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The Socioeconomic Water Problems & Challenges In the Middle East

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Abstract – Water is the most precious and valuable natural resource in the world, vital for the growth of society, economy, agriculture, and industry. This paper deals with the socio-economic water problems in the Middle East. It is an analytical and comprehensive study from a socio-economic perspective that examines the water status-quo, facts, challenges, problems, and solutions in several Middle Eastern countries including Lebanon, Jordan, Egypt, and Palestine. The different topics that are discussed in this paper are the water resources in the Middle East and their management including surface and ground water, water supply and demands, rainfalls and precipitations, rivers and basin, and water hydrological properties; the water problems and their challenges including water pollution, shortage of supply, and scarcity of rainfalls; the possible water solutions including water reuse, desalination, and reduction of population growth; the climate change and its impact on the economy and the social life; among many other issues and topics.

Keywords – Socioeconomics; Water Problems; Water Capital in the Middle East

1. Introduction

Inherently, water covers 71% of the surface of the Earth, and is the most important element in nature for all known aspects of life. The major capacity of water is located in oceans, rivers, seas, lakes, and ground aquifers. Water is vital for human, animal, and plant life, protecting the ecology, irrigating agriculture, preserving public health, as well as supporting industry, economy, and other human activities. However, several observers have predicted that by 2030 more than half of the world countries and population will suffer from water scarcity problems. Additionally, several have suggested that the water demand will surpass the water supply by 50%.

Water is the most precious and valuable natural resource in the Middle East, vital for society, economy, agriculture, and industry growth. This paper presents an overview of water standings and conditions in the Middle East states. It elaborately discusses the various water resources in Lebanon, Jordan, Egypt, Israel, and Palestine including surface and ground water, statistics and metrics, water supply and demands, rainfalls and precipitations, rivers and basin, hydrological properties, water consumption, waste of water, among other issues and topics. Next, the negative aspects affecting the water in the Middle East will be discussed as to outline the effect of climate change and global warming, population growth, bad water distribution and usage, pollution, and improper legislation framework, shedding the light on some possible solutions and remedies such as water desalination and reuse.

2. Water Supply in the Middle East

Water usage will carry on to increase with the growth of population and economic, and will be farther be affected by the agricultural applications, socioeconomic, governmental, and developmental policies. This norm applies to all countries in the Middle East including Saudi Arabia, Jordan, Israel, Lebanon, Syria, Iraq, among others. Table 1 shows the water supply per capita for several countries in the Middle East by 2025 in m^3/year [1]; while, Figure 1 shows the water usage distribution during the years from 1960 to 2010 [2].

Table 1. Water supply per Capita

Country	Water Supply in 1990	Water Supply in 2025
Saudi Arabia	160	50
Libya	160	60
Arab Emirates	190	110
Yemen	240	80
Jordan	260	80
Israel	470	310
Tunisia	530	330
Algeria	750	380
Egypt	1,070	620
Oman	1,330	470
Lebanon	1,600	960

Iran	2,080	960

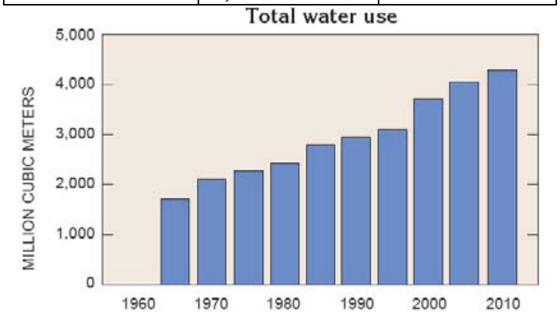

Figure 1. Water Usage Distribution

3. Water Renewal in the Middle East

Other sources of water can be the renewal of water which depends on the overall amount of rainfall and is influenced by evaporation, climate, and temperature, as well as rates of runoff and groundwater penetration and recharge.

- On the Western area of the Jordan Rift Valley, an average of roughly 30% of the total rain that falls in this area can be used: 70% is lost through evaporation, 5% is runoff, leaving only 25% for groundwater recharge.
- On the Eastern area of the Jordan Rift Valley, an average of 90% of the total rain is lost to evaporation, 5% is runoff, leaving only 5% to recharge groundwater. Obviously, out of the 5% of the recharging rainfall that penetrates into groundwater, only a small portion is discharged into underground streams and springs that end up to be surface-water resources. The remaining infiltrated water is kept in groundwater reservoirs called aquifers and is accessible for withdrawal from natural wells.
- The total water withdrawal in the region in the mid 90's was about 3,000 million cubic meters (MCM), of which 56% were withdrawn from wells, 35% from springs and surface-water sources, and 9% from wastewater reuse and artificially recharged water. The projected total renewable water supply in this region is about 2,500 million cubic meters per year (MCM/year).

4. Rainfalls in the Middle East

In the Middle East winter begins in November. Rainfall occurs mainly during the winter months, which then decreases from west to east and from north to south, ranging from 1,200 millimeters (mm) at the northern tip of the region to less than 50 mm in the desert areas. Climate also plays a critical role as temperature changes crossways the region, generally according to latitude, altitude, and province. The hills of the Mountain Belt and Jordan Highland and Plateau usually experience cold winters and hot summers due to their desert climate. For instance, in Amman and Jerusalem, the average daily temperatures for January-February varies from near 7 to 9 degrees °C; while, in summer, the average temperature would be around 25 °C. On the other hand, the average daily temperature in the Jordan Rift Valley region varies from 15 °C in winter to 31 °C in summer. In the Coastal Plain, the average daily temperature is between 16 and 22 °C in winter and between 20 and 31 °C in summer. In the desert, in August for instance, the daily maximum temperature could reach a peak of 40 °C; while in winter, due to the cold and dry air, the temperature could reach a minimum temperature of 2 °C. The region periodically experiences very hot days during the spring and autumn, called Sharav or Khamasini, which rises the ambient temperature from 10 to 20 °C and sometimes could reach 45 °C depending on the area.

