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Review

A Review of the 21st Century Challenges in the Food-Energy-Water Security in the Middle East

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Abstract: Developing countries have experienced significant challenges in meeting their needs for food, energy, and water security. This paper presents a country-level review of the current issues associated with Food-Energy-Water (FEW) security in the Middle East. In this study, sixteen countries in the Middle East are studied, namely Iraq, Iran, Syria, Lebanon, Israel, Palestine, Egypt, Turkey, and the Arabian Peninsula (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia (KSA), United Arab Emirates (UAE), and Yemen). Here, we conduct a comprehensive assessment to study and evaluate the emerging drivers of FEW systems in the region. The investigated drivers include water security, extreme events, economic growth, urbanization, population growth, poverty, and political stability. The results suggest that most of the studied countries are facing FEW resource insecurity or weak planning/management strategies. Our evaluation further revealed the current status of each country with respect to each factor, and suggested that climatic and socioeconomic factors have contributed to the subsequent stress on FEW resources, specifically on the water sector. In general, and with respect to the water-energy security, it was found that energy production in the Middle East is highly constrained by water deficiency, drought, and/or economic growth. The water-food security in the region is mainly affected by drought, water scarcity, population growth, urbanization, and/or political unrest.

Keywords: Middle East; FEW; security; water scarcity

1. Introduction

Despite the fact that water, food, and energy sectors are of high importance to sustain and develop human life, not everyone in the world has access to secure water, food, and energy. Globally, it is reported that 1.2 billion people do not have access to safe water [1]. Therefore, it is crucial to understand the complicated connection between the food, energy, and water sectors to ensure the safe and sustainable development for any nation [2].

Typically, there is no single definition of nexus, but generally, the concept is introduced as the process of linking stakeholders' ideas and activities under various conditions (i.e., sectors and states) to attain sustainable evolution [3]. The Stockholm Environment Institute (SEI) in the Bonn 2011 Nexus Conference introduced the food-energy-water (FEW) nexus where it first started. Then, the 2011/2012 European Report on Development proposed the water-energy-land (WEL) nexus. Over time, linkages that are more complex have been defined to include more core sectors, e.g., climate, land, energy and water (CLEW) nexus. The FEW system has an interference nature whereby the evolution of any sector may, in general, adversely influence the other two [4]. Therefore, many researchers have chosen to study only two sectors of the FEW system at a time. The water-energy nexus, originally studied by

Gleick [5], has received more attention than the other inter-linkage sectors, e.g., the water-food nexus and then the energy-food nexus [6].

A study by Cai and Rosegrant [7] investigated the water-food nexus in China and India by comparing water resources development and food production in both countries. The authors found that both China and India have limited land and water resources for agricultural purposes; therefore, they suggested that food production may increase in the future, depending on yield increase more than on area increase. Other dimensions can be integrated with the FEW nexus to address sustainability challenges and opportunities involving trade-offs, i.e., land, climate, and ecosystems [4]. The climate dimension has been linked with either all or some of the sectors in FEW system [8–15]. Hanjra and Qureshi [16] analyzed the global water-food nexus addressing the effects of climate change on food security. The analysis revealed that climate change and population growth are two factors that intensify food insecurity globally. Verdon-Kidd et al. [17] mentioned that food security is tightly connected to water availability at a large scale. However, drought may put this connection at risk by reducing vegetation health and productivity and water allocations to irrigated agriculture. Moreover, Verdon-Kidd et al. [17] concluded that better understanding of drought onset, duration, and cessation may assist drought management strategies, specifically in water scarce regions. Food production is more water intensive than energy production. Food production accounts for about 70% of global freshwater withdrawal, whereas energy production accounts for about 15% [18]. However, Lee et al. [19] suggested that the water-energy nexus might be a serious issue in future sustainable planning and policies, given the impacts of climate change.

Several nexus studies have been recently conducted in the Middle East. Dubreuil et al. [20] proposed an optimized model to assess the water-energy nexus in the Middle East region, taking into account reused and non-conventional water, i.e., desalination and wastewater. Saif et al. [21] analyzed the current state of water resources in the Gulf Cooperation Council (GCC) countries. The authors concluded that the region faces serious challenges in water-food security systems. Al-Mulali and Ozturk [22] studied the reasons behind environmental degradation in the Middle East and North Africa (MENA) region and discovered that ecological footprint, energy consumption, urbanization, trade openness, industrial development and political stability are the main contributors to induce environmental degradation in the region. Moreover, a FEW nexus modeling tool was developed by Daher and Mohtar [23]; the tool provided an assessment of resources' demand under different scenarios. Another study by Magazzino [24] investigated the carbon dioxide emissions, economic growth, and energy nexus for a total of ten Middle Eastern countries, i.e., GCC countries, Iran, Jordan, Syria, and Yemen for the period of 1971–2006. Here, we provide an overview of the current issues related to FEW security in the Middle East. We provide a comprehensive assessment for sixteen selected countries in the region to identify these issues and interpret the main findings as pertained to the FEW security concept.

2. The Food-Energy-Water (FEW) Security in the Middle East

FEW security is of paramount importance in the Middle East, given its influence in the region's stability and economic growth [25]. For instance, an extensive amount of energy is consumed powering the desalination and wastewater recycling units for water supply in the Gulf region [26]. Siddiqi and Anadon [27] studied the water-energy nexus over the MENA region and found that the water sector exhibits a strong level of dependency of on the energy sector, but not the opposite. In Arabian Peninsula countries, groundwater contributes to about 84% of the total water supply, whereas desalinated water covers about 8%; both groundwater extraction and desalination are energy demanding. Furthermore, carbon dioxide emissions can be a limitation factor for energy consumption when fossil fuels are used [28]. Globally, the GCC countries are among the top twenty-five countries for CO_2 emissions/capita because of their high dependency on fossil fuels to cover domestic energy demands [29]. The International Energy Agency (IEA) reported a significant increasing trend for carbon dioxide emissions in the Middle East since 2000, particularly for Saudi Arabia and Iran having

125% and 80% increase, respectively [30]. Therefore, there is a need to use green energy, e.g., wind, sunlight, geothermal heat, and hydropower [31].

The water-food security in the Arab region is limited by several factors: socio-economic growth, dry climate, reliance on external resources, climate change, and political conflict [32]. Figure 1 presents the Pardee RAND FEW security index [33]. The FEW index provides information about the availability and accessibility of the three resources in any region or country in the world. According to the definition, and as shown in Figure 1, Turkey is the most secure country in the Middle East, whereas Yemen is the most insecure [33]. The World Economic Forum 2010 Report underlined water insufficiency, energy insecurity, and weak investments in infrastructure as the most mutually dependent and chronic risks in the Middle East and North Africa (MENA) region. It was reported that these risks (including food security as a related risk) are extremely affected by economic production, population growth, and industrial potency in the region [34].

