Assessment of Water Crisis in Palestine: Resources, Challenges, and Practical Solutions

Sameer Shadeed[1], Itissam Abuiziah[2], Nidal Mahmoud[3], Hassan Sawalha[4*]

Abstract— **Palestine is experiencing an increasingly severe water crisis, stemming from the interplay of political constraints (Israeli occupation), environmental pressures (climate change), and managerial challenges (weak governance). Together, these factors have created a critical situation that poses a threat to public health, economic stability, and long-term environmental sustainability. This paper aims to assess the available water resources in Palestine and to identify the key challenges contributing to this critical situation, providing an evidence-based foundation for sustainable water management strategies. The findings are envisaged to equip public authorities, academic institutions, and international organizations with a comprehensive assessment of Palestine's water situation, outlining the available resources, critical challenges, and feasible, cost-effective interventions. The primary sources of accessible water are groundwater wells (approximately 300 MCM), springs (around 45 MCM), and purchased water from Mekorot, about 95 MCM. The study proposes practical and feasible solutions to enhance water security in Palestine. Investment in nonconventional water resources, such as treated wastewater reuse, seawater desalination, and rainwater harvesting, was identified as the primary intervention, with the potential to provide up to 250 MCM of additional water annually. Additional recommendations emphasize governance and management reforms, as well as upgrading water and wastewater infrastructure.**

Keywords: Water crisis, water resources, rainwater harvesting, treated wastewater reuse, desalination, feasible solutions, challenges, management.

I. Introduction

Water scarcity is generally considered to occur when the total annual available water for human use falls below 1000 m^3/capita/year (Brown and Matlock 2011). In this regard, Palestine is facing a severe water crisis, as the total accessible water resources were only 185 m^3/capita/year in the country in 2015, and are predicted to drop to less than 83 m^3/capita/year by 2050 (Baggio et al. 2021). The water shortage in Palestine is due to both natural and anthropogenic constraints. The natural constraints arise from the fact that Palestine is located in an arid to semi-arid region, with an average annual rainfall of about 525 mm in 2020, which varied significantly, from around 152 mm in arid areas like Jericho to as much as 898 mm in wetter regions such as Nablus (Fanack Water, 2020). The anthropogenic constraints result from Israeli practices and restrictions on the different available conventional water resources. For instance, about 87% of the groundwater reserves remain under Israeli control and are inaccessible to Palestinians (Amnesty International 2022; Human Rights Watch 2024).

Palestine primarily relies on two main water resources: the groundwater wells, which account for about 70% of the available water resources, and the water springs, which contribute to approximately 10% of the available water (PCBS 2022). Although these resources cannot fulfil the country's water demand, Palestinians are continuously restricted from accessing their water resources and, consequently, are forced to buy water from the Israeli water company "Mekorot", at elevated prices.

In the Gaza Strip, before the war in 2023, almost 97 % of the available renewable water resources were considered unsafe for human consumption (UNICEF 2018). This was due to over-extraction from the groundwater aquifer, seawater intrusion, and potential contamination of water bodies by the continuous discharge of untreated or partially treated wastewater. During the current war, most of the drinking water infrastructure was destroyed by the Israeli military attacks, including desalination plants, groundwater wells, pumps, and water distribution networks. International reports reveal that about 65% of all water and sanitation infrastructures were destroyed by April 2024 (World Bank 2024). Therefore, access to potable water is a serious challenge and may be impossible for Palestinians in the Gaza Strip. According to the United Nations reports, the average daily per capita water consumption in Gaza during the war was only 1.5 liters of water for all needs, which is 10 times lower than the emergency limit set by the United Nations of 15 liters per capita per day (l/c/d) (UNRWA 2024).

Beyond the aforementioned political restrictions and challenges, Palestine suffers from serious water management challenges. These include huge water losses of about 35% due to the deterioration of water distribution infrastructure (PCBS 2024). Additionally, climate change consequences are illustrated in the decline in the yearly rainfall amount, long drought periods, and desertification (UNDP, 2020). These environmental challenges have further exacerbated the water

[1]*Civil and Architectural Engineering Department, Faculty of Engineering and Information Technology, An-Najah National University, Nablus, Palestine.*
[2]*Civil Engineering Department, Palestine Polytechnic University, Wadi Al-Haria, P.O. Box 198, Hebron, Palestine*
[3]*Institute of Environmental and Water Studies (IEWS), Birzeit University, The West Bank, Birzeit P627, Palestine*
[4]*Center of Excellence in Water, Energy and Environment Research and Services, Mechanical Engineering Department, Palestine Polytechnic University, Wadi Al-Haria, P.O. Box 198, Hebron, Palestine*
** Correspondence: hsawalha@ppu.edu; Tel.: +972-569-1818-61*

situation and seriously hampered agricultural development, and contributed to food insecurity.

Alongside the water crisis, the wastewater sector in Palestine faces equally severe challenges. The wastewater sector suffers from poor management, characterized by inadequate infrastructure in both sewerage networks and treatment facilities, unsafe disposal of untreated or partially treated effluent, and unregulated use of low-quality water. The occupation has obstructed the development of essential wastewater treatment facilities, leading to inadequate systems that often result in the unsafe disposal of untreated or partially treated effluent. The existing wastewater collection systems, established during 1970–1980 under the Israeli occupation, are overloaded and badly maintained, resulting in frequent sewage flooding and complete failure of some systems (Samhan et al., 2011). This situation raises serious public health concerns about the spread of waterborne diseases. Additionally, poor wastewater management leads to soil and water pollution, endangering local ecosystems and agricultural practices.

While addressing and analyzing the challenges facing the water sector in Palestine, one should bear in mind that most of the root causes of these challenges are due to political restrictions that are beyond Palestinians' control. Therefore, innovative and comprehensive interventions should be immediately implemented to satisfy the urgent water needs. Non-conventional water resources, including rainwater harvesting, treated water reuse, and seawater desalination, appear to be promising options. Promoting rainwater harvesting and improving rainwater collection systems and infrastructure could potentially provide a significant amount of rainwater for domestic and agricultural uses (Alawna and Shadeed, 2019). Additionally, the reuse of treated wastewater could be an additional viable water resource that could provide about 80-90 MCM/year of good-quality reclaimed water for agricultural activities, industrial applications, groundwater recharge, and secondary household water demands (Fanack 2023). Seawater desalination seems to be one of the most practical solutions for addressing the critical water crises (PWA 2012). Other practical solutions include the implementation of smart water management systems and the reduction of water losses through upgrading existing distribution networks.

Furthermore, updating water and wastewater laws, policies, regulations, governance frameworks, and management systems is crucial to address the real challenges facing Palestine's water sector. Upgrading existing wastewater treatment facilities by incorporating advanced and cost-effective treatment technologies is also essential. Additionally, promoting water conservation measures such as efficient irrigation techniques and the use of water-saving appliances can significantly contribute to minimizing water loss.

This paper aims to assess the available water resources and evaluate the current water situation in Palestine. The study analyzes the main challenges facing the water sector and identifies the root causes of the water crisis in Palestine. Additionally, it explores potential and practical solutions to address water shortage problems. Ultimately, this paper serves as a valuable source to assist policymakers, researchers, and stakeholders involved in the water sector in tackling the critical water issues currently facing Palestine.

The paper begins by analyzing the current status of water resources in Palestine and examining the main political, environmental, and managerial challenges facing the sector. Subsequently, it proposes practical solutions and recommendations to enhance water security and sustainability.

II. Water Resources in Palestine

A. Rainfall Patterns

Palestine experiences a Mediterranean climate with extreme seasonal variations. The climate varies from hot and dry in summer to wet and cold in winter, with short transitional seasons (UNEP, 2003). The rainy season usually extends from October to April. In winter, more than 80% of the annual rainfall commonly occurs (Shadeed, 2012). In general, rainfall is characterized by its high temporal and spatial variability. Based on the available data from the Palestinian Meteorological Department (PMD, 2018) for 113 rain gauges distributed in the West Bank (Figure 1), the long-term annual average rainfall ranges from less than 150 mm in the Jordan Valley to more than 700 mm in the central mountains of the West Bank, with an average value of about 420 mm. In contrast, the annual average rainfall in Gaza is about 356 mm. Generally, the rainfall distribution pattern increases from northwest to southeast.

Inter-annual rainfall variability is significant, which leads to hydrological stresses (Water Global Practice, 2018). Furthermore, climate change is projected to worsen these variable patterns, potentially decreasing the average annual rainfall by up to 20% by 2050 while increasing the frequency of extreme weather events, such as droughts and flash floods (UNDP, 2020). This, in turn, will have acute consequences on the sustainable water resources management, particularly affecting surface water availability and groundwater recharge across Palestine.

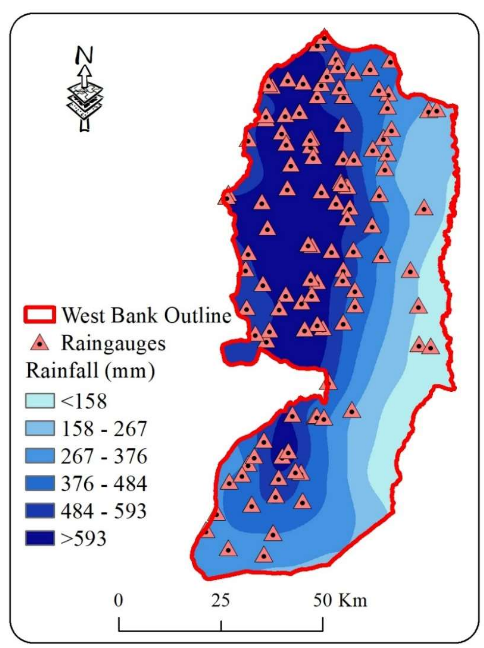

Figure 1. Long-term annual average rainfall distribution in the West Bank

B. Natural Water Resources

In Palestine, natural water resources are either surface water or groundwater. Both are being stressed due to climatic variability, over-extraction, pollution, and political constraints. These stresses have resulted in substantial difficulties in satisfying Palestinian water needs for different uses.