5. Groundwater & Springs in the Middle East

Another important source of water in the Middle East is the groundwater extracted from wells and springs which provides more than half of the total water consumption. Groundwater is contained in openings in water bearing rock units called aquifers. The capacity of the openings and the other water bearing characteristics of the aquifers depend on the mineral composition, texture, and structure of the rocks. Groundwater generally moves very slowly and follows the least resistive pathway from the point of recharge to the point of discharge. Superficial groundwater generally moves at rates up to one meter per day or greater. Deeply groundwater moves extremely slowly close to one meter or less per century. Freshwater supplies may be obtained from wells drilled to superficial depths in the Coastal Plain and Jordan Rift Valley and from deeper wells in the Mountain Belt, Jordan Highland and Plateau, and the desert regions. Water depths are highest in the hill and in the desert regions, and superficial in valley floors. Along with wells, springs also provide a great source of water supply from aquifers and constitute the root waters of many streams. Fundamentally, water springs occur where geologic structures, such as faults and fissures deliver a passage for groundwater discharge. Springs represent visible discharge from aquifers; whereas, invisible discharges include leakages, vaporization, transpiration to plants, and hidden springs [3, 4].

6. Basins in the Middle East

A basin also known as drainage basin is an area of land whose surface is covered by rain water and melting snow. A basin acts as a chimney by collecting all the water within the area covered by the basin and driving it to a single destination. Each basin is typically separated topographically from head-to-head basins by a natural geographical barrier such as a ridge, hill or mountain, often called water divide. Several Basins exist in the Middle East; the most notable are the Coastal Basin, the Dead Sea Basin, the Jordan Valley Floor Basin, the Yarmouk Basin, and the Nile Basin [5].

6.1 The Coastal Basin

The Coastal Basin covers an area of around 2,000 km^2 and is situated in the coastal plain alongside the eastern coast of the Mediterranean Sea. The costal basin is categorized as flat relief, and is surrounded from the east by the Mountain Belt, from the north by the Mountains of the Carmel, from the west by the Mediterranean Sea, and from the south by the Desert of Sinai. Its groundwater is constantly recharged by rainfalls at an average capacity of 372 MCM/year (million cubic meters) and usually flows west toward the Mediterranean Sea. This groundwater is the main source of freshwater in the basin, extracted basically from sand, sandstone, and gravel. Groundwater levels are influenced by precipitation and generally vary about 1 to 2 meters per year. Groundwater in the Coastal Basin is normally of decent quality for most of the usages, and has a chloride concentration between 50 and 250 mg/Liter, and a nitrate concentration between 10 and 70 mg/L. High Chloride concentrations up to 6,000 mg/Liter occur in local regions alongside the coast.

6.2 The Dead Sea Basin

The Dead Sea Basin covers an area around 1,525 km^2 and is located within three sections: the Jordan Rift Valley, Jordan Plateau, and the slopes of the Jordan Rift Valley. The Jordan Rift Valley is formed by downhill displacement of faults, which is caused by 900m thick sediments of the Belqa and Ajlun Groups, and sandstones of the Kurnub Group. Groundwater is recharged by rainfall at an average capacity of 57 MCM/year (million cubic meters), and usually flows toward the Dead Sea. Groundwater is the prime spring of freshwater in the Dead Sea basin and is extracted mostly from the Wadi of Amman. In the neighborhood of the Dead Sea, gravel and stones are used as a source of water supply. Foremost springs in the basin include El Maghara and Ein Gedi. In the Wadi of Amman, water is of good to fair quality, having a total dissolved solids concentration between 300 and 1,000 mg/Liter. Concentrations are higher in the lower part of the valley around 750 to 1,250 mg/Liter than the upper part which measures around 500 mg/Liter. In other areas, such as the Mujib Wadi, concentrations can reach sometimes to 1,500 mg/Liter.

6.3 The Jordan Valley Basin

The Jordan Valley Basin is situated in the delta of the Jordan River in the south of Tiberias Lake. The entire basin is located at an elevation that ranges from 210 to 400 meter below sea level. Groundwater is recharged by rainfalls at an average capacity of 21 MCM/year (million cubic meters). Because of the poor water quality in the Jordan River, groundwater is the key source of freshwater in the basin. Around 80% of the groundwater is present in the sandy fans of the wadi; while, the remaining 20% of freshwater sources are withdrawn from sand, and limestone, predominantly in regions where these sections are recharged alongside the hills of the eastern and western slopes. Groundwater levels in the Jordan Valley Floor Basin are of different depths and range from 5 meter in the central part of the valley to 150 meter at the cliffs. Likewise, groundwater quality in the Jordan basin is variable. In the south, water is somewhat salty with chloride concentration ranging from 700 to 1,850 mg/Liter; while, in the north, the water is more-less fresher with concentration ranging from 500 to 1,000 mg/Liter.

6.4 The Yarmouk Basin

The Yarmouk Basin covers an area about 1,426 km^2 and is located in the northern part of the Jordan Plateau. The basin is caused by limestone, chalk, and marl of the Balqa Group and sandstone of the Kurnub Group. In the east, basaltic streams cover rocks of the Balqa Group. Groundwater is recharged by rainfalls at an average capacity of 40 MCM/year (million cubic meters). Groundwater is managed by two chief faults that cut across the basin, one flows northward toward the Yarmouk River, and another one flows westward toward the Jordan River. The Yarmouk River and groundwater are the principal resources of freshwater in the basin, 65% of which are used for irrigation. Groundwater is supplied to springs and wells by four major aquifer systems: The Basalt system, the Riijam system, The Wadi of Amman, and The lower complex [6, 7].