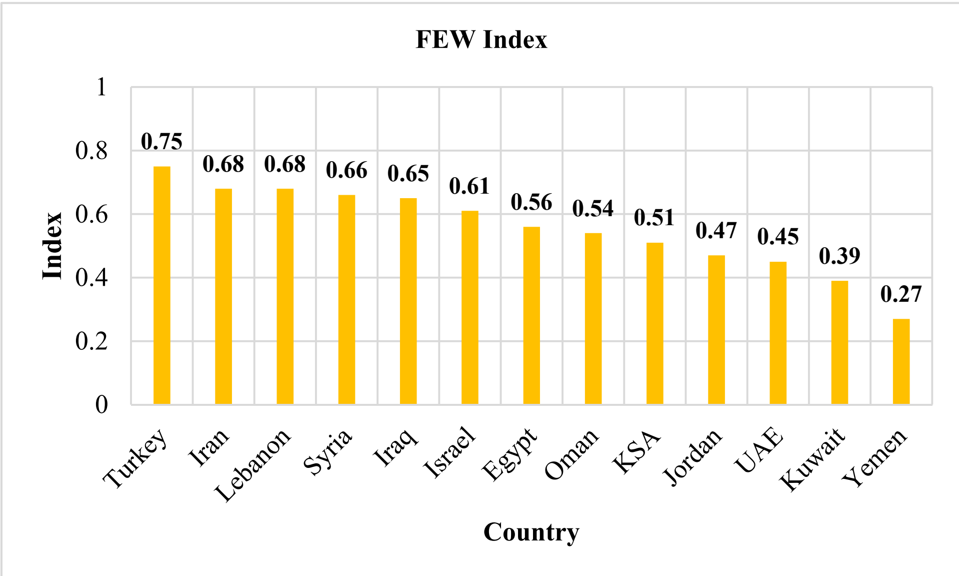
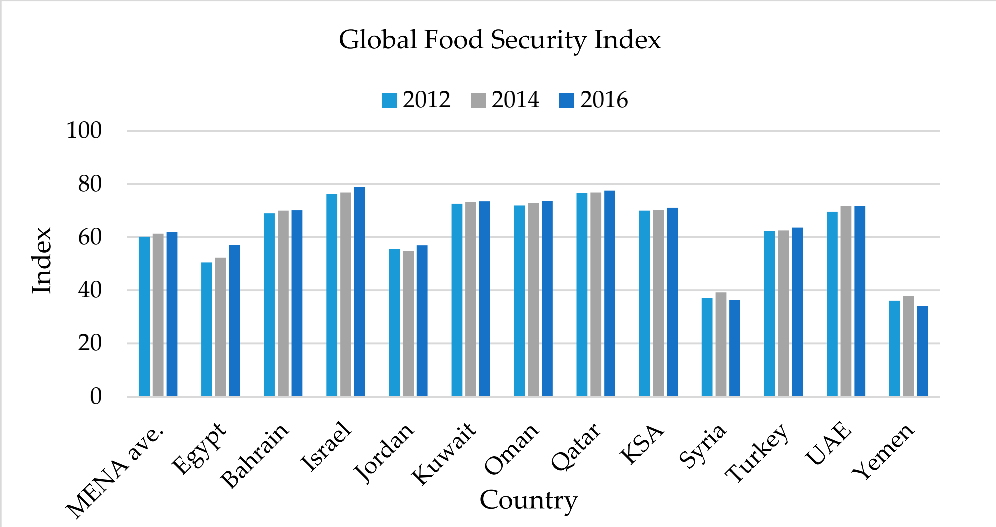


Figure 1. The Pardee RAND Food-Energy-Water security index. Note: the countries not listed in the figure were not reported due to data unavailability. The data is acquired from Willis et al. [33].

2.1. Food Security

Food security is the right of all individuals to have, at any time, access to adequate, safe, and healthy food in order to meet the required nutrients and food desire to ensure vital and nutritious life [35]. Two conclusive factors should be considered for determining food security: food quantities and demands. In other words, how much food can be produced under certain amount of water and environmental circumstances while remaining economically feasible? [36]. For instance, KSA was the sixth largest wheat exporter by the last decade of the 20th century; however, this was at the expense of groundwater depletion in the region, resulting in unsustainable agricultural production [37].

Food production is the most limited sector by water scarcity in the Arab region [38]. Figure 2 shows the Global Food Security Index (GFSI) for the years 2012, 2014, and 2016 across the Middle East. The GFSI accounts for the fundamental issues of food affordability, availability, quality, and safety in 113 countries around the world [39]. From Figure 2, Israel, Qatar, and Kuwait are categorized as the most food secure countries in the region for the years 2012, 2014, and 2016. However, Syria and Yemen are classified as food insecure countries. Overall, the GFSI shows a slight improvement across most of the Middle East countries except in Syria and Yemen. In a global context, the wealthy nations (i.e., the United States (US), Denmark, and France) are the most food secure countries. Sub-Saharan African countries are the most food insecure, and Burundi, Chad and the Democratic Republic of Congo (DRC) have the worst food insecurity situation in the world [40].



	GFSI Score
Best Environment	72.4-86.6
Good Environment	57.1-72.3
Moderate Environment	41.6-57.0
Needs Improvement	24.0-41.5

Figure 2. Global Food Security Index (0–100, 100 = ideal environment). Note: the countries not listed means the GFSI was not provided by the source for these countries due to data unavailability. The data is acquired from [40–42].

2.2. *Energy Security*

Energy security can include a broad range of aspects. Some of these aspects can be motivated by energy supply, geopolitical power, economic growth, sustainability, and social expansion [33]. In 2012, the Middle East countries consumed about 6.6% of the total residential energy consumption of the world. It is worth mentioning that electricity is the main energy consumption source in the Middle East [43].

The Middle East has a significant impact on the oil/gas market in the world, and the main income source of the Middle Eastern countries is oil and natural gas resources. More than 56% of the world oil reserves and about 36% of the world natural gas reserves are in the Middle East [28]. In 2009, the five largest natural gas reserves reported in the world were Russia, Iran, Qatar, KSA, and UAE, respectively [44]. Although the natural gas production has increased considerably in the Middle East during the period of 2010–2014, the demand has also increased significantly in the region due to population growth, economic expansion, urbanization, and desalination plants [45]. As a result, Qatar, KSA, and UAE are facing considerable energy deficiency mainly in the natural gas resources [44].

Understanding how energy is consumed may provide us valuable insights on the effectiveness of energy efficiency. Globally, the energy demand has increased 1.9% in 2017, the largest annual increase since 2010. Meanwhile, the progress of energy efficiency initiatives since 2000 prevented an additional 12% energy use in 2017. China, India, and the European Union (EU) are the main regions affecting 2017 energy demand growth. Energy demand in the US has decreased since 2015 [46]. A study by Nejat et al. [47] found that the global energy demand in the residential sector increased by 14% for the period of 2000 to 2011, and developing countries were the most contributors to this increase due to population growth, urbanization, and economic growth in these countries. The study further suggested that China, Iran, and India have experienced the most dramatic increase in CO_2 emissions (25%, 245%, and 84%, respectively) between 1990 and 2011. Russia, Germany, South Korea, Canada, and the United Kingdom have shown reductions in CO_2 emissions, with the greatest decline being in Germany (−30%).