B.1 Surface Water

The Jordan River is the main surface water resource in the West Bank; however, due to Israeli occupation, Palestinians have been denied access and utilization of their water rights in the River since 1967, which is estimated at 250 mcm (McCaffrey, 2007). There exist 33 catchments (Wadis) in the West Bank (Figure 2) at which surface water drains either to the Mediterranean Sea (western Wadis) or to the Dead Sea and the Jordan River (eastern Wadis), in addition to Wadi Gaza. Most of these catchments are ungauged, where streamflow (flood) data are not available. For these catchments, it was estimated that the long-term annual average streamflow is approximately 165 million cubic meters (mcm) in the West Bank and 20 mcm for Wadi Gaza (PWA, 2003). These numbers are accurate in their overall calculation-based methodology, but they are far from accurate when it comes to field measurements due to the lack of streamflow data (Shadeed, 2008).

Flow regimes in these Wadis are characterized by high temporal variability and short response times to rainfall events, making surface water a less reliable year-round source (Shadeed, 2008). Most winter Wadi flows are being lost as there are no storage structures except some small agricultural dams like the Auja dam (0.7 MCM) in Jericho, the Bani Neim dam (0.17 MCM) in Hebron (PWA, 2020).

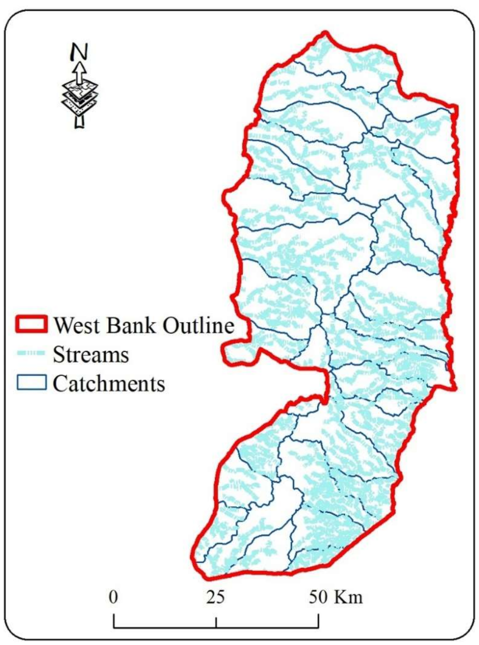

Figure 2. Location map for catchments and streams in the West Bank

B.2 Groundwater

Groundwater is the main freshwater resource in Palestine, accounting for about 70% of its water resources. The groundwater aquifer system in Palestine forms from several rock formations, particularly limestone, dolomite, and marl. The mountain aquifer (in the West Bank) and the coastal aquifer (in the Gaza Strip) are the main aquifer systems. The mountain aquifer is divided into the western, northeastern, and eastern aquifers (Figure 3). The eastern and part of the northeastern aquifers flow east towards the Jordan River. The western part of the northeastern and the coastal aquifer all flow westward towards the Mediterranean Sea.

The mountain aquifer is recharged directly from rainfall on the outcropping geologic formations in the West Bank mountains. About 90% of the recharge of the northeastern and western aquifers takes place within the West Bank, where annual rainfall recharge ranges between 135 – 187 mcm and 318 – 430 mcm on average for these two aquifers, respectively. The eastern is even a native Palestinian aquifer, as it is totally lying within the West Bank boundary, and this aquifer annually receives about 125 – 197 mcm from rainfall. Whereas the coastal aquifer annual recharge ranges between 55 and 60 mcm. Groundwater is the most significant and reliable source of natural water for Palestinians, accounting for about 95% of their total water needs (PWA, 2012).

Based on the published reports by the Palestinian Water Authority (PWA) in 2015 (Table 1), the total groundwater utilization by Palestinians in the West Bank and Gaza is about 300 mcm out of more than 1000 mcm, which accounts for about 28%. The West Bank aquifers are being utilized through about 500 wells (Figure 3), where the utilization under good conditions does not exceed 20% of the potential yield from the three aquifers. This is due to the unfair Israeli occupation's assaults on the Palestinian water resources. In Gaza, on the other hand, about 178 mcm were pumped out of the Coastal Aquifer in 2015, and the number increased to 191 mcm in 2020. This is leading to the alarming depletion of groundwater reserves, with the groundwater level in the Coastal Aquifer dropping 19 meters below sea level (PWA, 2021; PCBS, 2022).

TABLE I. UTILIZATION OF GROUNDWATER AQUIFERS IN 2015

Aquifer	Utilization (mcm)	
	Israeli Occupation	Palestine
Western	≥411	37.6
Northeastern	≥103	21.6
Eastern	≥150	64.8
Costal	≥400	177.5
Total	1064	301.5

There are around 300 springs in the West Bank (Figure 3). The average long-term annual discharge from these springs is about 54 mcm, which accounts for 10% of the water resources in the West Bank. However, most of these springs have a low flow rate of less than 0.1 liters per second. The most important springs in the West Bank are located within the Eastern Aquifer and are used mainly for agricultural purposes (Arij, 2015).

Excessive pumping from some existing wells has threatened the natural spring's discharge. For instance, Al-

Faria spring has been dried since 2008 by human acts, not by nature. Legally registered wells with permits from PWA have been pumping at rates higher than those permitted by the PWA (PWA, 2003). This lowered the water table to a level beneath the spring mouth, making it dry. As such, the spring failed to fulfill its historical share of water needs for the nearby communities (Mizyed and Haddad, 2009). Moreover, climate change poses a remarkable challenge to groundwater systems. Several springs (e.g., Faria spring) are being dried, making these natural springs vulnerable to satisfy the historical share of water needs. Rising temperatures and shifting rainfall patterns are expected to reduce groundwater recharge rates. Faquseh et. al (2024) studied future climate scenarios in the Al-Badan sub-catchment and predicted a significant decline in groundwater availability, urging the adoption of adaptive water management strategies.

Groundwater quality in the West Bank is deteriorating. This can be attributed to effluent of untreated/partially treated wastewater, the use of cesspits, and the intensive use of agrochemicals (Shadeed et al., 2016; Almasri et al., 2020; Judeh et al., 2022). In Gaza, the Coastal Aquifer is heavily over-extracted and polluted by seawater intrusion and untreated wastewater, rendering more than 97% of its water unfit for human consumption (OCHA, 2021).

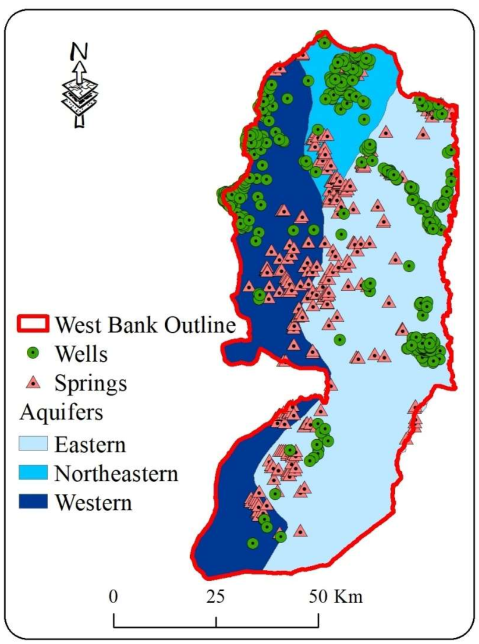

Figure 3. Location map for wells, springs, and aquifers in the West Bank

C. Non-conventional Water Resources

Population growth, enhanced living standards, climatic variability, and Israeli occupation have been intensifying the water shortage problem in Palestine. It is becoming increasingly unsustainable to rely on conventional natural water resources. As such, non-conventional water resources have become more important substitutes for the vulnerable natural supply. These include the reuse of treated wastewater, the desalination of brackish and saltwater, and rainwater harvesting.

C.1 Treated Wastewater Reuse

Wastewater in Palestine is poorly managed, posing a substantial environmental and public health challenge. This is due to limited infrastructure, fragmented institutional efforts, and political constraints. Despite some recent improvements, the sector still suffers from inadequate collecting systems, insufficient treatment capacity, and limited reuse practices (PWA, 2021; PCBS, 2022).

Annually, Palestine generates about 176 mcm of wastewater, with 96 mcm from the West Bank and 80 mcm from the Gaza Strip (Water Global Practice, 2018). In the West Bank, only about 38% of the generated wastewater from 54% of the population is collected through sewer networks (mainly urban centers). In Gaza, the collection system is much better, where about 80% of the generated wastewater from 84% of the population is collected. Non-connected communities (mainly rural) are discharging untreated wastewater into open areas, Wadis, or cesspits. The Israeli settlements exacerbate the issue by discharging untreated wastewater into Palestinian nearby Wadis (Water Global Practice, 2018; PCBS, 2019).

The treatment capacity in Palestine remains limited and unevenly distributed. In the West Bank, collected wastewater is treated in 14 wastewater treatment plants (WWTPs); few of them operate effectively, including those in Al-Bireh, Nablus West, and Jenin (PCBS, 2015). Table 2 lists the WWTPs in the West Bank and their design capacity (WSRC, 2018). In Gaza, 4 WWTPs are available and have faced operational challenges due to energy shortages and frequent damage by Israelis. This, in turn, hindered consistent performance (OCHA, 2021).

TABLE II. WWTPS IN THE WEST BANK

WWTP	Governorate	Design Capacity (m^3/day)
Nablus West	Nablus	15,000
Jenin	Jenin	7,500
Jericho	Jericho	6,600
Ramallah Al-Bireh	Ramallah	6,100
Ramallah Al-Tireh	Ramallah	2,000
Hebron Sair/Arroub	Hebron	1,200
Ramallah Rawabi	Ramallah	710
Nablus Beit Dajan	Nablus	540
Nablus Sarra	Nablus	460
Ramallah Taybeh-Rammun	Ramallah	450
Jenin Anza	Jenin	342
Nablus Beit Hasan	Nablus	211
Qalqilya Hajja	Qalqilya	173
Jenin Misilya	Jenin	150

Although WWTPs in the West Bank produce high-quality treated water, this resource remains underutilized, with only 9.5 mcm treated each year and less than 5% utilized for irrigating fodder crops like alfalfa and barley (Wawi, 2017). Hence, there is a dire need to develop a robust, comprehensive approach to wastewater reuse in Palestine, which could significantly reduce stress on freshwater resources, especially in agriculture-dominated regions.