6.5 The Nile Basin

The Nile basin covers around 3,254,555 km^2, which is about 10% of the total area of Africa. The two big tributaries join at Khartoum. The Nile basin is composed of two parts: The White Nile which commences in equatorial East Africa, and the Blue Nile which starts in Ethiopia. At north of Cairo, the Nile splits into two distributaries that pour ultimately into the Mediterranean: the Rosetta distributary to the west and the Damietta to the east, creating by that what is known as the Nile Delta. The Nile basin is complex, and its discharge depends on several factors including weather, evaporation, and groundwater flow. The aquifer system of the Nile is recharged largely from leakage of water from irrigation canals and separation of excess irrigation water from the fields. The recharge rate from irrigation can reach sometimes 1 mm/day. Groundwater heads fluctuate around the year, within a range of a few centimeters to more than one meter. The general flow direction is from south to north. Deviations can be found close the Nile basin, where groundwater stream is directed from the river or towards the river.

7. Statistics on Water in the Middle East

In the coming sections, numbers and metrics pertaining to water resources for various countries in the Middle East are to be presented.

7.1 Water in Lebanon

Lebanon has great water resources, however, due to the political, economic, and security situations, the quality of water, its usage, its conservation, and its drainage are being negatively affected, making water not sufficient for all the Lebanese population, and its flow does not reach all the Lebanese regions, especially the rural areas.

7.1.1 Water Stations

At first, Lebanon installed 70 limnographic network stations in 1930. In 1974, 50 of these stations were down and only 20 were still in operation. The total stations in Lebanon from 1870 till 1975 were 150 functional stations. By the end of the civil war in 1990, almost 10% of these stations have been rehabilitated. By the end of year 2010, only 312 water stations are in function to supply the Lebanese territories with water.

7.1.2 Hydro-Geography & Rainfall

Lebanon is a mountainous country having two parallel mountains that extend from north to south, and have the Bekaa Valley in between. As a result, Lebanon is subject to heavy precipitation and rains especially in the coastal plains and much less in the interior. Since Lebanon climate is generally Mediterranean, it has abundant rainfall in winter and much dryness in summer. The entire area of Lebanon is 10452 km^2, and it has two major hydrological regions: the coastal region, with an area of 5500 km^2, and 12 rivers from the western slopes of the mountain ranges, flowing from east to west and pouring into the Mediterranean sea; and the interior region, with an area of 4 700 km^2, and 3 rivers, the Litani, Assi, and Hasbani rivers. Furthermore, Lebanon can be divided into around 40 drainage basins. Due to the vast plains in Lebanon with good soil and sufficient rainfall, around 360000 ha of Lebanon's land are cultivable, of which around 190000 ha are presently being cultivated.

Rainfall in Lebanon is abundant in winter; where near 90% of all precipitation is received between November and April. January is the rainiest month, and snow is often present in regions higher than 1000m above sea level. Rainfall varies from region to region and from area to area. For instance, yearly average rainfall in the northern Bekaa region, near Hirmil, is 250 mm; in Baalbeck is 550 mm; and in Karoun and Marjoun is 700 mm. All in all, annual rainfall in the coast is 830 mm, 800 mm in the north, 800 mm in Beirut, and 700 mm in the south.

Lebanon has 2200 mm^3/year of surface water essentially available and 2600 mm^3/year possibly available. Several factors play a role in maintaining this amount of water over the Lebanese territories; they are listed in Table 2 [8]:

Table 2. Factors of Water Resources in Lebanon

Factors	Water budget according to Litani Water Authority (mm^3/year)
Total precipitation	+8 600
Evapotranspiration	-4 300
Percolation to groundwater	-880
and flow into the sea	
Flow into Israel	
Hasbani River	-160
Groundwater flow to Huleh and northern Israel	-150
Flow into Syria	
Assi River	-415
Kabir River	-95
Net available surface water	+2 600

The 2600 mm^3/year includes 2400 mm^3/year of surface water and 200 mm^3/year of groundwater. The volume of potentially usable groundwater is 600 mm^3/year, but only 160 mm^3 of this is used. Lebanon does experience a scarcity every 7 to 10 years, lasting for 3 or more years. The United Nations in 1992 estimated that 2557 mm^3/year of available water in Lebanon are being received during the wet season, and a smaller portion of 818 mm^3 during the dry season. This makes a total of 3375 mm^3 of available water. Table 3 delineates significant spatial and seasonal differences in distribution of water in Lebanon in mm^3/year [8].

Table 3. Distribution of Water in Lebanon

Geographic area	Wet season	Dry season	Total
Western Slopes	1 958	515	2 473
Bekaa			
Assi Basin	54	43	97
Upper Litani basin	488	153	641
Hasbani River, springs, and other waters	68	96	164
Total	2 557	818	3 375

7.1.3 The Litani River

The Litani River goes down a total of 1000m from its springs to the Karoun Dam. The sharpest descent is between Karoun and Khardali, where the river drops 600m within a short distance. In its final section, the Litani slowly drops a total of 300m over a distance of 50 km from Khardali to the sea north of Sur. The Karoun reservoir is used for irrigation, supply of potable water, hydroelectric generation, and recreation such as water sports and fishing.

The average rainfall in the Litani is about 700 mm/year, sometimes lower about 450 mm. In the upper Litani, above Karoun, the average rainfall is 800 mm/year in an area of 1600 km^2. In total, 1280 mm^3/year of water is received in this region, 60% of which leaks into groundwater and are lost due to evapotranspiration. As a result, this only leaves 500 mm^3/year of surface water in the upper Litani, 80 mm^3/year of which is used before reaching the Karoun; and hence leaving 420 mm^3/year to reach the reservoir.