According to the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) 2015 report, Jordan is the most optimum country among the 12 Middle Eastern countries given its energy efficiency status. Figure 3 displays the efficiency status in the Middle East. The energy efficiency score reported in Figure 3 is evaluated under four categories, i.e., energy pricing, policy framework, institutional capacity, and utility [48].

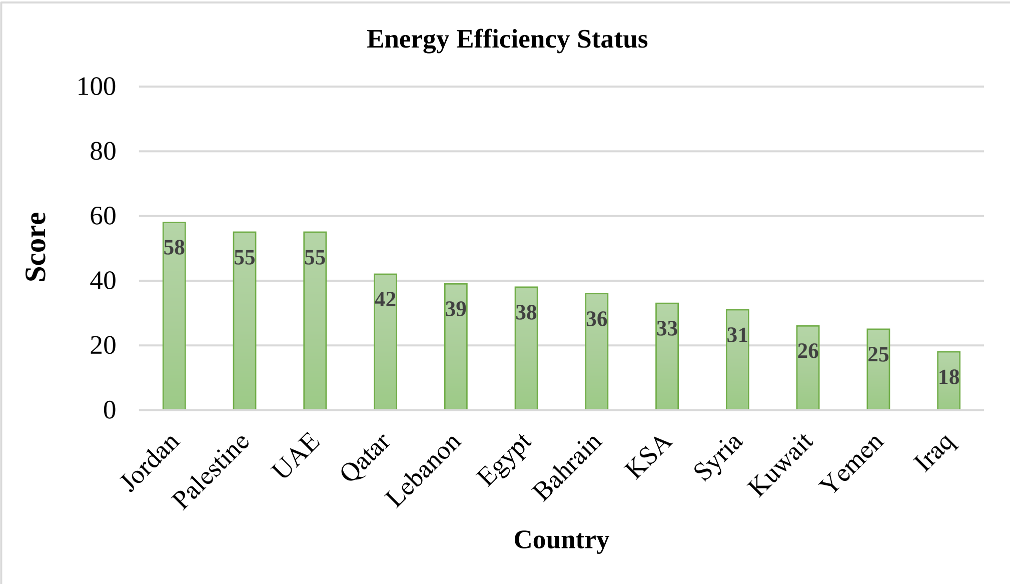


Figure 3. Energy Efficiency Status in the Middle East. The higher score indicates better energy efficiency status. The data is acquired from RCREEE [48].

Nematollahi et al. [28] assessed the prospective of solar and wind energy sources in the Middle East. The results showed that Middle East has a high potential to use renewable energy resources. Furthermore, El Bassam [49] mentioned that the Middle East has the highest potential of solar energy source on the earth. However, solar energy accounts for less than 0.2% (on average) of the electricity supply in the region. In addition, the percentage of the renewable energy used for electricity production (including hydro) in the Middle East has decreased from 4.3% in 2005 to 2.2% in 2015 [44]. Hajj [50] stated that electricity production by wind energy is approximately 0.6% in the Arab region.

2.3. Water Security

Water security is the proportion of people that can insure sustainable access to sufficient amounts of usable water to sustain living needs, human welfare and socio-economic progress, to protect people from water related pollution and disasters, and to guard ecosystems in peaceful and politically stable conditions [51]. Water security is one of the greatest challenges in the Arab region [32]. Freshwater in the Arab region has declined due to the reliance on transboundary water bodies, poor water quality, political instability, climate change, non-beneficial water losses, absence of water use efficiency, and excessive population growth [52]. In addition, the mean annual evaporation rate in MENA can exceed 2000 mm/year, which significantly contributes to freshwater scarcity in the region [53]. In 2011, most of the Arab countries reported that the total renewable water resources were less than 1000 m^3/capita/year, which represents the water poverty line. For Bahrain, Kuwait, Qatar, KSA, UAE and Yemen, the total renewable water resources were even less than 100 m^3/capita/year [54].

Groundwater depletion is of high concern in the Middle East especially in the Gulf countries where groundwater has over-exploited for irrigation and agricultural purposes [55]. Extreme pressure on the already scarce groundwater resources in the GCC countries has occurred as a consequence of rapid population growth, urbanization, industrialization, and agricultural production since the 1970s [21,56]. Therefore, currently the Gulf countries are mainly relying on the desalinated water supply to assure their water demands [6]. However, water production via the desalination process has markedly increased energy consumption.

Industry is one of the main drivers of water usage in the Middle East especially the crude oil industry. Figure 4 shows industrial water consumption in the Middle East in 2011. The oil exporter countries use large amounts of water to produce crude oil. For instance, KSA consumes over 1600 million m^3/year water in crude oil production [57].

Damerau et al. [58] reported that the MENA region has the largest fossil energy reservoirs in the globe and extensive renewable energy resources, however it is also the highest water scarce region. Therefore, the future water-energy linkages might become critical and complex in the region. Climate change and socio-economic factors including population growth, globalization, economic progression, and urbanization play a part in the FEW nexus [3]. Therefore, the next section will highlight the predominant challenges in the Middle East and their interconnections with FEW security in the region.

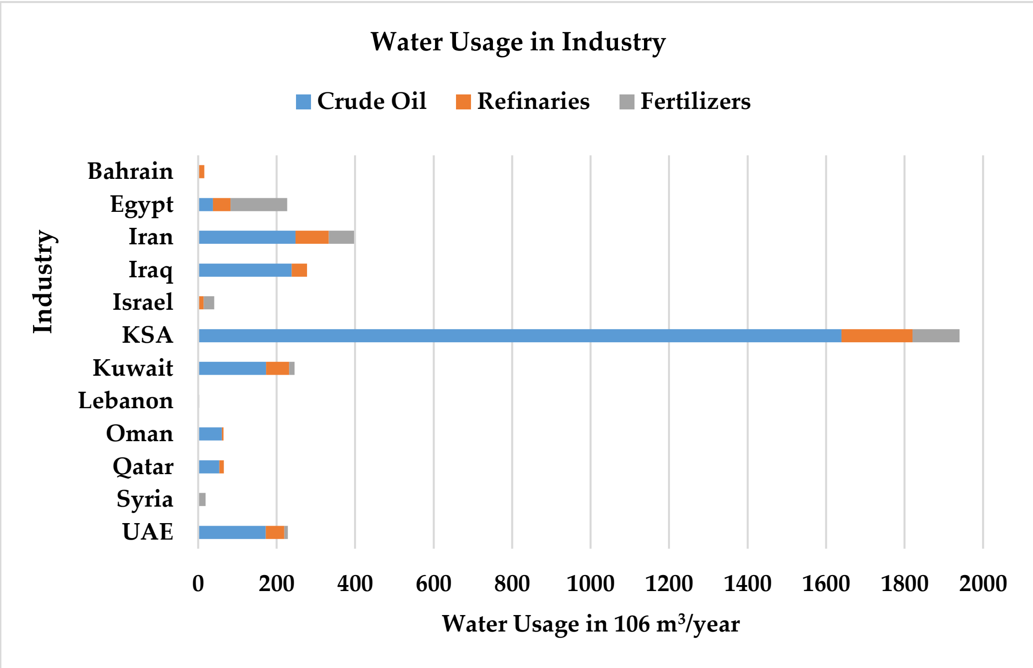


Figure 4. Industrial water consumption in the Middle East in 2011. The data are acquired from Sakhel et al. [57].