C.2 Desalination

Desalinated water is a potential water resource that can be used to fulfill the increasing water demand under a limited supply of freshwater, mainly in arid and semi-arid regions such as Palestine. For several reasons, including the high cost of desalination plant construction and operation, a lack of experience, high energy demand, and, on top of that, the political constraints, its potential use is still vulnerable.

Desalination in Palestine is applied to both seawater (mainly in Gaza) and brackish groundwater (in Gaza and the Jordan Valley). As of 2019, the total volume of desalinated water in Palestine reached approximately 4.1 mcm. In Gaza, over 150 small-capacity desalination plants were in operation, with about 17% of them managed by public utilities and the remainder operated by private commercial entities (Peiris et al., 2017). While these facilities play a crucial role in addressing acute water shortages, brackish water desalination plants contribute to the further degradation of Gaza's Coastal Aquifer by accelerating its overexploitation and exacerbating salinity levels (Water Global Practice, 2018). Moreover, to meet the increasing water demand, the PWA, with support from some international agencies (such as the UNICEF), plans to implement three seawater desalination plants, with a total capacity of 35,000 m3/day (Peiris et al., 2017; Union for the Mediterranean, 2022). Details for the three plants are summarized in Table 3.

TABLE III. SEAWATER DESALINATION PLANT LOCATIONS AND CAPACITY

SDP location	SDP capacity (m^3/day)
North Gaza	10,000
Middle Gaza	5,000
Southern Gaza	20,000

In the long term, there is a plan to build the Gaza Central Desalination Plant at $562 million to produce an annual total of 100 mcm of desalinated water, which will serve about 2 million people in Gaza (Union for the Mediterranean, 2022).

In the Jordan Valley, there exist about 160 agricultural wells extracting brackish groundwater. Therefore, several small-scale brackish groundwater desalination pilots were constructed and operated by the private sector and primarily serving agricultural needs. The total annual production capacity of these facilities is estimated at less than 0.5 mcm. Studies have demonstrated that integrating reverse osmosis desalination technology with solar energy is economically feasible and can significantly reduce the desalination operational costs (Taha and Al-Sa'ed, 2017). A large-scale desalination plant has been proposed for development downstream of the Fashka Springs, in the vicinity of the Dead Sea, with a projected annual capacity of at least 22 mcm (Dweik et al., 2017).

C.3 Rainwater Harvesting

Rainwater Harvesting (RWH) can be defined as the process of collection and storage of rainwater to be used later to increase the availability of water for different uses (e.g., domestic, agriculture, etc.) mainly in arid and semi-arid areas (Critchley et. al., 1991; Yannopoulos et. al., 2019). RWH is recognized as an ancient and enduring practice that continues to play a vital role in water resource management for both domestic and agricultural applications, especially in regions characterized by limited and irregular rainfall (Critchley et al., 1991; Qadir et al., 2007). Palestinians have been harvesting rainwater for a long time, particularly in rural areas (Shadeed and Lange, 2010). In the West Bank, RWH is considered a strategic alternative to satisfy the increasing water needs for both domestic and agricultural uses (Shadeed, 2011). About 60% and 65% of the entire West Bank area (Figure 4) is classified as suitable to highly suitable for RWH for domestic and agricultural uses, respectively. Moreover, high to very high water-poor conditions cover about 60% of the West Bank area, where 60% of Palestinians live. Hence, there is a dire need to look into adaptive and sustainable water supply alternatives, among which RWH would be a viable one to partially fulfill water needs for both domestic and agricultural uses therein (Shadeed et. al., 2019; Shadeed et. al., 2020).

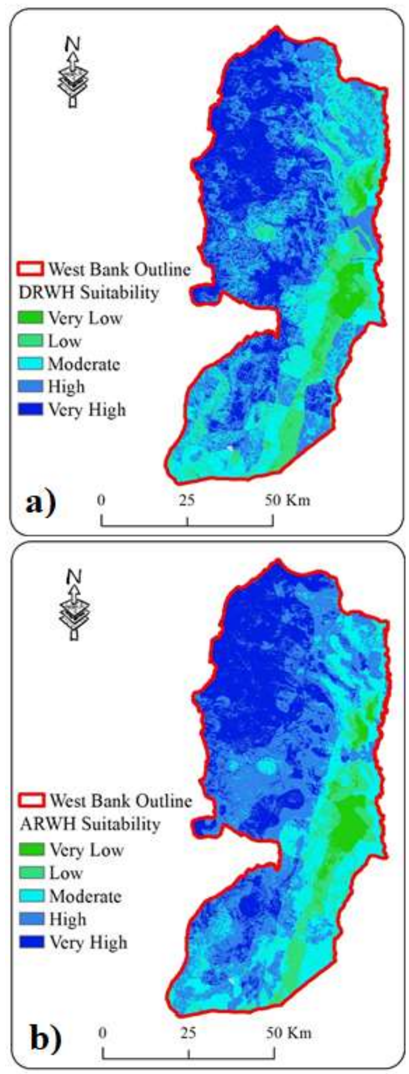

Figure 4. DRWH (a) and ARWH (b) suitability maps for the West Bank

Rooftop RWH can be viewed as one of the most commonly used practices in several communities in Palestine. It was estimated that the potential average annual rooftop RWH volume that can be theoretically harvested from West Bank rooftops is 37 MCM, with 86% of it potentially collectible from rooftops in areas classified as suitable to highly suitable for domestic RWH (Alawna and Shadeed, 2019). The rooftop RWH contributed about 4 mcm for domestic use in the West Bank (PWA, 2016). Shadeed and Alawna (2021) studied the optimal sizing of rooftop RWH storage tanks for sustainable domestic water use in the West Bank. They found that for the rainy season (October to May), an average rooftop area of 150 m^2, a family size of 4.8, water demand of 90 liters per capita per day, and optimal storage tank size ranges between 20 m^3 (in Jericho) to 51 m^3 (in Jerusalem) (Figure 5).

Schild et al. (2023) assess the cost-benefit analysis of deploying various rainwater harvesting systems in the West Bank. They determined that the construction cost of cisterns is typically excessively high for cost-effectiveness. Nevertheless, the majority of Palestinians are willing to pay such expenses due to the uncertainty of the water supply. Furthermore, the establishment of cisterns at the household level would likely improve welfare.

Suitability mapping for seven domestic and agricultural RWH techniques was accomplished for the entire West Bank. Multiple suitability criteria were employed to map seven RWH techniques. Each technique's suitability was assessed on a scale of low, moderate, and high (Table 4) (Adham et. al., 2022).

TABLE IV. PERCENTAGE OF THE WEST BANK SUITABILITY FOR SEVEN RWH TECHNIQUES

RWH Technique	Suitability		
	Low	Moderate	High
On-farm pond	3.4	52.9	43.8
Bench terraces	0.9	29.6	69.5
Check dam	1.7	40.1	58.1
Eyebrow terraces	14.8	72.8	12.3
Cistern	0.0	53.7	46.3
Contour ridges	3.3	33.0	63.7
Runoff basin	6.3	64.4	29.2

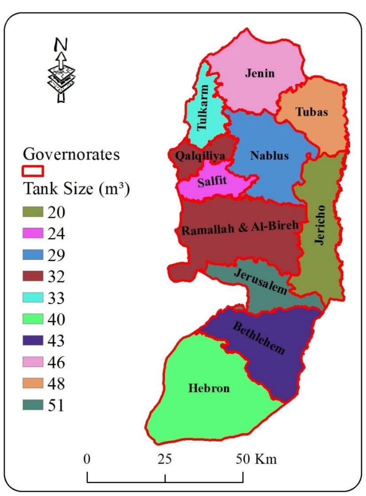

Figure 5, Rooftop RWH tank size for the different West Bank governorates

D. Water Supply Services and Water Consumption

In the West Bank, approximately 94% of the population is connected to a water network, 3% receive water services through water tanks, while some communities rely on specialized tanks for their water supply. Consequently, 97% of the West Bank's population has access to water utilities at their households (WSRC, 2022). Most of the West Bank population has access to good-quality freshwater services. Whereas, in Gaza, as water quality deteriorates, only about 1% of the population has reliable access to good-quality freshwater sources (WSRC, 2018). Water supply services are being introduced to approximately 97% of the population in the West Bank, through 286 service providers, and to 25 service providers in Gaza, covering around 90% of the population in Gaza (WSRC, 2022).

Water supply for Palestinians is available either from local groundwater wells and springs or purchased from the Israeli Water Company (Mekorot). Service providers in the West Bank depend heavily on purchased water from Mekorot. This is because the challenges they face in digging new groundwater wells, particularly due to the occupation's control over the C areas. In contrast, in Gaza, service providers primarily rely on groundwater wells to meet their water needs (WSRC, 2022).

In 2022, the amount of water available to Palestinians for different uses was 445.7 mcm, of which 98.8 mcm (22% of the available water) was purchased from Mekorot. Additionally, 298.5 mcm of water was pumped from the Palestinian groundwater wells, while 38.8 mcm was discharged from springs, and 9.6 mcm of desalinated water for drinking in Gaza. It is worth noting that 211 mcm (the available water in Gaza) out of the 445.8 mcm available water for Palestinians is unsuitable for human use due to pollution (PWA, 2022). However, these values are being changed from year to year, as shown in Table 5.

TABLE V. WATER AVAILABILITY STATISTICS IN PALESTINE FROM 2020 TO 2022 (MCM)

Annual Indicator	2020	2021	2022
Water Available	448.4	438.4	445.7
Wells	299.1	297.8	298.5
Springs	53.3	37.0	38.8
Purchased (Mekorot)	90.3	96.1	98.8
Desalinated Drinking Water	5.7	7.5	9.6
Water Supply for Domestic Use	232.6	250.7	250.8

Based on the data of the available water in 2022, the daily per capita allocation of water for domestic use in Palestine is 85.7 (l/c/d), with 86.4 (l/c/d) in the West Bank and 84.6 (l/c/d) in Gaza. Taking into consideration the rapid population growth, the high levels of water pollution, and the limited available fresh water in Gaza, the estimated per capita share of fresh water is merely 20.5 liters per day. In comparison, the average daily water allocation per capita in Israel exceeds 300 liters, which is more than three times the amount available to a

Palestinian individual. The disparity is even greater when considering Israeli settlers, whose per capita water consumption is reported to be more than seven times that of Palestinians (BCBS and PWA, 2024).