The Litani watershed is 2168 km^2 approximately equal to 216800 ha, 80% of which is located at higher than 800m above sea level. Inherently, four cities with 10000 population, six towns with populations of 5000 to 10000, 57 villages with populations of 1000 to 5000, and other settlements with populations of less than 1000 live

in Litani *caza*. A total of 360000 people live in the Litani surroundings.
100 mm^3/year of Litani water is averted near Markaba into the Awali River. 12 Mm^3/year is used for irrigation between Markaba and Kilyah, 18 Mm^3/year between Kilyah and Al Ghandourieh. The flow is again averted in the town of Kassmieh to provide 40 mm^3/year to Kassmieh irrigation. The complete flow of the upper Litani River is utilized to generate hydroelectric power. 420 mm^3/year is employed to generate around 600 kW/h via three power plants: Markaba, Awali, and Jun [9].

7.1.4 Water Consumption in Lebanon

In 1966, 94 mm^3 of water were consumed by the industrial and domestic sectors; whereas, the agricultural sector consumed 400 mm^3. In 1996, Lebanon was assessed to consume around 890 mm^3/year of water. Table 4 delineates the estimated water consumption and water demand in Lebanon per mm^3/year.

Table 4. Water Consumption in Lebanon

Year	Domestic	Industrial	Irrigation	Total
1966	94		400	494
1990	310	130	740	
1996	185–368	35–70	669–900	889–1 338
2000	280	400	1 600	2 280
2015	900	240	1 700	2 840

Domestic water consumption was estimated at 165 L per capita daily in 1996. It reached 215 L by year 2000 and is expected to reach 260 L by year 2015. The capital of Lebanon, Beirut presently harnesses 80 mm^3/year of water, 30 mm^3 of which derives from the Damour area and 50 mm^3 derives from Jeita. The average water consumption of Beirut is estimated to be 250 mm^3/year, and therefore water supply infrastructure is inadequate especially during the summer time.
As for irrigation, 146000 ha of land was fed by rain in 1996. The irrigated area was 23 000 ha in 1956 which is around 10% of the then cultivated area, 54000 ha in 1966, 48 000 ha in the early 1970s, and 87500 ha in 1993. According to the Food and Agriculture Organization of the Nations and the United Nations Development Programme, the irrigated area of Lebanon is expected to rise to 170000 ha by 2015, and this would require 1700 Mm^3/year.

7.1.5 Water Waste in Lebanon

In 1994, the total wastewater flow of Lebanon was 454,000m^3/d, out of which 209,000m^3/d were generated in industrial areas. In 2020, projected wastewater flow is 1.376Mm^3/d with 619,000m^3/d generated in industrial regions. To understand the scale of the task facing officials from the Ministry of Energy & Water and project planners from the country's Council for Development and Reconstruction (CDR), it should be noted that there are currently a limited number of sewers in Lebanon and those which are functioning will need to be replaced soon.

Lebanon has ambitious plans for pollution control by constructing a series of Wastewater Treatment Plant Design Packages along its Mediterranean coastline from Sour (Tyre) in the south to Tripoli in the north of the country. Sewerage and wastewater treatment projects planned or in progress include those at Ghadir, Tripoli and Sidon. At the Ghadir Wastewater Treatment Plant Design Packages, a feasibility study for secondary treatment is currently under preparation and bids for a three-year O&M contract are being evaluated. The project is being financed by the Kuwait Fund for Arab Economic Development.
A further Wastewater Treatment Plant Design Packages for primary and secondary treatment to serve the Greater Beirut area is planned to be built as part of a large construction project to reclaim around 4Mm^2 of land between Antelias and Dbayeh called the Linord, or Littoral Nord. The project aims to recover land using dredged sand from the sea which involves the construction of an 800-1000 berth marina.
A large Wastewater Treatment Plant Design Packages is also to be built to serve Tripoli and its suburbs in the north of Lebanon. The project is funded by the European Investment Bank (EIB) to the tune of $120 million and bidding by contractors is in progress.

A further project involves construction of a Wastewater Treatment Plant Design Packages and sea outfall for the city of Saida, or Sidon, and its suburbs. The project awarded to Arabian contractors is entirely funded by Japanese development aid. The supervision work has been awarded to Nippon of Japan.

Other selected wastewater projects include a Wastewater Treatment Plant Design Packages for Sour (Tyre), associated collector sewers, local sewers and main pumping stations. The treatment plant will achieve a final effluent concentration of 25mg/l BOD5 and 35mg/l suspended solids with further effluent treatment achieved through a UV disinfection system.

As well as construction of coastal treatment plants, sewer systems are also required inland to protect some of Lebanon's major water resources. Construction of a sewer network and associated Wastewater Treatment Plant Design Packages is expected to cost in the region of $400 million but is not considered a priority, according to Associated Consulting Engineers' Nauful.

The Lebanese government recently appointed Société Générale of France and Société Generale de Banque au Liban to advise it on the privatization of water and wastewater services [10].

7.1.6 Possible Solutions for Lebanon

The following is a list of some of the actions needed to improve Lebanon's water management capabilities during the 21st century:

- Refurbish, enlarge the capacity of, and expand the geographic coverage of existing infrastructure. The aim of this attempt is to improve water delivery and reduce water loss, which will also protect groundwater from wastewater contamination.
- Upgrade and update the skills and other capacities of staff.

- Strengthen management in order to develop more efficient use of limited financial resources.
- Update hydrological maps at a scale of 1:2500000, showing major catchment areas, drainage lines, rivers, lakes, and other major and minor water bodies, as well as rainfall distribution patterns.
- Produce hydrogeological maps at a scale of 1:2500000, showing groundwater flow patterns, water-quality levels, aquifer boundaries, existing development, and areas for potential future development.
- Provide drainage to areas at high risk of soil salinization.

7.2 Water in Palestine

7.2.1 Rainfall

Rainfall in Palestine differs from area to area as it can be as low as 150 mm/year in the eastern parts of Central and Southern Palestine and as high as 1100 mm/year in the northern and mountainous parts of Central Palestine. On average yearly rainfall was estimated at 409 mm in Central Palestine and at 275 mm in the south. This makes a total volume of 2349 mm^3, 100 mm^3 of which is located in the southern parts of Palestine. Although most of this water is lost to evapotranspiration and surface runoff, an estimated 550 to 700 Mm^3 percolates into groundwater aquifers.