3. Drivers Impacting the FEW Security in the Middle East in the 21st Century

3.1. Water Scarcity

The means of addressing the challenges of water deficiency for a region may differ across the spatiotemporal scales, according to people needs, and resources availability [59]. Rijsberman [59] defined the water being "insecure" when safe and consumable water is not available to satisfy individual living needs whereas the water was defined as "scarce" when a large group of people are water insecure for a long period in a specific region. Dubreuil et al. [20] explained that water scarcity happens when the water demands exceed water supply.

The Middle East region is one of the most arid regions in the world and substantially suffering from scarce water resources [60]. Albeit several large rivers are located in the Middle East, transboundary water resources are also a struggle in the region. For example, the Tigris-Euphrates basin water is shared between Turkey, Syria, and Iraq. Mainly, Turkey has been controlling the discharge of both rivers across its borders with Syria and Iraq. Turkey has constructed 15 major dams on the Tigris and Euphrates rivers. Based on Food and Agriculture Organization's Information System on Water and

Agriculture (FAO AQUASTAT) Database, 98% of Turkey water resources originate within its borders. Whereas Syria and Iraq respectively have about 28% and 39% of their water inside their borders [61]. Figure 5 expresses the percentage of the total renewable water resources that originate outside the country borders. From Figure 5, Kuwait, Egypt, and Bahrain are the most dependent countries on shared water resources from neighboring countries.

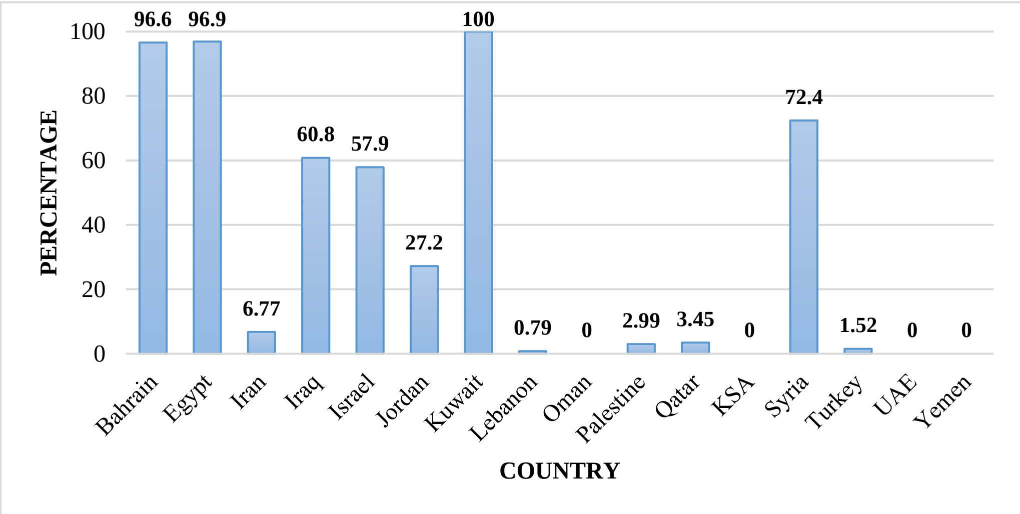


Figure 5. The percentage of the total renewable water resources originating outside a country in 2014. A country with a dependency ratio equal to 0% does not receive any water from neighboring countries, whereas a country with a dependency ratio equal to 100% receives all its renewable water resources from upstream countries. The data is acquired from: https://idea.usaid.gov.

Negewo [62] mentioned that for the period of 2000–2009, the Gulf countries had the lowest per capita water availability in the MENA region, with an annual average of <300 m^3/capita, which may decrease to <200 m^3/capita, as a consequent of climate change impacts. Voss et al. [63] reported that about 144 km^3 of water was depleted mostly from the groundwater in the Tigris-Euphrates-Western Iran region during the period of 2003–2009 due to a combined effect of drought and groundwater withdrawals. Therefore, water depletion resulted in reduction of crop yields and economic damages in the region [63,64]. On the other hand, water scarcity in the Middle East is a limitation factor on energy productivity [44].

3.2. Extreme Events: Droughts, Floods, Storm Surges, and Dust Storms

Disaster risk management is one of the top concerns in the MENA region. Floods, droughts, and earthquakes are the most consequential catastrophes that threaten growth and resources security in the region. Historically, it is identified that food security is vulnerable to extreme weather events [65]. For the period of 1981–2011, the World Bank reported that 53% of the total number of natural disasters in the MENA region were floods, 24% were earthquakes, and about 10% were storms and droughts. However, data availability is a limitation for drought events records [66].

Lately, the frequency of extreme events, i.e., droughts, floods, storm surges, and dust storms, has shown an increasing trend in the Arab region [67], but the consequences of these events have not been thoroughly investigated [68]. In most arid regions, flash floods are a natural phenomenon because rainfall can be very intense in a short time period, especially when these events are accompanied by dry or low infiltration capacity soils in the region [69]. The flash flood events in 2009, 2010, and 2011 in KSA were documented as the worst since the 1980s [66]. Regarding the seismic risk, the World Bank reported that Iran is the most vulnerable country in the Middle East to seismic hazard; it accounts for about 95% of the total mortality during catastrophes in Iran. Moreover, Egypt and Yemen have also experienced earthquake events, floods, and landslides [66]. These events impose crucial risk of failure to the infrastructures concerning energy security in the region.

Frequent drought events have increased in the Fertile Crescent countries, namely, Iraq, Syria, Jordan, Israel, and western Iran since 2006 wet season [70]. This long-term drying trend coincides with the active period of dust storms, which has evoked during the period of 2007–2013 in the region [70]. Given that agriculture is the most sensitive sector to drought [71], and because of persistent drought over the region, vegetation cover has decreased, consequently intensifying dust storm occurrence in the aforementioned Fertile Crescent countries, and transporting dust to the Arabian Peninsula [70]. A study by Amin et al. [72] revealed that in the past twenty years, KSA has faced severe and extreme drought conditions mostly in agricultural areas, underlining the risk of water depletion and vegetation cover reduction in the region. In Turkey, about 15.3% reduction in crop yield occurred in 2007 [71]. Figure 6 shows climate risk index in the Middle East, where countries with lower scores indicate those at higher risk to climate change. From Figure 6, Oman and Yemen are the most vulnerable countries to the risks of climate change in the Middle East.