Moreover, one of the primary challenges hindering the development of an integrated national water management system in Palestine is the inequitable allocation of water supplies among localities across different governorates. This can be attributed to the physical constraints imposed by the Israeli occupation, which limit Palestinian access to and control over their water resources, thereby undermining efforts to ensure water justice and equitable distribution (BCBS and PWA, 2024). This discrepancy is clearly illustrated in Table 6. To meet the World Health Organization's recommended water supply of 150 (l/c/d), the West Bank requires approximately 32 mcm more than the currently available water resources. When actual consumption levels are considered in comparison to the required quantities, the gap increased significantly to an estimated 65 mcm. In Gaza, the situation is similarly critical, with the consumption-demand gap reaching approximately 53 mcm in 2021 (PCBS, 2022; PWA, 2021).

TABLE VI. DOMESTIC WATER SUPPLY-DEMAND AND CONSUMPTION-DEMAND GAP FOR THE DIFFERENT WEST BANK GOVERNORATES FOR THE YEAR 2021

Governorate	**Population**	**Demand (mcm)**	**Supply (mcm)**	**Surplus (mcm)**	**Deficit (mcm)**	**Consumption (mcm)**	**Actual Surplus**	**Actual Deficit**	**Losses (%)**
Jenin	342,396	18.8	14.0	-	4.8	8.8	-	10.0	37
Tubas & Northern Valleys	66,628	3.7	3.3	-	0.4	1.8	-	1.9	45
Tulkarm	200,629	11.0	16.8	5.8	-	10.0	-	1.0	40
Nablus	419,589	23.0	19.8	-	3.2	14.4	-	8.6	27
Qalqiliya	123,002	6.7	9.6	2.9	-	7.3	0.6	-	24
Salfit	83,050	4.6	4.8	0.2	-	3.8	-	0.8	21
Ramallah & Al-Bireh and Jerusalem (1)	528,107	28.9	30.8	1.9	-	22.0	-	6.9	29
Jericho & Al-Aghwar	53,802	2.9	5.4	2.5	-	3.6	0.7	-	33
Bethlehem and Hebron (3)	1,029,471	56.4	32.9	-	23.5	20.8	-	35.6	37
West Bank	2,846,674	156.0	137.4	13.3	31.9	92.5	1.3	64.8	33

(1) Data exclude those parts of Jerusalem which were annexed by the Israeli Occupation in 1967. 307,744 Palestinian citizens inhabit this area, and no information is available regarding the water supply provided to them.
(2) The needed quantity of water is calculated based on a water supply of 150 l/c/d, according to WHO standards.
(3) It is not possible to separate data for the governorates of Ramallah, Al-Bireh, and Jerusalem, as well as the governorates of Hebron and Bethlehem, due to the nature of their shared water supply system.

III. MAJOR CHALLENGES FACING THE WATER SECTOR IN PALESTINE

One of the worst water crises in the Middle East has resulted from the strict limitations facing Palestine's water sector. The current water availability is far below international standards. Even though Palestine is legally entitled to significant water resources under international law, especially from the Jordan River and Mountain Aquifer system, this shortage still exists. Water security for the Palestinian population is threatened by a complex interplay of political control, population growth (averaging 2.5 percent per year), environmental degradation, and infrastructure constraints (UNCTAD, 2020).

A. Political Challenges

The biggest political barrier to Palestine's water security is the Israeli occupation. Israel unfairly controls Palestinian water development through the Oslo Accords' mechanisms, especially the Joint Water Committee (Selby, 2013). Data indicate that between 2010 and 2020, Israel authorized only 13% of Palestinian applications for new groundwater wells or the rehabilitation of existing ones in Area C of the West Bank, demonstrating the stark limitations on Palestinian water infrastructure projects (OCHA, 2021). Additional obstacles have been brought about in Gaza by the Israeli blockade; according to reports, 61% of materials used for water, sanitation, and hygiene (WASH) infrastructure were refused entry between 2017 and 2021 (GVC, 2022). Significant differences in water allocation are another aspect of the political dimension; The World Bank (2009) reports that Israeli settlers in the West Bank, constituting approximately 15% of the territory's population, get over 80% of the region's shared freshwater resources, resulting in substantial shortages for Palestinians.

Principles of international water law about the fair and reasonable use of common water resources are flagrantly violated by this unequal distribution, which has been institutionalized through military orders and permit systems (Al-Haq, 2019).

B. Environmental Challenges

Water scarcity in Palestine is made worse by growing environmental pressures. Groundwater depletion is the most pressing problem, as current extraction rates are higher than natural recharge (PWA, 2022). In Gaza, where 90% of wells in the coastal aquifer system are affected by severe seawater intrusion due to pumping 200 MCM/year from an aquifer that only receives 55 MCM/year in recharge, this over-extraction is especially severe (UNEP, 2020). These issues are made worse by climate change; estimates suggest that by 2050, rainfall will have decreased by 15–25%, which will result in an estimated 20% decrease in groundwater aquifer recharge (ESCWA, 2013). Another significant issue is the quality of the water; 90% of Gaza's wells have nitrate levels above WHO safety limits (PCBS, 2021), and Israeli settlements in the West Bank release about 40 MCM of untreated wastewater annually into Palestinian valleys and agricultural areas (B'Tselem, 2022). Due to a vicious cycle created by these environmental stressors, development options are further restricted by the limited quantity and declining quality of water resources.

C. Technical Challenges

The water crisis is greatly exacerbated by technical flaws in Palestine's water infrastructure. An average estimated 33% of supplied water is lost due to leaks and unauthorized connections in aging distribution systems, which causes significant water losses (World Bank, 2021). Due to the sanitation crisis, which causes about 108,000 cubic meters of untreated or partially treated sewage to be released daily, contaminating the Mediterranean coastal waters and the coastal aquifer, Gaza faces especially difficult technical issues (CMWU, 2022). Another significant technical barrier is energy dependence; desalination, which is becoming more and more necessary in Gaza, requires 5 kWh per cubic meter, which is unsustainable given the region's ongoing electricity shortages, which cause 12- to 16-hour blackouts every day (UNDP, 2021). With 45% of Palestinian water technicians lacking advanced training in contemporary water management techniques, capacity gaps further impede technical solutions (PWA, 2022). Due to these technical difficulties, even readily available water resources cannot be effectively used or sufficiently treated to satisfy the increasing population demands.

D. Economic Challenges

Addressing Palestine's water crisis is severely hampered by economic limitations. Households in Palestine are severely impacted by the high cost of alternative water sources; on average, tankered water costs $4.5 per cubic meter, while piped water costs $1.2 (World Bank, 2020). Due to high rates of poverty and ineffective billing systems, Palestinian water authorities only recover 40% of billed amounts, undermining the financial viability of water service providers (IMF, 2021). Since about 85% of WASH projects are funded by donors, this financial instability leads to a significant reliance on donor assistance (OECD, 2022). Gaza is in a particularly bad economic situation, with a 45% poverty rate (PCBS, 2022) that significantly reduces household income for water services and a blockade that prevents the import of supplies for infrastructure upkeep and repair. Without substantial external assistance and political reforms to foster economic growth, these economic challenges render technical solutions to the water crisis financially unsustainable.

IV. Potential and Practical Solutions

Palestine's water crisis is a significant challenge driven by political, economic, and environmental factors. Water scarcity is exacerbated by unfair Israeli control over Palestinians' water supplies, restrictions on infrastructure development, and the potential negative impacts of climate change. Nonetheless, practical and feasible solutions exist to improve water security in Palestine, alongside promising opportunities for the future. Several potential and actionable solutions are proposed in the following section.

A. Rainwater Harvesting

In regions where water is strictly vulnerable, every drop truly counts. RWH offers a practical and effective method to alleviate water shortage by enabling individuals and communities to collect and store rainwater from rooftops or other potential engineering surfaces. This approach provides a valuable supplementary water source, especially during prolonged dry seasons.

Palestine receives moderate rainfall during the winter months, particularly from November through March. Rainfall amounts vary significantly, ranging from approximately 150 mm in the Jordan Valley to more than 700 mm in the central mountains of the West Bank, and effective capture of this resource can have a substantial impact (PWA, 2020). Historically, many Palestinian homes were equipped with cisterns for RWH; however, this practice diminished over time as piped systems expanded. Today, with these networks experiencing growing pressure and uncertainty, individuals and communities are increasingly turning back to RWH as a reliable alternative and even a primary water source in some rural areas.

Numerous successful projects illustrate the significant impact of RWH. In the southern West Bank, particularly in areas such as Hebron and Yatta, the Palestinian Hydrology Group (PHG) has assisted over 400 families in installing rooftop rainwater collection systems. These systems typically include essential components such as gutters, filters, and sealed storage tanks designed to preserve water for extended periods. According to PHG reports, families using these systems benefit from reduced expenditure on trucked water, improved water security, and enhanced hygiene and health outcomes (PHG, 2017).

Gaza, which faces severe water shortages and where much of the groundwater is unsafe for drinking, has seen an increase in RWH projects. UNICEF and its partners have implemented rooftop RWH systems in residences and educational institutions throughout the Gaza Strip. Even small-scale systems have been transformative, especially during power outages or infrastructure failures that disrupt access to running water (UNICEF, 2018).

Collecting rainwater provides numerous distinct benefits. It empowers families and communities by restoring local water self-sufficiency, reduces reliance on overexploited groundwater aquifers, and is considerably more cost-effective than large-scale infrastructure projects such as desalination plants. Additionally, RWH is environmentally friendly, helping to reduce runoff that can lead to soil erosion or flooding. In rural areas, the use of RWH for irrigation or livestock supports food security and sustains local livelihoods (Nazer et al., 2010).

Nonetheless, RWH faces several challenges. Rainfall occurs only during a few months annually, necessitating adequate storage capacity to sustain the water supply throughout dry periods. If systems are not properly maintained—such as roofs that are unclean or storage tanks that are not regularly cleaned—water quality may deteriorate. While first-flush systems and simple filters can improve water quality, they also increase costs. Although many RWH systems in Palestine have received financial support from donors or NGOs, there remains no national policy or building code that mandates or promotes their widespread implementation (World Bank, 2018).