7.2.2 Surface Water

Five riparian exist for the Jordan River: Palestine, Israel, Jordan, Lebanon, and Syria. It is worth noting that after the war of 1967, Palestinians were not allowed to use their share of Jordan River waters, in spite of the fact that Israel increased its usage to the river, seemingly to supply Central Palestine needs [11].

7.2.3 Groundwater Aquifers

Groundwater aquifers are the ultimate water resource in Palestine. They are actually four major ones, three are located in Central Palestine (the western, northeastern, and eastern aquifers) and one is located in Southern Palestine and is part of the Israeli coastal aquifer. Water from these aquifers is derived from about 370 wells in Central Palestine and about 250 wells in Southern Palestine. Most of the Palestinian wells were built before the Israeli occupation started in 1967. After this time, Palestinians were forbidden to drill new wells or to maintain their original existing ones. Meanwhile, Mekorot built 36 new wells to supply Israeli settlements in Central Palestine with water for irrigation and domestic use. While an Israeli well in Central Palestine provides 1 mm^3/year, Palestinian wells provide only 150000 m^3/year.

7.3 Water in Jordan

The population in Jordan presently exceeds 7 million, and it is increasing in a factor of 2.5% per year. As a result, Jordan has experienced shortages in water resources since early 1960. The country is considered as having water scarcity compared with other countries in the Middle East such as Lebanon or Syria [12].

7.3.1 Water Supply in Jordan

The chief sources of water for Jordan are aquifers and basins fed and recharged through annual rainfall. The Yarmouk Basin is the largest in the country. Other sources of waters exist; however, they are instable as they show short and long term variations. Water supply in Jordan suffers as 85% of the total amount of water is lost to evaporation yearly, leaving only a small amount of surface and groundwater to pour into water supply. The government suggested increasing the water supply by employing various techniques and technologies such as intensive capturing of rainwater through the use of micro and macro dams, desalination of sea water, and importation of water from neighboring countries, as well as other alternatives. However, all these are subject to cost–benefit analyses and geopolitical constraints.

7.3.2 Water Usage in Jordan

Chiefly 77.5% of all water is Jordan is used for agriculture; the remaining amount of water is used for domestic and industrial purposes. Due to urbanization, industrial expansion, and population growth, the yearly demand for water in Jordan is estimated at 25mm^3/year.

7.4 Water in Egypt

The Nile River is the greatest source of water in Egypt and it is has an estimated length of more than 6800 km, and it is considered the longest river flowing from south to north in a 35^o degrees of latitude. It is mainly fed by two big rivers: the White Nile, having sources on the Equatorial Lake Plateau that includes Tanzania, Burundi, Zaire, Rwanda, Kenya, and Uganda, and the Blue Nile having sources in the Ethiopian lands. The average annual rainfall is over 1000 mm. The dry region of the river starts in Sudan where rainfall can reach 1500 mm per year; there exists also a fertile region where rainfall can be between 400 to 800 mm per year; and a desert region where rainfall reaches just 20 mm per year. Some regions in the north of Egypt, rainfalls can be less than 20 mm per year. The total area of the Nile constitutes about 10.3% of the African continent area and spans over 10 countries. For many countries such as Zaire, the Nile basin barely takes part of their land. Other, such as Egypt, Burundi, Rwanda, Uganda, and Sudan are totally cohesive with the Nile basin.

7.4.1 Rainfall

Rainfall is considered somewhat average in certain region in Egypt especially if we go toward the south. Obviously, the Average rainfall is about 200 mm at northern coasts in Alexandria, and it decreases going toward the south to reach 50-100 mm in the Nile Delta region. In Cairo, rainfall ranges between 10-30 mm, fluctuating from year to year. Rainfall is too low and sometimes absent as we go to the south approaching more into the African continent. Rainfall starts in winter between November and January, and sometimes it continues in February and March.

7.4.2 Agriculture & Irrigation

The finest soils in Egypt cover an area of only 1 million ha; whereas, the less good soils cover an area of around 3.6 million ha. In total, the maximum area suitable for agriculture is around 4.8 million ha. The rest of soils in Egypt are unsuitable for agriculture.

7.4.3 Groundwater

Egypt has four different groundwater aquifers: the Nile Aquifer, the Moghra Aquifer, the Nubian Sandstone Aquifer, and the Coastal Aquifer. An aquifer is an underground layer of water from which water can be extracted via wells and is made out of rocks and unconsolidated materials such as gravel, sand, and clay. As a matter of fact, Egypt is a country rich in water but the exponential growth in population makes it a water scarce country. By 2005, Egypt was categorized as a water scarce country since it has less than 1000 m^3 of water per capita per year. Moreover, it is estimated that in 2025 the population will reach 100 million, leading to only a 600 m^3 per capita per year. In 2000, the overall water withdrawal in Egypt was assessed as 68 billion m^3 per year. Doing simple math, Egypt is currently using about 95 % of its available fresh water and thus the situation is considered very critical.