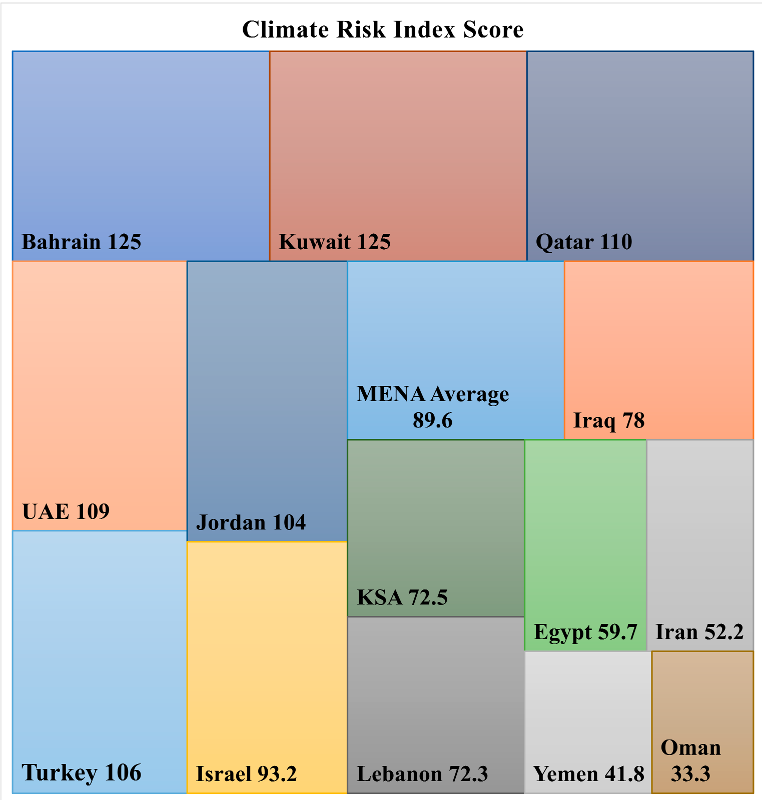


Figure 6. Climate Risk Index Score in the Middle East in 2015. The index is a weighted score calculated according to the following setting: Number of Deaths (weight: 1/6), Deaths per 100,000 inhabitants (weight: 1/3), losses in Purchasing Power Party (PPP) (weight: 1/6), and Losses per GDP unit (weight: 1/3). Lower score indicates a country being more at risk to climate change events. The data is acquired from: https://idea.usaid.gov.

3.3. Economic Growth

The abundant oil resources in the Middle East have increased the economic growth level in the region. However, economic growth is different from the economic advancement or sustainable development [73]. Energy consumption is highly connected to economic development. Al-Awad and Harb [74] underlined the fact that the weakness of the financial sector and unstable economic growth in the Middle East are the factors that most affect sustainable economic development in the region. Gross domestic product (GDP) is a measure of total products of a country [75]. GDP is calculated in terms of purchasing power parity (PPP), and it is one of the main indicators to estimate a country's economy. Qatar and Iraq have experienced the highest GDP growth rates in the Middle East during the period of 2011–2015. In contrast, the compound growth rate for the period of 2011–2015 in Yemen reveals a decline, and in Iran, there was no economic growth. However, the economy of Iran was estimated to grow at a mean annual rate of 4.6% for the period of 2016–2018 [76]. Silva et al. [65] discussed that the absence of investments in infrastructure could be a potential risk to FEW security in any region. For instance, food processing and production are significantly affected by infrastructure.

The GDP growth in the Middle East is highly connected to oil and natural gas investment. The dependency of the GCC countries on oil has increased since 2006 [76]. For instance, by mid-2014 to 2016, oil prices sharply declined affecting the economy of the oil exporting countries of MENA region [77]. Therefore, the GDP growth in the MENA region was expected to be lower in 2017 [78]. Figure 7 shows the actual GDP growth in the Middle East for the years of 2015–2017. The GDP estimates show that Yemen has faced the worst decline in 2015 and 2016 across the Middle East. The GDP growth for 2017 shows that Iraq experienced a decline in GDP in that year.

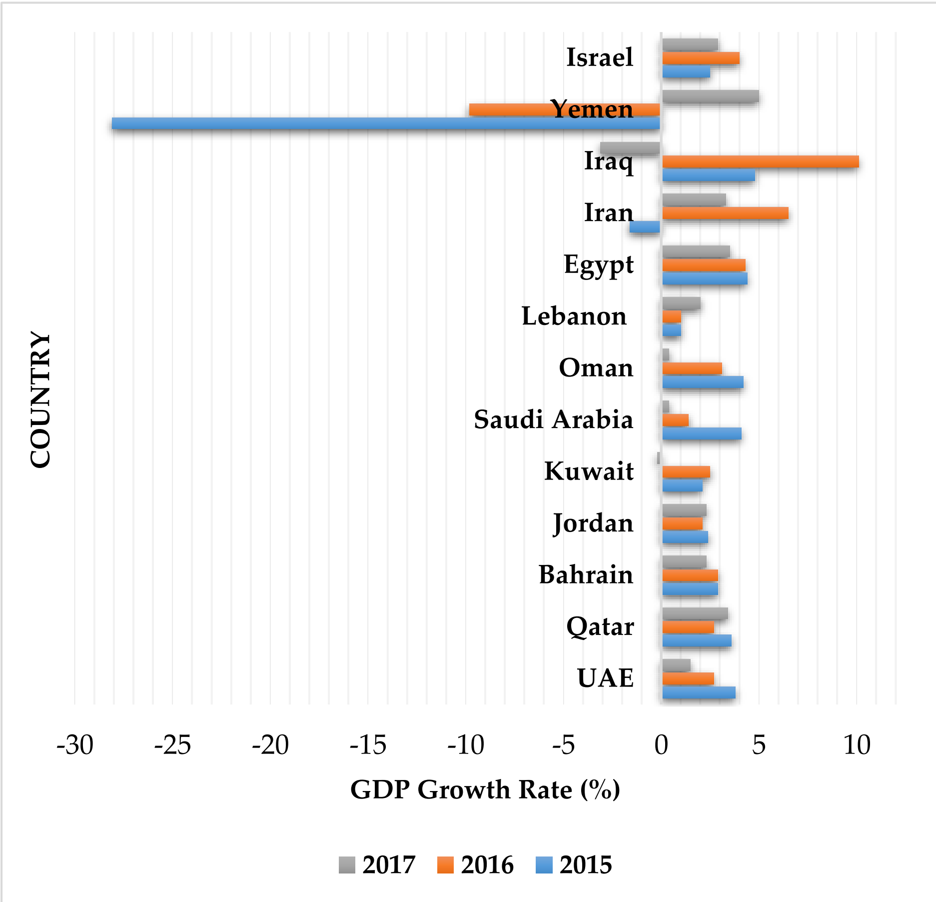


Figure 7. Actual GDP Growth rate for the years of 2015−2017. The data is acquired from: IMF Data Mapper.