For RWH to achieve significant expansion throughout Palestine, support from the government and local authorities is essential. The PWA could integrate RWH into its border water management strategies and mandate the installation of RWH systems in new constructions, particularly in public facilities such as schools and health centers. Providing incentives or small grants to low-income families for the installation of storage tanks and filters would be highly beneficial. Equally important, community training and public awareness campaigns are necessary to educate individuals on proper construction, operation, and maintenance of these systems to ensure their safety and effectiveness.

To sum up, RWH may not entirely resolve Palestine's water challenges, but it can play a significant role in alleviating them. It is effective, environmentally sustainable, and socially empowering. By strong policy support, targeted technical assistance, and active community participation, RWH has the potential to help Palestinian households to bridge the persistent water supply-demand gap.

B. Smart Water Management

Smart Water Management (SWM) refers to the application of modern technologies—such as sensors, real-time data platforms, remote monitoring, and advanced analytics—to enhance the management, distribution, conservation, and reuse of water. In regions such as Palestine, where water availability is limited, infrastructures are often outdated or inefficient, SWM has the potential to transform water resources management. It enables water authorities and municipalities to take faster, data-driven decisions that reduce waste, improve access, and help communities maximize the value of every water drop.

Palestine's water infrastructure faces multiple challenges, including intermittent supply, aging pipelines, unregulated consumption, and significant water losses due to leaks and theft. According to the PWA reports (PWA, 2020), in some areas up to30% of water is lost before reaching households. Smart technologies can help address these issues by detecting leaks in real time, monitoring pipeline pressure, and alerting technicians before problems escalate to critical levels. The use of smart meters also enables consumers to track their water usage and adjust consumption habits, conserving both water and financial resources.

A notable instance arises from a pilot initiative started in Ramallah, where smart meters were deployed in selected neighborhoods. These meters offered households and local officials immediate insights into water usage, leak identification, and billing precision. Early reports suggested a 15–20% reduction in water consumption solely because of increased consumer awareness and transparency (World Bank, 2018). Other areas, like Jericho and Tulkarm, have experimented with sensor-driven monitoring systems for groundwater wells and pumping stations, aiding in the optimization of discharge and avoiding over-pumping of groundwater.

An additional advantage of SWM is its ability to facilitate long-term planning. Information gathered from smart infrastructure can assist decision-makers in analyzing consumption trends, predicting future needs, and making better investment choices. This is particularly significant in Palestine, where political uncertainty and reliance on donors frequently hinder long-term infrastructure initiatives. Improved data empowers water authorities to prioritize maintenance, plan system expansions, and advocate for resources more effectively (Khatib et al., 2017).

Nonetheless, the deployment of smart water solutions in Palestine faces several challenges. First, the capital costs of installing digital meters, sensors, and data systems can be substantial, particularly for smaller or financially constrained municipalities. Second, many areas lack internet connectivity or reliable electricity required to operate real-time monitoring systems. Third, there is a shortage of skilled personnel to operate and maintain these technologies. However, these challenges are not unbeatable. donor support, public-private partnerships, and targeted skills training programs, Palestine can gradually strengthen its SWM systems—starting with high-need urban areas and later expanding to rural communities.

C. Efficient Irrigation Techniques

Agriculture is essential to Palestine's economy and culture, yet it also requires a significant share of the limited water resources. Consequently, implementing effective irrigation methods is crucial for supporting farmers' livelihoods. Conventional irrigation techniques like flood irrigation are commonly practiced but frequently result in considerable water loss due to evaporation, runoff, and deep percolation.

Contemporary irrigation techniques, such as drip systems and sprinklers, have proven to be more efficient by supplying water directly to plant roots or distributing it evenly across crops. Drip irrigation, specifically, is well-suited to the water-limited conditions in Palestine. This technique applies small amounts of water slowly and precisely, reducing water consumption by up to 50% compared to traditional methods.

Furthermore, drip irrigation reduces weed growth and prevents soil erosion by concentrating water delivery (FAO, 2019). Sprinkler irrigation is an alternate option that provides effective water utilization for different types of crops and larger fields. While it demands energy for operation and upkeep, solar-powered pumps have been implemented in certain regions to enhance sustainability and reduce costs (PWA, 2020). Additionally, integrating effective irrigation systems with appropriate irrigation timing—watering plants according to weather patterns and soil moisture levels—can further minimize water loss.

Enhancing water availability for agriculture is also achieved by integrating efficient irrigation with water-saving measures such as RWH and the reuse of treated wastewater (UNDP, 2018). Although the benefits are clear, significant challenges, such as high upfront costs, limited technical expertise, and political as well as infrastructural constraints, hinder the widespread adoption of these methods among farmers in Palestine.

Effective irrigation methods, such as drip and sprinkler systems, offer practical and efficient remedies to the water shortage challenges facing Palestinian agriculture. With the support of appropriate policies, training, and subsidies, these approaches can significantly improve sustainable water use and strengthen food security.

D. Wastewater Reuse

Alsa'di et al. (2024) investigated the motivations and practices of using treated wastewater (TWW) to irrigate crop fields in Jenin, Palestine. Around 40 farmers were surveyed for data collection. The results showed that 66% of the farmers grew alfalfa crops, while 30% grew fruit trees. The main obstacles the farmers faced before starting to use TWW were disgust (68.2%), worries about the quality of TWW (68.2%), health concerns (63.6%), and concerns about adverse effects on the soil (63.6%). All interviewed farmers considered the establishment and funding of an irrigation project to be the cornerstone for any reuse project. The second most important driving factor was the price of TWW, which is 10–25% of the fresh water prices.

After reusing TWW for irrigation, 59% of the farmers did not use any fertilizer, but they were not sufficiently aware of the crops' water needs or the nutrients in the TWW. All the fodder-growing farmers abstained from selling their crops before drying. The farmers used the TWW for five to nine months annually. After the TWW was reused, the main positive impacts of the TWW reuse were increased crop yields (77.3%), crop quality (50.0%), and crop marketing (47.7%). On the other hand, the main negative impacts were the blocking of the irrigation systems (77.3%) and the release of odors (54.5%). After practicing TWW use in crop irrigation, the key factors contributing to the "no difference" index were the effects on human health (100%), soil quality (56.8%), and insect spread (54.5%).

Therefore, the results of the study support the decision makers in implementing TWW reuse policies for crop irrigation in arid regions with scarce water resources. Monitoring TWW reuse and training farmers and helping them overcome obstacles is essential.

E. Desalination

Desalination is the process of removing salt and other contaminants from seawater or brackish water to produce freshwater for drinking and agricultural use. In Palestine, where freshwater is limited, desalination offers a promising option to expand water availability, particularly in coastal areas such as Gaza, where groundwater quality is greatly degraded.

The Gaza Strip is experiencing a severe water crisis caused by excessive groundwater pumping, seawater intrusion, and contamination. About 97% of the groundwater in Gaza is not suitable for domestic use (PWA, 2020). Desalination plants can provide a reliable supply of clean water to meet the domestic, agricultural, and industrial needs, thereby reducing dependence on limited groundwater and purchased water.

Numerous desalination initiatives have been launched in Gaza, featuring small to medium-sized reverse osmosis (RO) facilities. These facilities have improved access to safe drinking water for many residents (UNICEF, 2019). Plans for larger desalination plants are underway to increase capacity and serve a wider population.

Even with its potential, desalination encounters various challenges in Palestine. The high costs of construction, operation, and maintenance, combined with the need for a reliable electricity supply, limit the scalability of desalination facilities. Their substantial energy consumption raises concerns about environmental sustainability unless renewable energy sources are integrated (World Bank, 2018). Political and logistical challenges, particularly in Gaza, further complicate project implementation.

To ensure optimal benefits, desalination must be incorporated into a comprehensive national water management plan encompassing water conservation, the reuse of wastewater, and RWH. Investing in renewable energy and energy-saving technologies can lower expenses and minimize environmental negative impacts. International donor support and strategic partnerships are essential for the successful implementation of desalination initiatives in Palestine.

In summary, desalination represents a critical solution to address water shortages in Palestine, especially in areas where freshwater resources are depleted or polluted. Despite existing challenges, with strategic planning and targeted investment, desalination can significantly contribute to securing a sustainable water supply for Palestinian communities.

F. Public Awareness

Palestine's water shortage results from a combination of political and environmental constraints, compounded by limited public awareness and low community participation in water resource management. In this regard, raising public awareness becomes a viable, affordable, and expandable solution that supports regulatory actions and infrastructure development (UNESCO, 2020).

Public awareness is vital in shaping water usage behaviors and promoting conservation efforts. In Palestine, where the average water availability per person is significantly lower than the global water poverty benchmark of 1,000 m^3/year (World Bank, 2018), both individual and community initiatives are crucial to tackle the crisis. Awareness campaigns that educate citizens on water limitations, the actual costs associated with water, and effective strategies for minimizing consumption—such as fixing leaks and installing water-saving appliances—have demonstrated success in enhancing water use efficiency (Abu-Madi & Trifunovic, 2010). In agriculture, increasing knowledge about efficient irrigation techniques and the selection of appropriate crops can lead to significant reductions in water use.

Education plays a crucial role in fostering lasting behavioral changes. Incorporating water-related subjects into educational programs can help instill values of water stewardship in younger generations. In Palestine, organizations such as the Palestinian Hydrology Group (PHG) and global entities like UNICEF have rolled out awareness initiatives in schools, which include workshops, environmental clubs, and campaigns aimed at conserving water (PHG, 2021). These programs facilitate knowledge sharing not only within *educational* institutions but also among families and the surrounding communities, thereby enhancing their overall effectiveness.

Engaging with the community and conducting media campaigns greatly improves the scope and impact of public awareness efforts. Leveraging local organizations—like mosques, community centers, and municipal councils—can aid in spreading culturally relevant messages regarding water conservation (Nazer et al., 2010). Furthermore, radio, television, and social media platforms play vital roles in reaching broader audiences. Effective media campaigns often highlight local water-saving champions and offer clear, actionable recommendations tailored to specific contexts (UNDP, 2019). Women in Palestine are vital in managing household water usage and can play an important role in encouraging conservation initiatives. Educational programs aimed at women that provide practical tips and training have demonstrated improvements in water efficiency and hygiene practices within households (UN Women, 2014). In a similar vein, it is crucial to involve refugee camps and marginal rural areas—often overlooked in national strategies—in awareness initiatives to guarantee fair access to information and foster community engagement in water governance (PWA, 2020).

