. A. (2020). The international law and politics of water access: experiences of displacement, statelessness, and armed conflict. *Water* 12:340. doi: 10.3390/w12020340

Kuttab, J., and Ishaq, J. (1994). "Approaches to the legal aspects of the conflict on water rights in Palestine/Israel" in Studies in environmental science. ed. D. D. Chiras (Amsterdam: Elsevier), 239–249.

Maity, R., Srivastava, A., Sarkar, S., and Khan, M. I. (2024). Revolutionizing the future of hydrological science: impact of machine learning and deep learning amidst emerging explainable AI and transfer learning. *Appl. Comput. Geosci.* 24:100206. doi: 10.1016/j.acags.2024.100206

Masterman, E. W. G. (1902). The water supply of Jerusalem, ancient and modern. *Biblical World* 19, 87–112. doi: 10.1086/472951

McCarthy, J. (1990). The population of Palestine: Population history and statistics of the late ottoman period and the mandate. Columbia, NY: Columbia University Press.

Mehta, L., Allouche, J., Nicol, A., and Walnycki, A. (2014). Global environmental justice and the right to water: the case of peri-urban Cochabamba and Delhi. *Geoforum* 54, 158–166. doi: 10.1016/J.GEOFORUM.2013.05.014

Mousa, M. (1994). A general view of the water situation in the occupied Palestinian territories (OFT). Stu. Environ Sci. 58, 523–528. doi: 10.1016/S0166-1116(08)71436-5

Mukhairez, H. H. A., and Al-Halees, A. (2018). Medium-term forecasting for City water demand and revenue. *Int. J. Int. Comput. Res.* 9, 913–920. doi: 10.20533/ijicr.2042.4655.2018.0110

Muratoglu, A. (2020). Assessment of wheat's water footprint and virtual water trade: a case study for Turkey. *Ecol. Process.* 9:13. doi: 10.1186/s13717-020-0217-1

Nassar, Y. (2007). Virtual water trade as a policy instrument for achieving water security in Palestine. *Water Res. Middle East* 22, 141–146. doi: 10.1007/978-3-540-69509-7_13

Nijim, B. K. (1990). Water resources in the history of the Palestine-Israel conflict. *GeoJournal* 21, 317–323. doi: 10.1007/BF00174593

Niksic, O., Eddin, N. N., and Cali, M. (2014). Area C and the future of the Palestinian economy. Washington, DC: The World Bank.

NPG (1941). Jewish population of Palestine. *Nature* 147:413. doi: 10.1038/147413b0

OCHA (2015). The Gaza strip: The humanitarian impact of the blockade. New York, NY: UN Office for the Coordination of Humanitarian Affairs.

OCHA (2023). United Nations Office for the coordination of humanitarian affairs (OCHA) occupied Palestinian territory (oPt). New York, NY: UN Office for the Coordination of Humanitarian Affairs.

Onion, A., Sullivan, M., Mullen, M., and Zapata, C. (2023). Palestine: history, religion and conflicts. History. Available at: https://www.history.com/topics/middle-east/palestine (Accessed December 29, 2023).

PCBS (2021). Water tables in Palestine, 2021. Palestinian central Bureau of Statistics. Available at: (https://www.pcbs.gov.ps/site/lang__en/1022/Default.aspx).

PCBS (2022). The Palestinian central Bureau of Statistics (PCBS), and the Palestinian water authority (PWA) joint press release on the occasion of World water day. Available at: https://www.pcbs.gov.ps/portals/_pcbs/PressRelease/Press_En_22-3-2022-Water-en.pdf (Accessed March 22, 2022).

PCBS (2023a). Israeli settlements in the West Bank annual statistical report, 2022. Ramallah: State of Palestine Palestinian Central Bureau of Statistics.

PCBS (2023b). Palestine in Figures 2022. Ramallah: Palestinian Central Bureau of Statistics.

PCBS (2023c). Sustainable development goals statistical report 2022. Ramallah: State of Palestine Palestinian Central Bureau of Statistics.

PMA (2018). Climate Bulletin (2018). Ramallah: State of Palestine, Palestinian Meteorological Authority (PMA).

PWA (2012). National Water Strategy for Palestine: Palestinian Water Authorithy.

PWA (2013). Status report of water resources in the occupied state of Palestine-2012. Ramallah: Palestinian Water Authority.

PWA (2023). Rainfall is the source of water in Palestine. *State of Palestine water Authorith*. Ramallah: Palestinian Water Authority.