3.4. Urbanization

The world has witnessed relatively rapid growth in urbanization since the 1950s [79]. Such growth in the urban population has caused serious challenges related to poverty and unemployment [79]. By the beginning of the 21st century, urban population in the MENA region was about 60% of the total population, and it increased to 70% in 2015. However, urbanization in the MENA region can be a major challenge because it is unplanned [22]. Efficient urban planning and sustainable food supply system are required to achieve a healthy growing urban population [65].

The general trend of expanded urbanization and reduced agricultural share in the MENA region can have serious direct effects on water demand and indirect impacts on energy sector [27]. Qatar and Kuwait were among the ten most urbanized countries, each having about 90,000 inhabitants in 2014 estimates; they are expected to stay the same in 2050 projections [80]. Figure 8 presents the decadal mean annual rate of change of urban population in the Middle East. Overall, the increase in urban population was the highest starting from the mid-1950s to mid-1970s in the region. For the decade of 1985–1995, the urban population rate in Kuwait decreased possibly due to the First Gulf War. For the most recent decade (2005–2015), Qatar and UAE have witnessed the highest growth in urbanization [80].

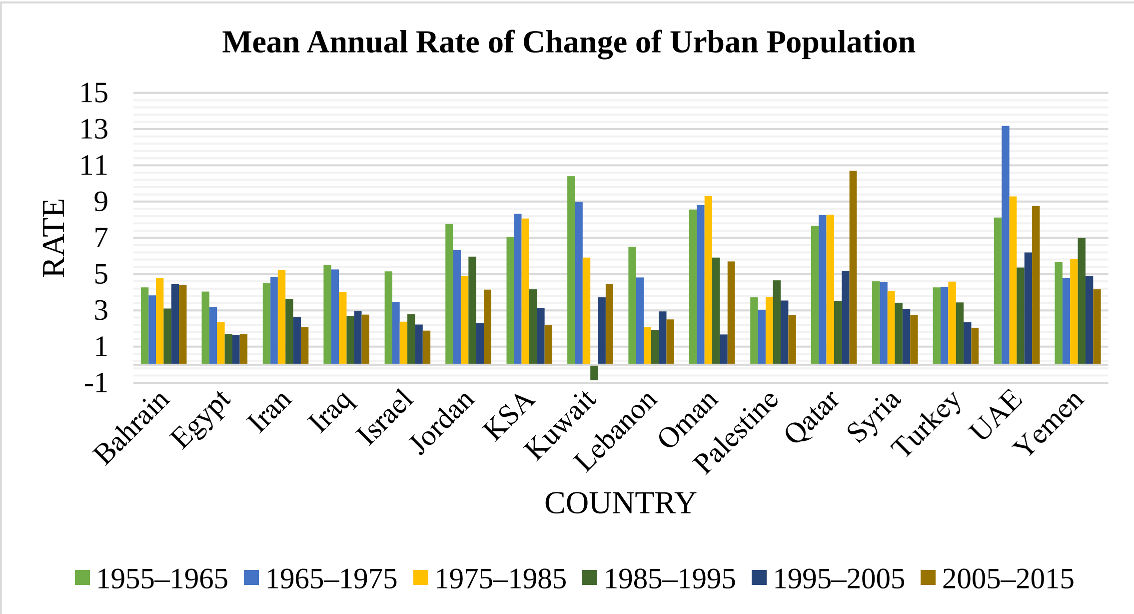


Figure 8. Decadal mean annual rate of change of urban population for each country. The data is acquired from the UN-Water [80].

3.5. Population Growth

In a world facing issues such as severe poverty, scarce water resources, and persisting hunger, rapid population growth may pose serious challenges. In terms of poverty, growing population may mitigate infrastructure, aggravate natural resources depletion, and intensify the dependency ratio [81,82]. Moreover, population growth is a main contributor to the industrial and municipal water consumption [62]. Thereby, population expansion can be a direct concern for resource exhaustion, especially in developing countries [83]. The significant modifications of population dynamics in the Arab region (e.g., population growth, urbanization, population age, and migration fluxes) have increased water demand in the region in the last three decades. For example, population increase has imposed an unsustainable strain on the agriculture sector, consequently increasing the burden on diminished freshwater resources in the Arab region.

It was found that the population growth in the Arab region for the period of 1982–2012 resulted in approximately 50% reduction in the mean amount of total water resource per capita [54]. The high rate of growing population in developing countries may affect the health and education sectors that can influence poverty mitigation efforts and possible economic growth in the region [54].

Based on the total population, the most populated countries in the Middle East are Egypt, Iran, and Turkey, respectively. Figure 9 shows a five-year average population in the Middle East countries. From the figure, the first cluster indicates that Egypt has the highest population growth considerably from the beginning of the 21st century followed by Iran and Turkey. The second cluster, including Iraq, KSA, and Yemen, has also witnessed population growth since late 1980s. In contrast, the population in Syria has declined after 2008, most likely due to the political conflict in the country. Furthermore, the World Meter (www.Worldometers.info) reported that Iraq, Palestine, Yemen, and Kuwait had the highest population growth rates in 2017, respectively, as seen in Figure 10.