Although public awareness initiatives hold great promise, they encounter several challenges. These include a lack of trust in public institutions, limited access to affordable water-saving technologies, and heavy reliance on external funding sources. Additionally, effective awareness campaigns must be integrated within broader water policy frameworks. Without concurrent investments in infrastructure, regulatory measures, and institutional capacity, raising awareness alone may not result in lasting change. Public awareness should be regarded as a fundamental component of integrated water resource management in Palestine. When supported by an enabling policy and institutional framework, it can significantly enhance sustainability, equity, and resilience within the water sector.

G. International Support and Funding

Due to the ongoing challenges facing Palestine's water sector—including limited access to water sources, aging infrastructure, and political constraints—international assistance and funding are essential for sustaining and advancing water resources. The Palestinian Authority's capacity to independently develop and robust water infrastructure has been constrained by the region's geopolitical complexities. Consequently, donor support has become a critical component of both emergency relief efforts and long-term water development strategies. International donors such as the World Bank, the EU, and various UN agencies have funded infrastructure projects, capacity-building programs, and policy development initiatives to improve water access and quality in the West Bank and Gaza Strip. These initiatives include building desalination plants, rehabilitating sewage systems, expanding wastewater treatment plants, and promoting non-conventional water resources such as RWH and greywater reuse (World Bank, 2018; EU Neighbours, 2022). In Gaza, where more than 95% of the groundwater is unsuitable for domestic use, international assistance has been crucial for building large-scale desalination plants, including the Gaza Central Desalination Plant, backed by the EU and other partners (UNICEF, 2020).

In addition to infrastructure development, international funding supports institutional capacity building and regulatory reform of regulations. Initiatives led by organizations such as GIZ, the United Nations Development Programme (UNDP), and the Netherlands aid in establishing water governance frameworks, improving monitoring abilities, and promoting data-driven decision-making (GIZ, 2019). These efforts aim to reduce inefficiencies, ensure equitable water distribution, and strengthen resilience against political and climate-related shocks.

Another crucial aspect is emergency support. During periods of escalating conflict and water shortages, international organizations provide essential resources like bottled water, mobile water purification units, and emergency repairs to damaged infrastructure. Humanitarian interventions in water, sanitation, and hygiene (WASH) led by groups such as Oxfam, the International Committee of the Red Cross (ICRC), and the United Nations Relief and Works Agency (UNRWA) have been crucial in safeguarding public health, especially in densely populated areas like Gaza and West Bank refugee camps (OCHA, 2021).

Even with these contributions, international support has its limitations. Donor coordination remains fragmented, political constraints imposed by the Israeli occupation persist, and there are restrictions on the movement of materials and personnel that frequently cause delays or blockages in project implementation. These factors often lead to delays or obstructions in project implementation. Moreover, dependence on donors threatens the sector's long-term sustainability, particularly in the absence of a stable national budget and internal investment in water services.

To ensure that international support has the greatest possible impact, it is essential to better align initiatives with national water priorities, enhance transparency, and improve coordination among all potential stakeholders. Sustainable progress depends on locally owned and operated systems, supported by capacity development and policy reforms, rather than externally driven solutions.

International backing and financing remain essential elements of Palestine's water sector. Despite persistent challenges, donor involvement continues to play a key role in infrastructure development, emergency response, and institutional robustness. Achieving long-term water security in Palestine requires reinforcing these partnerships and fostering sustainable solutions grounded in the local context.

H. Policy and Governance Reforms

In Palestine, effective water management involves not just technical and financial challenges, but also significant governance issues. Inadequate policy frameworks, fragmented institutional responsibilities, and weak regulatory enforcement have hindered the efficient use and safeguarding of water resources. As a result, comprehensive policy and governance reforms are crucial to enhance efficiency, equity, and sustainability in the Palestinian water sector.

Overlapping responsibilities, inadequate coordination among key institutions, and weak enforcement mechanisms characterize Palestine's existing water governance system. The PWA acts as the main regulatory body but often struggles to implement its strategies due to limited political authority and institutional fragmentation. Differing priorities and capacities among municipalities, service providers, and donor agencies frequently result in inefficiencies and duplicated efforts (World Bank, 2018).

Recent policy advancements, including the Palestinian Water Law No. 14 of 2014, represent a positive step toward reorganizing the water sector. This legislation established the Water Sector Regulatory Council (WSRC) and mandated the creation of regional water utilities to centralize and professionalize service provision. However, the implementation of these reforms remains partial, with many service providers operating below capacity due to institutional inertia, budget constraints, and political instability (WSRC, 2020).

To strengthen governance, it is necessary to improve transparency and accountability while increasing stakeholder participation in decision-making processes. For example, transparent pricing mechanisms can support cost recovery and encourage water conservation, whereas public consultations and participatory planning ensure that local needs and knowledge inform water strategies. In addition, clearly defining the roles of the PWA, WSRC, and water utilities is essential to avoid overlaps and clarify sector responsibilities (OECD, 2016).

Capacity-building is another vital component of effective governance reform. Numerous local water operators lack the technical, administrative, and financial skills needed for efficient system management. Investment in training programs, digital tools, and monitoring systems can improve service provision and facilitate data-driven policy development. Moreover, robust regulatory oversight is necessary to ensure compliance with water quality standards, licensing requirements, and equitable service access (GIZ, 2019).

Governance reforms are significantly impeded by political constraints, especially the Israeli control over crucial water resources and infrastructure development in Area C of the West Bank. Nonetheless, internally driven improvements in policy coherence and institutional coordination among Palestinians can lay the groundwork for more resilient and responsive water systems.

Reforming policy and governance are essential to addressing Palestine's water challenges. Such reforms can enhance service delivery, enhance resilience, and promote more equitable and sustainable water resources management by strengthening institutional capacity, clarifying roles, ensuring accountability, and encouraging participatory governance.

V. Conclusion

Palestine's water sector is facing a complex crisis driven by political limitations, environmental degradation, technical shortcomings, and economic obstacles. These interconnected challenges have created a persistent condition of water insecurity that affects all aspects of life for Palestinians. This study assessed the water situation in Palestine, identifying available and accessible water resources, major challenges, and feasible solutions. The total annual water supply in Palestine is approximately 450 MCM, which constitutes only one-third of the total available water. Water supply is mainly sourced from local groundwater wells (~70%), springs (~ 10% MCM), and 20% is purchased from Mekorot (~20%).

The political constraints imposed by the Israeli occupation are the primary drivers of the water crisis. The Palestinians were denied access to most of their groundwater resources, with nearly 87% of Palestinian applications for new wells or the rehabilitation of existing ones being rejected by the Israeli occupation in the last decade. Additionally, environmental pressures, particularly climate change, further exacerbate the situation. Rainfall has been declining, and groundwater depletion is severe; pumping rates are about 60% higher than natural recharge. Projections indicate that average annual rainfall could decline by about 20% by 2050. Technical deficiencies in the water infrastructure add to the problem. Approximately 35% of supplied water is lost through leaks and unauthorized connections in aging water distribution systems.

Addressing these challenges requires urgent interventions and sustainable water management strategies aimed at both increasing supply and protecting limited resources. Non-conventional water sources such as RWH, treated wastewater reuse, and desalination offer some of the most promising and feasible solutions. Together, they could provide up to 250 MCM of water annually, including an estimated 50–80 MCM from RWH, 100 MCM from desalination, and approximately 80–90 MCM of high-quality reclaimed water if 50% of wastewater is effectively treated and reused. Additionally, immediate implementation of corrective technical and management improvements is essential to reduce water losses and enhance resource conservation.

In conclusion, Palestine's water crisis is severe and worsening. However, by implementing the feasible solutions outlined in this study, it may be possible to overcome the major challenges facing this vital sector.

VI. Recommendations

Based on the findings of this study, the following short- and long-term interventions are recommended to address the critical water crisis in Palestine.

A. High-priority short-term actions

- Scaling up of RWH by mandating its integration into building codes, especially in the 60% high-suitable areas in the West Bank.
- Maximizing treated wastewater reuse to fully utilize the 175 MCM of the annually generated wastewater. This requires upgrading the existing WWTPs, constructing new treatment facilities with modern, efficient technologies, and replicating the successful reuse projects from Nablus and Jenin. In addition, awareness campaigns should be launched to address public concerns and promote the safe use of treated wastewater in agriculture and industry.
- Repairing and upgrading water and sanitation infrastructure, including aging water distribution networks, storage facilities, pumps, and groundwater wells. Priority should be given to Gaza, where 65% of the water infrastructure has been destroyed.

B. Long-term actions

- Constructing the central seawater desalination plant in Gaza with a production capacity of about 100 MCM/year to substantially meet Gaza's water needs.
- Adopting and promoting efficient irrigation technologies, such as drip and sprinkler systems, to improve water use efficiency and reduce agricultural consumption by up to 50%.
- Implementing smart water management systems incorporating advanced leakage detection and real-time monitoring to reduce the current 35% water losses.
- Strengthening institutional capacity and advancing policy reforms through targeted training in modern water management practices, infrastructure planning, and strategic policy development.

References

[1] Abu-Madi, M., and N. Trifunovic 2010 Public perception of water supply and sanitation services in the Gaza Strip. Desalination 251(1–3):87–93.

[2] Adham, A., M. Riksen, R. Abed, S. Shadeed, and C. Ritsema 2022 Assessing Suitable Techniques for Rainwater Harvesting Using Analytical Hierarchy Process (AHP) Methods and GIS Techniques. Water 14:2110.

[3] Al-Haq 2019 Water apartheid: Israel's discriminatory water policies.

[4] Al-Khatib, I. A., H. A. Arafat, R. Daoud, and H. Shwahneh 2017 Water health and

[5] Alawna, S., and S. Shadeed 2021 Rooftop Rainwater Harvesting to Alleviate Domestic Water Shortage in the West Bank, Palestine. An-Najah University Journal of Research (Natural Sciences) 35(1).

[6] Almasri, M., T. Judeh, and S. Shadeed 2020 Identification of the Nitrogen Sources in the Eocene Aquifer Area (Palestine). Water 12:1121.