8. Water Problems & Challenges in the Middle East

A nation is considered “Water Stressed” if its total renewable freshwater resources are between 1,000 m^3 and 1,700 m^3 per person annually. However, “Water Scarce” nations have an average of less than 1,000 m^3 of renewable fresh water per person annually. 12 out of the world’s 15 “water scarce” nations are Arab countries and located in the Middle East & North Africa, a region known as the MENA [14]. The Middle East is considered one of the driest and thirstiest areas in the world, and will experience severe water scarcity by 2015. In 2015, Arabs would have to live on around less than 500 m^3 of water yearly. According to many resources, the rapid population growth will farther increase the crisis as more people demands more water for domestic and irrigation purposes. The Arab population is now almost 300 million and is going to multiply to around 600 million by 2050. The hot Climate will worsen the problem. By the end of the 2100, Middle East countries will experience a 25% drop in rainfalls and a 25% increase in evaporation rates. Consequently, agriculture is to be endangered, with estimated decrease in production by 20%. 13 Arab countries are amongst the world 19 most water scarce countries. People in 8 Arab countries have to do with 200 m^3 yearly. It is obvious that without vital changes in policies and regulations, the situation will get worse. Agriculture uses 85% of Arab water use; this is compared with a world average of 70%. Irrigation competence is only 30%, compared to a world average of 45%. Groundwater is over and over exploited, leading to drastic failures in water resources, more pollution of aquifers and seawater mix especially in coastal regions. It is estimated that more than 43% of wastewater is discharged raw, whereas only 20% is reused. On top of that, the Arab world has 5% of the world population, however, only 1% of its renewable water, and that’s why several Gulf Arab countries count on desalinating the sea water, counting around more than 50% of the world desalination volume. Some of this desalinated water is usually used to irrigate crops, golf paths, and plants. In spite of its scarcity, water is often wasted in the Arab world due to its low prices as free water is wasted water, noticing an average price charged in the region around 35% of water production costs and only 10% for desalinated water. Arab governments that most of the time seek new supplies of water, must instead work on enhancing water management, downsizing consumption, promoting reuse and securing water supplies from pollution and overuse. New Water pricing strategies are required to attract new investment and the implementation of policies, rules, regulations, institutional reforms so as to support the management of water. This critical situation is due to several causes and they are listed in the coming sections.

8.1 Population Growth

The Middle East population has more than doubled between 1970 and 2001, going from 173 million persons to 300 million persons and consequently reducing the amount of freshwater to 1,640 m^3 per person per year that is reducing the amount by more than half per capita per year [15]. The average amount of renewable freshwater available in Jordan, Libya, Bahrain, Kuwait, Qatar, Yemen, Saudi Arabia, and the United Arab Emirates is already less than 250 m^3 per person per year. Currently, Arab population is growing by 2% every year or around 7 million per year and it is expected to double in 50 years, reducing the average water per capita to around 1,100 m^3 per year. Figure 2 shows several countries in the MENA region with amount of freshwater [16].

	Population (millions)			Percent of Population Living in Urban Areas, 2001	Annual Renewable Fresh Water (km^2)[b]	Per Capita Annual Renewable Fresh Water (m^3)		
	1970	2001	2025			1970	2001	2025
MIDDLE EAST AND NORTH AFRICA[a]	173.4	385.6	568.0	59	632.3	3,645	1,640	1,113
Algeria	13.8	31.0	43.2	49	14.3	1,040	462	331
Bahrain	0.2	0.7	1.0	88	0.1	455	140	97
Egypt	35.3	69.8	96.2	43	86.8	2,460	1,243	903
Iran	28.8	66.1	88.4	64	137.5	4,770	2,079	1,555
Iraq	9.4	23.6	40.3	68	96.4	10,304	4,087	2,392
Israel	3.0	6.4	8.9	91	2.2	740	342	247
Jordan	1.6	5.2	8.7	79	0.9	555	174	103
Kuwait	0.7	2.3	4.2	100	0.02	27	9	5
Lebanon	2.5	4.3	5.4	88	4.8	1,944	1,120	896
Libya	2.0	5.2	8.3	86	0.6	302	114	72
Morocco	15.3	29.2	40.5	55	30.0	1,960	1,027	741
Oman	0.7	2.4	4.9	72	1.0	1,383	416	206
Qatar	0.1	0.6	0.8	91	0.1	901	170	129
Saudi Arabia	5.7	21.1	40.9	83	2.4	418	114	59
Syria	6.3	17.1	27.1	50	46.1	7,367	2,700	1,701
Tunisia	5.1	9.7	12.5	62	4.1	800	422	327
Turkey	35.3	66.3	85.2	66	200.7	5,682	3,029	2,356
United Arab Emirates	0.2	3.3	4.5	84	0.2	897	60	44
Yemen	6.3	18.0	39.6	26	4.1	648	228	103

Figure 2. Water in the MENA Region

8.2 Urbanization

Around 60% of the Middle East population lives in cities and urban areas. Cities are growing faster than rural areas and a lot of migrants are moving from villages to urban. As a result, more than three-quarters of the people resides in cities. Water management is seriously affected by this situation as people who live in cities have a habit of using more water than the ones living in rural regions and villages. Fast urbanization can hamper the expansion of adequate infrastructure, such as appropriate distribution techniques, governing mechanisms, and sewage schemes.

8.3 Shortage of Supply

In the Middle East actual water withdrawals in 2000 was equal to 263 km^3 which is around 73% of the annual renewable water resources. Nonetheless, several countries are in the dry areas, such as Egypt, Jordan and those in the Arabian Peninsula. As a result, groundwater is being quickly exhausted, especially in the regions far from the rivers of the Nile and the Tigris/Euphrates, which are already the only source of supply such as Egypt, Saudi Arabia, and the Gulf [17].

8.4 Water Pollution

The quality of water in the Middle East is at the stake as according to the UNDP in 2003, 15% of the overall population has access to unsafe domestic water leading to health problems and a constant increased number of mortality rates especially amongst children who live in poor and rural regions. Pollution of groundwater resources is majorly caused by unprocessed agricultural, industrial and urban waste, bad ecosystems, and quality of life. Another important factor is the intrusion of sea water into groundwater leading to the salinization of springs and wells [18].

8.5 Scarcity in Rainfalls

The yearly precipitation or rainfalls in the Middle East is nearly closed to some millimeters in the desert to more than 1,500 mm in some mountainous regions with most rain falling in the winter months. Other areas particularly in Lebanon, Syrian and the Maghreb are of moderate rainfall close to 500-750 mm. Groundwater suffers too much from low precipitation phenomenon as water availability may be decreased and lands may undergoes droughts and deficiencies.