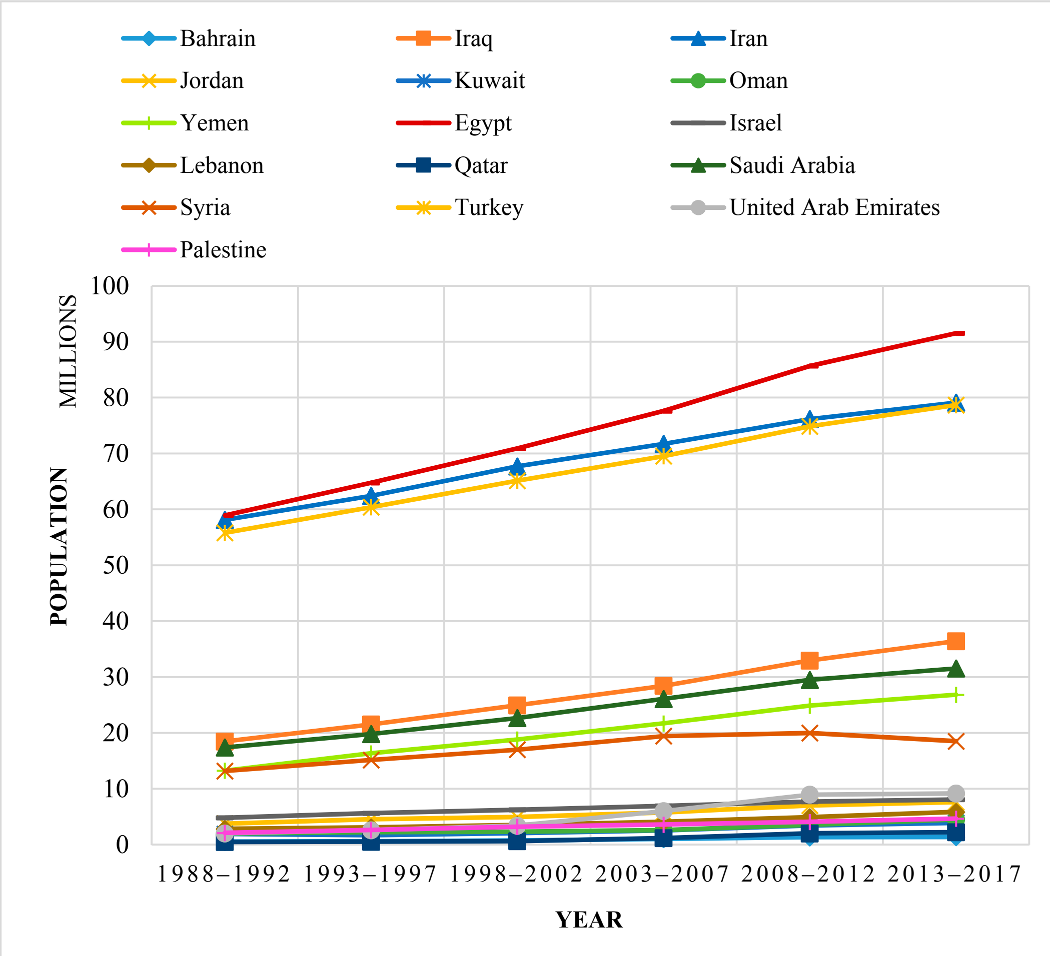


Figure 9. Five-year average population of each country in the Middle East. Source: FAO-AQUASTAT Database and Worldometers. The data is acquired from: www.Worldometers.info.

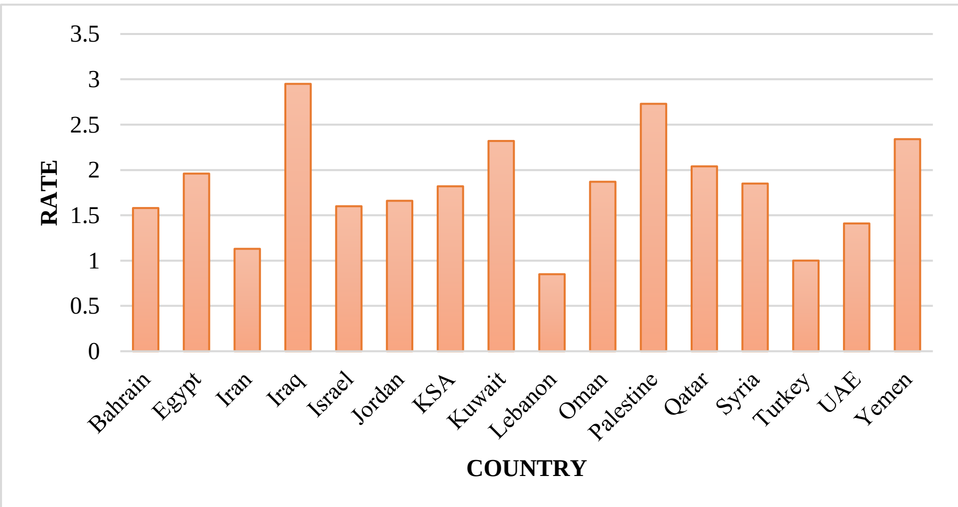


Figure 10. Annual population growth rate of the Middle Eastern countries in 2017. The data is acquired from: http://www.worldometers.info.

3.6. Poverty

Societies with insufficient market access and scarce natural resources are characterized by communities which have been exposed to prolonged poverty. Awulachew et al. [84] studied the food-water-poverty nexus across ten countries within the Nile basin. The authors defined poverty as a composite of different elements, i.e., politics, economy, environment, socio-culture, and history. Vulnerability to poverty is very high in the MENA region, and large groups of people live around the poverty line. For instance, a large portion of population is distributed close to the poverty line in Iraq and Yemen, thereby people are at high risk of economic collapse in these countries [35]. According to FAO-AQUASTAT database, Iraq has recorded the highest number of undernourished people (8.1 million) for the period of 2013–2017. Similarly, Yemen was the second highest in terms of the number of undernourished people (6.7 million) in the Middle East. Water scarcity that impacted the agriculture sector, population growth that affected employment, and poor economic policy are among the key drivers for the high poverty rate in Yemen [78]. Figure 11 displays the percentage of population that were undernourished in the Middle East in 2005 and 2015 (data of Syria are not available from this source). From the figure, the percentage of undernourished people in 2015 is lower than in 2005. Yemen and Iraq were outliers with the highest percentages of undernourished population in 2005 and 2015.

Syria is currently the poorest country in the Middle East. The Syrian Center for Policy Research (SCPR) reported that the poverty rate in Syria has increased 14% in 2014 compared to 2010 [78]. Dramatically, the percentage of people who live in poverty in Syria reached 85.2% in 2015 compared to 64.8% in 2013, and about 35% of whom lived in extreme poverty levels (limited access to basic food) especially in the conflict zones [78].

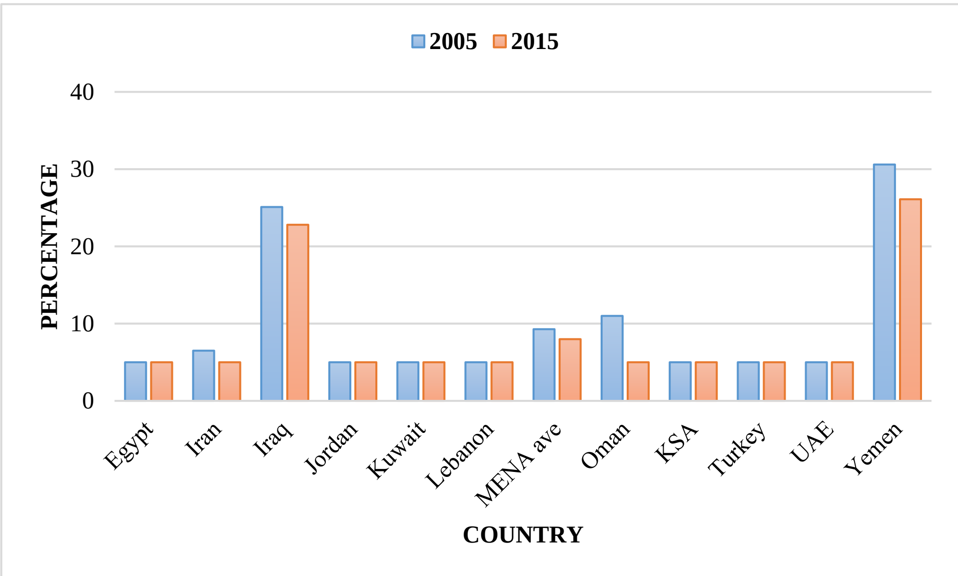


Figure 11. Percentage of undernourished population in each country of the Middle East. Note: data for Syria was not available. The data is acquired from: https://idea.usaid.gov.