[7] Alsa'di, A., N. Mahmoud, and I. A. Al-Khatib 2024 Utilization of treated municipal effluent for irrigating agricultural land in Palestine: The driving factors and existing practices. Environmental Research 242:117578.

[8] Al-Weshah, R. A. 2000 Optimal use of rainwater harvesting in arid and semi-arid regions. Water Resources Management 14(4):295–311.

[9] Amnesty International 2017 The occupation of water. Report No. MDE 15/6420/2017.

[10] Amnesty International 2022 The Occupation of Water. Electronic document, https://www.amnesty.org/en/latest/campaigns/2017/11/the-occupation-of-water/, accessed August 10, 2025.

[11] Applied Research Institute-Jerusalem (ARIJ) 2015 Status of the Environment in the State of Palestine.

[12] B'Tselem 2022 Settler wastewater contamination in the West Bank.

[13] Baggio, G., M. Qadir, and V. Smakhtin 2021 Freshwater Availability Status across Countries for Human and Ecosystem Needs. Science of The Total Environment 792:148230.

[14] Brown, A., and M. D. Matlock 2011 A Review of Water Scarcity Indices and Methodologies. The Sustainability Consortium Whitepaper 106. Fayetteville: University of Arkansas.

[15] Coastal Municipalities Water Utility (CMWU) 2022 Gaza water status report.

[16] Critchley, W., K. Siegert, C. Chapman, and M. Finkel 1991 Water Harvesting: A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production. Rome: Food and Agriculture Organization of the United Nations.

[17] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) 2019 Water Governance Programme in Palestine. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

[18] Dweik, F., M. Rahil, and M. S. Salama 2017 Evaluation and assessment of water budget in the eastern aquifer basin of the West Bank, Palestine. International Journal of Global Environmental Issues 16(1-3):17-28.

[19] ESCWA (Economic and Social Commission for Western Asia) 2013 Inventory of Shared Water Resources in Western Asia. New York: United Nations Publications.

[20] EU Neighbours 2022 EU supports desalination in Gaza: a lifeline for 2 million Palestinians. Electronic document, https://www.euneighbours.eu, Accessed August 10, 2025..

[21] Fanack Water. 2023. "Water Resources in Palestine." Fanack Water: Water Resources in the Middle East and North Africa. https://water.fanack.com/palestine/water-resources-in-palestine, Accessed August 10, 2025.

[22] Faquseh, H., S. Shadeed, and G. Grossi 2024 Impacts of Climate Change on Groundwater in the Al-Badan Sub-Catchment, Palestine: Analyzing Historical Data and Future Scenarios. Hydrology 11(10):169.

[23] Food and Agriculture Organization (FAO) 2019 Efficient Irrigation Techniques in the Middle East and North Africa. Rome: FAO Publications.

[24] Human Rights Watch 2024 Extermination and Acts of Genocide: Israel Deliberately Depriving Palestinians in Gaza of Water. Electronic document, https://www.hrw.org/report/2024/12/19/extermination-and-acts-genocide/israel-deliberately-depriving-palestinians-gaza, accessed August 10, 2025.

[25] Judeh, T., M. Almasri, S. Shadeed, H. Bian, and I. Shahrour 2022 Use of GIS, Statistics and Machine Learning for Groundwater Quality Management: Application to Nitrate Contamination. Water Resources 49(3):503–514.

[26] Khatib, I., G. Naser, and G. Sarsour 2017 Sustainable Water Management in Palestine: Rainwater Harvesting as a Tool for Adaptation. Journal of Environmental Studies 24(3):123–134.

[27] Mahmoud, N., and A. Yasin 2013 Analysis of Wastewater Management Sector in Palestine. In Water in Palestine. Pp. 103-115. The Ibrahim Abu-Lughod Institute of International Studies (IALIIS).

[28] McCaffrey, S. C. 2007 The Law of International Watercourses. 2nd edition. Oxford: Oxford University Press.

[29] Messerschmid, C. 2021 Water in Palestine: A photographic documentation. Institute for Palestine Studies.

[30] Mizyed, N., and M. Haddad 2009 The drying of Al-Fara'a Spring: Causes and Consequences. In Proceedings for 2nd International Conference on: Water Values and Rights. Palestine Academy Press.

[31] Nazer, D. W., M. A. Siebel, P. van der Zaag, Z. Mimi, and H. J. Gijzen 2010 Water–food–trade–environment nexus of the Western Galilee and West Bank under climate change scenarios. Water Resources Management 24(2):431–446.

[32] Organisation for Economic Co-operation and Development (OECD) 2016 Water Governance in Cities. Organisation for Economic Co-operation and Development.

[33] Organisation for Economic Co-operation and Development (OECD) 2022 Donor financing in the Palestinian water sector. OECD Publishing.
[34] Palestinian Central Bureau of Statistics (PCBS) 2015 Relative distribution of households in Palestine according to the method of wastewater disposal. Ramallah: Palestinian Central Bureau of Statistics.
[35] Palestinian Central Bureau of Statistics (PCBS) 2019 Water Statistics in Palestine. Ramallah: Palestinian Central Bureau of Statistics.
[36] Palestinian Central Bureau of Statistics (PCBS) 2021a Press Release on the Occasion of World Water Day, on March 22nd. Ramallah: Palestinian Central Bureau of Statistics.
[37] Palestinian Central Bureau of Statistics (PCBS) 2021b Water statistics in Palestine. Ramallah: Palestinian Central Bureau of Statistics.
[38] Palestinian Central Bureau of Statistics (PCBS) 2022a Water Tables in Palestine 2021. Ramallah: Palestinian Central Bureau of Statistics.
[39] Palestinian Central Bureau of Statistics (PCBS) 2022b Water and sanitation survey. Ramallah: Palestinian Central Bureau of Statistics.
[40] Palestinian Central Bureau of Statistics (PCBS) 2022c Water access survey. Ramallah: Palestinian Central Bureau of Statistics.
[41] Palestinian Central Bureau of Statistics (PCBS) and Palestinian Water Authority (PWA) 2022 Water Tables in Palestine 2021. Ramallah: PCBS.
[42] Palestinian Central Bureau of Statistics (PCBS) and Palestinian Water Authority (PWA) 2023 The World Water Day; on March 22nd, 2023. Joint Press Release. Ramallah: PCBS. Electronic document, https://www.pcbs.gov.ps/post.aspx?lang=en&ItemID=4468, accessed August 10, 2025.
[43] Palestinian Central Bureau of Statistics (PCBS) and Palestinian Water Authority (PWA) 2024a A joint Press Release on World Water Day on March 22nd. Ramallah: Palestinian Central Bureau of Statistics and Palestinian Water Authority.
[44] Palestinian Central Bureau of Statistics (PCBS) and Palestinian Water Authority (PWA) 2024b The World Water Day; on March 22nd, 2024. Joint Press Release. Ramallah: PCBS. Electronic document, https://www.pcbs.gov.ps/post.aspx?lang=en&ItemID=4716, accessed August 10, 2025.
[45] Palestinian Hydrology Group (PHG) 2015 Rainwater Harvesting and Artificial Recharge in Palestine: Potential and Practices. Jerusalem: Palestinian Hydrology Group.
[46] Palestinian Hydrology Group (PHG) 2017 Rainwater Harvesting Projects in the Southern West Bank: Final Evaluation Report.
[47] Palestinian Hydrology Group (PHG) 2021 Water Education Programs in Palestinian Schools. PHG Reports.
[48] Palestinian Meteorological Department (PMD) 2018 Meteorological Database. Ramallah: Palestinian Meteorological Department.
[49] Palestinian Water Authority (PWA) 2003 Water Database (springs and Wells Data). Ramallah: Palestinian Water Authority.
[50] Palestinian Water Authority (PWA) 2012 National Water Strategy for Palestine: Toward Building a Palestinian State from a Water Perspective. Ramallah: Palestinian Water Authority.
[51] Palestinian Water Authority (PWA) 2014 Palestinian Water Law No. 14/2014. Ramallah: Palestinian Water Authority.
[52] Palestinian Water Authority (PWA) 2015 Water Supply Report. Ramallah: Palestinian Water Authority.
[53] Palestinian Water Authority (PWA) 2016 Water Authority Strategic Plan 2016-2018. Ramallah: Palestinian Water Authority.
[54] Palestinian Water Authority (PWA) 2020a Water and Wastewater Sector Strategy 2020–2030. Ramallah: Palestinian Water Authority.
[55] Palestinian Water Authority (PWA) 2020b Water Resources Status Summary Report. Ramallah: Palestinian Water Authority.
[56] Palestinian Water Authority (PWA) 2021 Water Information System. Ramallah: Palestinian Water Authority.
[57] Palestinian Water Authority (PWA) 2022a Water Information System. Ramallah: Palestinian Water Authority.
[58] Palestinian Water Authority (PWA) 2022b Annual water report. Ramallah: Palestinian Water Authority.
[59] Peiris, M., G. Medeazza, and Z. AbuZuhry 2017 Seawater desalination transforming the Gaza Strip. In the 40th WEDC International Conference, Loughborough, UK. Local Action with International Cooperation to Improve and Sustain Water, Sanitation, and Hygiene Services.
[60] Qadir, M., B. R. Sharma, A. Bruggeman, R. Choukr-Allah, and F. Karajeh 2007 Non-conventional water resources and opportunities for water augmentation to achieve food security in water-scarce countries. Agricultural Water Management 87:2–22.
[61] Schild, J. E. M., L. Fleskens, M. Riksen, and S. Shadeed 2023 Economic Feasibility of Rainwater Harvesting Applications in the West Bank, Palestine. Water 15:1023.
[62] Selby, J. 2013 Cooperation, domination and colonization: The Israeli-Palestinian Joint Water Committee. Water Alternatives 6(1):1-24.
[63] Selby, J. 2019 Water, power and politics in the Middle East. London: Bloomsbury Academic.
[64] Shadeed, S. 2008 Up To Date Hydrological Modeling in Arid and Semi-Arid Catchment, the Case of Faria Catchment, West Bank, Palestine. Ph.D. dissertation, Department of Hydrology, University of Freiburg.
[65] Shadeed, S. 2011 Developing a GIS-based suitability map for rainwater harvesting in the West Bank, Palestine. In Proceedings of the International Conference on Environmental Education for Sustainable Development: Plugging the Hole, Birzeit University, Palestine, November 16–17, 2011.
[66] Shadeed, S. 2012 Spatio-temporal drought analysis in arid and semi-arid regions: A case study from Palestine. The Arabian Journal for Science and Engineering 38:2303–2313.
[67] Shadeed, S., and J. Lange 2010 Rainwater harvesting to alleviate water scarcity in dry regions: A case study in Faria Catchment, Palestine. Environmental Earth Sciences 59:1129–1138.
[68] Shadeed, S., and S. Alawna 2021 Optimal Sizing of Rooftop Rainwater Harvesting Tanks for Sustainable Domestic Water Use in the West Bank, Palestine. Water 13(573).
[69] Shadeed, S., M. Sawalhah, and M. Haddad 2016 Groundwater Quality Characterization and Assessment of Faria Catchment, Palestine. An-Najah University Journal of Research (Natural Sciences) 30.
[70] Shadeed, S., T. Judeh, and M. Almasri 2019 Developing a GIS-based water poverty and rainwater harvesting suitability maps for domestic use in the Dead Sea region (West Bank, Palestine). Hydrology and Earth System Sciences 23:1581–1592.
[71] Shadeed, S., T. Judeh, and M. Riksen 2020 Rainwater Harvesting for Sustainable Agriculture in High Water Poor Areas in the West Bank, Palestine. Water 12(380).
[72] Taha, M., and R. Al-Sa'ed 2017 Application potential of small-scale solar desalination for brackish water in the Jordan Valley, Palestine. International Journal of Environmental Studies 75(1):214-225.
[73] Trottier, J. 2008 A wall, water and power: The Israeli 'separation fence'. Review of International Studies 34(1):105-127.
[74] UNDP (United Nations Development Programme) 2018 Integrated Water Resources Management in Palestine: Sustainable Solutions for Water Scarcity. Jerusalem: United Nations Development Programme.
[75] UNDP (United Nations Development Programme) 2019 Community-Based Water Awareness Campaigns: Lessons from Palestine. United Nations Development Programme.
[76] UNDP (United Nations Development Programme) 2020 Climate Change Adaptation in the Occupied Palestinian Territory. New York: UNDP.
[77] UNDP (United Nations Development Programme) 2021 Supporting Sustainable Water Resource Management in Palestine. United Nations Development Programme.
[78] UNICEF (United Nations Children's Fund) 2018a Improving Access to Safe Water in Gaza through Household Rainwater Harvesting. Gaza Field Report.
[79] UNICEF (United Nations Children's Fund) 2018b Increasing Water Scarcity in Gaza through Seawater Desalination. WASH Field Note. New York: UNICEF.
[80] UNICEF (United Nations Children's Fund) 2020 Water, sanitation and hygiene in Gaza: Situation Report. United Nations Children's Fund.
[81] UNICEF (United Nations Children's Fund) 2023 WASH infrastructure gaps in Gaza. United Nations Children's Fund.
[82] Union for the Mediterranean 2022 The Desalination Facility for the Gaza Strip.
[83] United Nations Conference on Trade and Development (UNCTAD) 2020 The economic costs of the Israeli occupation for Palestinians: The unrealized oil and natural gas potential. United Nations Conference on Trade and Development.
[84] United Nations Conference on Trade and Development (UNCTAD) 2021a The besieged Palestinian water sector. United Nations Conference on Trade and Development.
[85] United Nations Conference on Trade and Development (UNCTAD) 2021b Development challenges in the Palestinian water sector. United Nations Conference on Trade and Development.