8.6 High Demands

Due to the population growth in the Middle East, demand for water is progressively increasing year after year. In other terms, large population has higher demands for drinking water, for irrigation, and for domestic use. Egypt is the most visible example as its number of populations is growing so fast at higher pace than what water resources can provide.

8.7 Low Efficiencies in Water Usage

Irrigation and agriculture in the Middle East use mainly surface techniques which characteristically have very low efficiencies. This is not to mention that irrigation generates water losses via evaporation, leakage, and deep filtration. Likewise, domestic water supply infrastructure is old and not appropriately managed and maintained, resulting in high water losses. Additionally, the industrial sector generates too high polluted wastewater that it is hard to be filtered and reused.

8.8 Improper Legislative Frameworks

Most of the current water legislations, rules and regulations in the Middle East are to some extent old and need to be updated so as to meet tomorrow needs. It is worth noting that the judicial system is very slow and bureaucratic, which contradicts the nature of water which need instant action.

8.9 Low Funds

Most water services are mainly governmental, and since most of the governments in the Middle East are characterized by being poor, the allotted funds are much less than the required investments. Therefore, the water infrastructure is fading at high pace, leading to frequent interruptions and failures in the services, increased water losses and inaccurate water distribution. Besides, the operation and maintenance of water services have overcome and strained the budgets of many countries, leading to a lack in funding new projects and in maintain the already exiting water resources and assets.

8.10 Lack of Public Awareness

Public awareness establishes an important balancing element to other technical issues belonging to the rise of conflicts around the appropriate usage of water resources. The insufficiency of public awareness together with lack of access to correct and complete information, make the public opinion prone to be easily misguided. Generally speaking, false news and rumors can all lead to disputes and conflicts among diverse groups of people, mostly driven by political and personal interests rather than being based on true facts.

9. Possible Water Solutions for the Middle East

Many solutions exist whose purpose is to provide answers and roadmap for the many water challenges and problems in the Middle East. They are summed up in the following sections [19].

9.1 Qanats and Rainwater Harvesting

A Qanat is the conventional way for bringing water to the surface of the earth. It consists of a series of tunnels drilled into a cliff. Such intersected tunnels are inclined, allowing water to pour out and form an oasis in a drier area. Another method is rainwater harvesting, which consists of collecting water from roofs, reservoirs, and other sources, and use them for agricultural use. In Egypt, the farmers of Bedouin have reformed the degraded lands to be used for agriculture by storing extra water in *wadis* and then using the water for irrigation.

9.2 Water Reuse

Water reuse implicates the capturing and handling of water from one sector to another. For instance, Domestic water needs to be the cleanest, so the perfect solution is for the water to be employed first in the houses, then in industry, and then in agriculture. Urban wastewater, known as “brown water” can be processed and channeled from cities to villages to be used in farms; hence, increasing the harvest yields and decreasing the necessity of chemical fertilizers. Taking for instance Israel, its sewage is sanitized and purified so as to be used for irrigating farm land. Likewise, Wastewater in Tunis is used to irrigate the olive fields and gardens nearby the city.

9.3 Desalination

Extracting salt from seawater is tremendously expensive. Desalination delivers a clean and perfect source of water, but it requires huge quantities of heat and has some negative consequences on the environment. 60% of the world desalination capacity is located in the Gulf states; while, 30% of the world total is located in Saudi Arabia, which has access to both the Gulf of Aden and the Red Sea. Kuwait is very known for developing desalination facilities to deliver freshwater to domestic use.

9.4 Trading Water

Water could be transported from one region to another and from one country to another through shipping it by ships, transporting it via vehicles or via pipelines. Importing water can be very beneficial to the governments in the Middle East in order to meet the increased water demand, reduce the potential motivation for people to migrate. Notwithstanding, the ecological influences of water transfer techniques can be noteworthy since driving water from one basin to another, could extremely affect the ecosystem and local hydrology.

9.5 Using Technologies

Better technologies could help reduce costs and improve efficiency for long run. Researches have shown that drip irrigation cuts water use by between 30% and 70% and increases crop yields by between 20% and 90%, compared with old-fashioned irrigation. Drip systems bring water directly to plants and vegetable roots, via a network of pierced plastic tubes implanted below the soil surface. Another fruitful technique called “fertigation”, which involves applying fertilizer to irrigation water via the use of computer-controlled drip methods. It saves water and fertilizer, and limits soil salinization and pollution of groundwater. For example, farmers in Israel utilize highly effective drip-irrigation techniques, and as a consequence, they have doubled their food production in the last two decades without increasing their water usage [20].

9.6 Effective Distribution

Distribution of water could be enhanced so as to improve the quality of water delivery. Some attempts may include repairing leakage, fixing sewer pipes, constantly maintaining central sewage systems, metering water networks, and regulating and controlling water usage. For example, in Jordan a mandate oblige engineers to construct buildings according to water conservation specifications.

9.7 Public Education

Communities and societies can be taught how to preserve and operate water systems. In Tunisia, for instance, there are around 2500 water associations that are managing and controlling drinking and irrigation water systems. Relying on the community to conserve water is often very effective to control and limit water usage. In Jordan, for instance, the Business and Professional Women Organization (BPWO) trains and teach poor women to promote and sell water conservation devices, such as shut-off nozzles for hoses, aerators for faucets, and waterless soap.

9.8 Conservation

Many Countries in the Middle East are implementing an assortment of methods to encourage voluntary free water conservation, which includes possible ways for integrating religious messages with conservation practices. For instance, the Gulf countries asked the native religious speakers to dedicate their Friday speeches to the subject of Islam and water conservation. In a similar context, the Israeli Water Commission (IWC) has approximated that implementing voluntary conservation measures may reduce the water domestic use by 55 million m^3 annually.