Sadoff, C. W., Borgomeo, E., and Uhlenbrook, S. (2020). Rethinking water for SDG 6. *Nat. Sust.* 3, 346–347. doi: 10.1038/s41893-020-0530-9

Salem, H. (2023). Socioeconomic, environmental, and health impacts of reusing treated wastewater in agriculture in some Arab countries, including occupied Palestine, in view of climate change. *Nat. Res. Conserv. Res.* 6:2229. doi: 10.24294/nrcr.v6i2.2229

Salem, M. Z., and Ertz, M. (2023). Water consumption rationalization using demarketing strategies in the Gaza strip, Palestine. *Water Res. Econ.* 43:100227. doi: 10.1016/j.wre.2023.100227

Salman, S. M. A. (2014). The human right to water and sanitation: is the obligation deliverable? *Water Int.* 39, 969–982. doi: 10.1080/02508060.2015.986616

Sawka, M. N., Cheuvront, S. N., and Carter, R. (2005). Human water needs. *Nutr. Rev.* 63, S30–S39. doi: 10.1111/j.1753-4887.2005.tb00152.x

Shadeed, S., Judeh, T., and Riksen, M. (2020). Rainwater harvesting for sustainable agriculture in high water-poor areas in the West Bank, Palestine. *Water* 2:380. doi: 10.3390/w12020380

Shomar, B. (2011). Water scenarios in the Gaza strip, Palestine: thirst, hunger and disease. *Int. J. Environ. Stud.* 68, 477–493. doi: 10.1080/00207233.2011.582724

Shuval, H. (1992). Approaches to resolving the water conflicts between Israel and her neighbors—a regional water-for-peace plan. *Water Int.* 17, 133–143. doi: 10.1080/02508069208686133

Simpson, W. (1891). Irrigation and water supply in Palestine. *Palest. Explor. Q.* 23, 160–161. doi: 10.1179/peq.1891.23.2.160

Sokolower, J. (2023). A short history of the conflict in Palestine/Israel. Available at: https://teachpalestine.org/wp-content/uploads/2018/03/Sokolower_3.1_A-Short-History-of-the-Conflict-in-Palestine-Israel.pdf (Accessed March 13, 2018).

Tamarin, M. (2018). The human(ised) right to water and its limits: the case of Israel-Palestine 6, 135–152. doi: 10.7564/16-IJWG120

TRT World (2019). A brief history of the Israeli occupation of Palestine. *A brief history of the Israeli occupation of Palestine*. Available at: (https://www.trtworld.com/magazine/a-brief-history-of-the-israeli-occupation-of-palestine-12733173).

UN (1967). Security council resolution 242: the situation in the Middle East | UN peacemaker. Available at: https://peacemaker.un.org/middle-east-resolution242 (Accessed December 30, 2023).

UN (1999). 5. A protocol on water and health to the 1992 convention on the protection and use of transboundary watercourses and International Lakes. United Nations treaty collection. Available at: https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-5-a&chapter=27&clang=_en (Accessed December 9, 2023).

UN (2020). Atlas of sustainable development 2020, state of Palestine. United Nations country team, occupied Palestinian territory Office of the Prime Minister of the state of Palestine. United Nations. Available at: https://palestine.un.org/sites/default/files/2021-10/atlas_of_sustainable_development_2020.pdf

UN (2023). History of the question of Palestine. Question of Palestine. Available at: https://www.un.org/unispal/history/ (Accessed December 21, 2023).

UNDP (2006). Human development report 2006. Beyond scarcity: Power, poverty and the global water crisis. New York, NY: United Nations Development Program.

WFN (2023). Product gallery – water footprint network. Available at: https://www.waterfootprint.org/resources/interactive-tools/product-gallery/ (Accessed January 7, 2024).

World Bank (2023). Population estimates and projections. Washington, DC: World Bank.

World Bank Group (2018). Securing water for development in West Bank and Gaza. Washington, DC: World Bank.

Yaqoub, E. (2023). "Water resources management crisis in Palestine" in The handbook of environmental chemistry. ed. O. Part (Berlin: Springer Berlin Heidelberg), 1–13.

Yousef, A. S. (2004). "Water resources, protection and Management in Palestine" in Water in the Middle East and in North Africa: Resources, protection and management. eds. F. Zereini and W. Jaeschke (Berlin: Springer Berlin Heidelberg), 87–99.

Zeitoun, M. (2008). Power and water in the Middle East. London: IB TAURIS & Company Limited.

Zohud, A., and Alam, L. (2022). A review of groundwater contamination in West Bank, Palestine: quality, sources, risks, and management. *Water* 14:3417. doi: 10.3390/w14213417

Zwarteveen, M., and Boelens, R. (2014). Defining, researching and struggling for water justice: some conceptual building blocks for research and action. *Water Int.* 39, 143–158. doi: 10.1080/02508060.2014.891168