[86] United Nations Educational, Scientific and Cultural Organization (UNESCO) 2020 Water Security and the Sustainable Development Goals in Palestine. United Nations Educational, Scientific and Cultural Organization.
[87] United Nations Environment Programme (UNEP) 2003 Desk Study on the Environment in the Occupied Palestinian Territories.
[88] United Nations Environment Programme (UNEP) 2020 Environmental assessment of the Gaza Strip. United Nations Environment Programme.
[89] United Nations Office for the Coordination of Humanitarian Affairs (OCHA) 2021a Gaza Strip: Humanitarian Needs Overview. United Nations Office for the Coordination of Humanitarian Affairs.
[90] United Nations Office for the Coordination of Humanitarian Affairs (OCHA) 2021b Humanitarian needs overview: Occupied Palestinian territory. United Nations Office for the Coordination of Humanitarian Affairs.
[91] United Nations Office for the Coordination of Humanitarian Affairs (OCHA) 2023a Humanitarian bulletin - Occupied Palestinian territory. United Nations Office for the Coordination of Humanitarian Affairs.
[92] United Nations Office for the Coordination of Humanitarian Affairs (OCHA) 2023b West Bank: Access restrictions to water infrastructure. United Nations Office for the Coordination of Humanitarian Affairs.
[93] United Nations Relief and Works Agency (UNRWA) 2022 Water security in Palestinian refugee camps. United Nations Relief and Works Agency.
[94] United Nations Relief and Works Agency (UNRWA) 2018a Improving Access to Safe Water in Gaza through Household Rainwater Harvesting. Gaza Field Report.
[95] UNICEF (United Nations Children's Fund) 2018b Increasing Water Scarcity in Gaza through Seawater Desalination. WASH Field Note. New York: UNICEF.
[96] UNICEF (United Nations Children's Fund) 2020 Water, sanitation and hygiene in Gaza: Situation Report. United Nations Children's Fund.
[97] UNICEF (United Nations Children's Fund) 2023 WASH infrastructure gaps in Gaza. United Nations Children's Fund.
[98] Union for the Mediterranean 2022: The Desalination Facility for the Gaza Strip.
[99] United Nations Conference on Trade and Development (UNCTAD) 2020 The economic costs of the Israeli occupation for Palestinians: The unrealized oil and natural gas potential. United Nations Conference on Trade and Development.
[100] United Nations Conference on Trade and Development (UNCTAD) 2021a The besieged Palestinian water sector. United Nations Conference on Trade and Development.
[101] United Nations Conference on Trade and Development (UNCTAD) 2021b Development challenges in the Palestinian water sector. United Nations Conference on Trade and Development.
[102] United Nations Educational, Scientific and Cultural Organization (UNESCO) 2020 Water Security and the Sustainable Development Goals in Palestine. United Nations Educational, Scientific and Cultural Organization.
[103] United Nations Environment Programme (UNEP) 2003 Desk Study on the Environment in the Occupied Palestinian Territories.
[104] United Nations Environment Programme (UNEP) 2020 Environmental assessment of the Gaza Strip. United Nations Environment Programme.
[105] United Nations Office for the Coordination of Humanitarian Affairs (OCHA) 2021a Gaza Strip: Humanitarian Needs Overview. United Nations Office for the Coordination of Humanitarian Affairs.
[106] United Nations Office for the Coordination of Humanitarian Affairs (OCHA) 2021b Humanitarian needs overview: Occupied Palestinian territory. United Nations Office for the Coordination of Humanitarian Affairs.
[107] United Nations Office for the Coordination of Humanitarian Affairs (OCHA) 2023a Humanitarian bulletin - Occupied Palestinian territory. United Nations Office for the Coordination of Humanitarian Affairs.
[108] United Nations Office for the Coordination of Humanitarian Affairs (OCHA) 2023b West Bank: Access restrictions to water infrastructure. United Nations Office for the Coordination of Humanitarian Affairs.
[109] United Nations Relief and Works Agency (UNRWA) 2022 Water security in Palestinian refugee camps. United Nations Relief and Works Agency.
[110] United Nations Relief and Works Agency (UNRWA) 2024 67% of Water, Sanitation Infrastructure Destroyed in Gaza Since Oct. 7: UN Refugee Agency. Anadolu Agency, July 17. Electronic document, https://www.aa.com.tr/en/middle-east/67-of-water-sanitation-infrastructure-destroyed-in-gaza-since-oct-7-un-refugee-agency/3253711, accessed August 10, 2025.
[111] UN Women 2014 Empowering Palestinian Women in Water Management. United Nations Entity for Gender Equality and the Empowerment of Women.
[112] Water Global Practice 2018 Securing Water for Development in the West Bank and Gaza. World Bank Group.
[113] Water Sector Regulatory Council (WSRC) 2018 Performance Report for Water and Wastewater Service Providers. Ramallah: Water Sector Regulatory Council.
[114] Water Sector Regulatory Council (WSRC) 2020 Annual Performance Monitoring Report of Water Service Providers in Palestine. Ramallah: Water Sector Regulatory Council.
[115] Water Sector Regulatory Council (WSRC) 2022 Performance Monitoring Report of Water and Wastewater Service Providers. Ramallah: Water Sector Regulatory Council.
[116] Water Sector Regulatory Council (WSRC) 2023 Performance Monitoring Report for Water and Wastewater Service Providers. Ramallah: Water Sector Regulatory Council.
[117] Wawi, A. 2017 Governance Assessment of the Wastewater Reuse Policies and Practices in Palestine: The Cases of Jenin and Nablus. M.Sc. thesis, University of Twente.
[118] World Bank 2018 Securing Water for Development in the West Bank and Gaza. Washington, D.C.: World Bank Publications.
[119] World Bank 2021 West Bank and Gaza: Assessment of restrictions on Palestinian water sector development. Washington, D.C.: World Bank Publications.
[120] World Bank 2024 Joint World Bank, UN Report Assesses Damage to Gaza's Infrastructure. Press Release, April 2. Electronic document, https://www.worldbank.org/en/news/press-release/2024/04/02/joint-world-bank-un-report-assesses-damage-to-gaza-s-infrastructure, accessed August 10, 2025.
[121] World Bank Climate Change Knowledge Portal 2023 State of Palestine - Climatology. Electronic document, https://climateknowledgeportal.worldbank.org/country/state-palestine/climate-data-historical, accessed August 10, 2025.
[122] World Health Organization 2021. Health risks from water contamination in Gaza. World Health Organization.
[123] Yannopoulos, S., I. Giannopoulou, and M. Kaiafa-Saropoulou. 2019 Investigation of the current situation and prospects for the development of rainwater harvesting as a tool to confront water scarcity worldwide. Water 11:2168.

Withdrawn Paper

This contribution has been withdrawn and is not included in the proceedings.

978-9950-8599-0-6

Withdrawn Paper

This contribution has been withdrawn and is not included in the proceedings.