9.9 Pricing Policies

Governments in the Middle East have customarily sponsored the cost of delivering safe water to citizens; however, they are gradually looking for methods to put part of the cost on to consumers. Some strategies include imposing water tariffs such as putting charges on extracting water, pricing water, providing conservation grants, and charging more depending on the day and season. Basically, households who get their water from pipes have no problem in paying 3% to 5% of their revenue to access to clean water. Water pricing policies and fees can push industrial and commercial consumers to reduce their water usage. In Jordan, for instance, daily water demand dropped from 450 m^3 to 20 m^3 when cooling water was recycled.

9.10 Reducing Population Growth

The United Nations International Conference on Population and Development (ICPD) provided in 1994 a chance for states to inspect their population problems and propose possible solutions for attaining socially equitable and sustainable development. The Program of Action emphasized the human development and provided an outline for braking population growth and improving the quality of people lives such as to improving human rights, health, and education especially for women and girls.

10. Climate Change and its Impact on Water in the Middle East

The water strain in the Middle East is expected to be farther worsened by climate change and global warming in the next decade. The climate change has a threat multiplier on several countries in the Middle East. With the global warming, less rainfall is expected as more hard weather events will mean precipitation will run off more quickly over the surface of the land, and consequently reducing water in aquifers and decreasing groundwater. This will result in water shortage, for instance, Syria, Jordan, and Israel are expected to experience water shortages by 2020 as the average storage capacity in Jordan River basin could drop by as much as 25% by 2100. Likewise, The Litani River is no longer expected to flow into the Mediterranean; thus, Lebanon will be incapable to meet the population demands in the next 10-15 years. Lebanon will be obliged to extract more water out of the Wazzani River in the south, which is shared between Lebanon and Israel, leading to a conflict [21].

Groundwater aquifers in the Middle East will experience an increase seawater intrusion due to an increase in the sea level. The differences between predictions reach a maximum 1.5 °C for Syria in hot Summer time. As a result, irrigation water will be highly demanded due to higher evaporation. Average winter temperatures will also increase; though, the rise is lower than for the summer. Higher winter temperatures will enhance evaporation and thus reducing potential groundwater recharge.

10.1 Socio-Economic Impact

The global warming and the climate change will negatively affect the Middle East countries including their GDP, domestic and industrial water, water quality, and hydro-electric power [22].

10.1.1 Impact on the GDP

Economic impact of climate change is estimated at 2 to 9 % of annual national Gross Domestic Product (GDP) for developing countries, compared with 1 to 1.5 % reductions in GDP for developed countries. Potential reduction in GDP due to climate change was estimated for the six countries. Reduction is lowest for Israel and Jordan which ranges from 1 to 2%. Syria and Iraq could have significant GDP reduction up to 7% due to the important reliance on agriculture and a currently low adaptation capacity.

10.1.2 Impact on Domestic Water

Industrial water is usually not that much affected by climate change, whereas, domestic water demand is negatively connected with water prices and precipitation and positively connected with climate temperatures. Temperature rise is anticipated to be highest in Syria, Iraq, and Jordan while rainfall is not expected to be considerably reduced. Price variations are very hard to guess in the region since the market does not entirely control prices in many of the countries. Increase in domestic water demand is not anticipated to be momentous in Jordan, Israel, and Palestine as their climate is already dry and water prices are expected to increase ominously with the increase of demand. Alternatively, Syria, Iraq, and Lebanon are expected to have some increase in domestic water demand as the period of the dry seasons in these countries is possibly to increase and water prices could be lesser than other counties due to the moderately more plentiful water resources.

10.1.3 Impact on Water Quality

The impact of the climate warming in the Middle East will certainly be negative. All countries will witness a theoretically bad impact since water quality is already problematic in most of these nations and a decrease in water resources is connected with a lower dilution possibility of existing pollution. Besides, to economic impacts, water quality deterioration will lead to an environmental damages and marine species death. Moreover, the water quality might be affected by the rising of sea level as many countries heavily depend on groundwater resources, plus groundwater salinity is expected to increase because of the sea water being mixed with the groundwater.

10.1.4 Impact on Hydropower

Hydropower loss is typically a problem in countries that highly rely on Hydroelectric to generate electric power. Lebanon is anticipated to be affected as it has several hydropower plants and several plans to build other ones. Conversely, reduction in hydropower in Lebanon are expected to be reasonably low as the government is more and more relying on fossil fuel to generate power rather than on hydroelectric capacity.

Table 5 summarizes the socio-economic impact of climate change on the various countries in the Middle East [23].

Table 5. Climate Change Impact

Impact	Iraq	Israel	Jordan	Lebanon	Palestinian Authority	Syria
Increased industrial and domestic water demand	++	+	+	++	+	++
Increased agricultural water demand	+++	++	+	+++	+++	+++
Water resources distribution equity decline	+++	++	+++	++	+++	+++
Flood damage	+++	+	+	++	+	+
Water quality damage	+++	+++	+++	+++	+++	+++
Hydropower loss	+	+	+	++	+	+
Ecosystems damage and species loss	++	++	+	+++	++	++
GDP reduction (percent)	3-6	1-2	1-2	2-5	2-5	4-7

+++: high; ++: moderate; +: insignificant

11. Conclusions

This paper tackled the numerous water problems and challenges in the Middle East from a socio-economic perspective. A general overview of the water current situation in Lebanon, Jordan, Israel, Palestine, Egypt, the Gulf, and other countries in the Middle East was presented along with facts, numbers, and statistics. Syria and Iraq were the most abundant with water; while, the gulf countries were among the countries with the lowest water capacity. Lebanon and Egypt have a high water capacity, nonetheless, Lebanon suffers from water waste and Egypt suffers from the exponential growth of population, making water demands in these countries overpass the supply of their water resources. Additionally, climate change and global warming is expected to further worsen existing water shortages, rendering the majority of the Arab countries almost deserted and suffering from water scarcity problems, water quality damage, and GDP reduction.

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