Figure 12 shows the Global Hunger Index (GHI) for the years of 2008 and 2016 over the Middle East region. The index is a tool to estimate and trace hunger at different scales, i.e., global, regional, and local levels. The GHI is generated based on four indicators including undernourishment, child wasting, child stunting, and child mortality. The range of GHI is from 0 to 100 where zero indicates no hunger [85]. Overall, the GHI in 2016 revealed less hunger levels than in 2008. However, the reduction in hunger levels were mostly insignificant within a decade. According to the GHI severity scale, Yemen is at an alarming stage of hunger, Iraq faces a serious hunger condition, and the rest of the countries are in moderate to low hunger conditions (Figure 12).

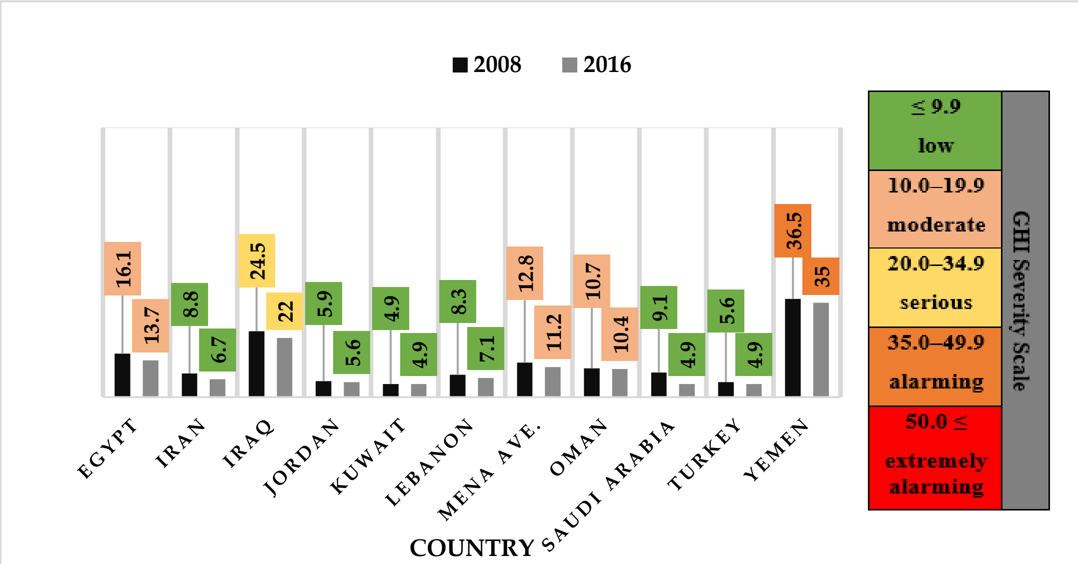


Figure 12. Global Hunger Index (GHI) for the Middle Eastern countries with a range of 0–100, where lower score indicates less hunger. Note: data for Syria was not available. The data is acquired from: https://idea.usaid.gov.

3.7. Political Stability

Political insecurity is a key feature of the Middle East [32]. Conflict and insecure conditions are among the main obstacles of progression in the MENA region in 2016, especially in Iraq, Libya, Syria, and Yemen where approximately 50% of the population (about 40 million people) demand humanitarian aid [86]. Seven years of Conflict in Syria has affected the socio-economic development of the country. The United Nations High Commissioner for Refugees (UNHCR) in September 2016 reported that the total number of Syrian refugees in neighboring countries, i.e., Egypt, Iraq, Jordan, Lebanon, and Turkey, was about 4.8 million. Moreover, in August 2016, the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) reported that about 6.1 million of Syrians displaced from the conflict zones into more secure areas inside the country [87].

Evidence from the Middle East revealed that the political unrest is associated with economic inequality (income inequality), where the latter can be the main reason of civil anxiety. For example, income inequality in Egypt was counted as one of the causes of the Egyptian revolution during the Arab Spring uprisings period [88]. In Syria, the economic sector has been completely destroyed because of the Syrian civil war since 2011 [78]. In Iraq, conflict and instabilities have severe impacts on agricultural and rural environment of the country [89]. Sowers [90] discussed that the countries facing wars and civil unrest are the most vulnerable countries to water and energy systems destruction. Elasha [68] argued that climate change can be a threat in the regions experiencing political instability, and it may aggravate stress in the region especially between nations sharing hydrological, geographical, and political boundaries. Elasha [68] further explained that water scarcity may exacerbate potential anxiety in the region knowing that about 80% of surface water resources and 66% of total water resources are shared in the Arab region.

4. Discussion

The issues presented in this paper are interconnected and have either direct or indirect effects on the FEW system in the Middle East region. For instance, limited access to water resources diminishes agricultural activities, intensifies poverty, and reduces the coping capacity of poor people to face risks. Furthermore, the extreme water deficit in the Eastern Mediterranean region has affected the socio-economic potency, exacerbated land vulnerability to salinization and desertification, and increased the risk of political unrest in the Middle East. In general, political unrest for any reason can cause food instability and struggle [91]. FAO report identified Syrian people that are in need of food assistance into two categories: 9.4 million as food insecure people and about 2.7 million of them at risk of food insecurity [87].

Wars and political instability made the urbanization process more complicated in the Arab region [79]. In general, urbanization is controlled by natural urban population growth, rural to urban migration, and reduced urban mortality compared to rural [54]. For instance, the drought period of 2006−2009 in eastern Syria influenced 1.3 million people after the loss of 2008 harvest, resulting in increased migration from rural to urban areas and extreme poverty levels in the region [11].

The connection between population growth and food insecurity is evident [81]. Egypt as the most populated country in the Middle East is one of the most food insecure countries in the region. In the Middle East, food security is impacted by several current challenges, namely, political unrest, global financial crisis, poverty, growing population, corruption, parochialism, and climate change related disasters [91]. However, decreasing human fertility may play an important role in poor countries to reduce poverty, lowering the pressure on livelihoods, and expediting economic growth [83].

Despite the fact that economic growth in developing countries may reduce poverty, the rate of poverty reduction depends on how economic growth is characterized. For example, there is a significantly negative relation between economic growth and poverty when economic growth is defined in terms of consumptions. However, a non-significant relation occurs between economic growth and poverty when economic growth is measured based on the changes in GDP/capita [92]. Ncube et al. [93] supported this argument by concluding that income inequality in the MENA region can increase poverty and decrease economic growth.

Countries can make an instant improvement in their economic growth by increasing the economic freedom in the society regardless of their current level of development. The index of economic freedom provides a comprehensive evaluation of an individual well-being, i.e., health, education, environment, innovation, society development, democratic governance, and freedom in acquiring and benefitting economic resources in countries that are more economically free [75]. Figure 13 shows the economic freedom of the countries of interest within the MENA region. From the figure, it can be seen that most of the Middle East countries are moderately free countries in terms of liberty and free markets. UAE and Qatar are mostly free; Iran, Egypt, and Lebanon are mostly repressed countries.

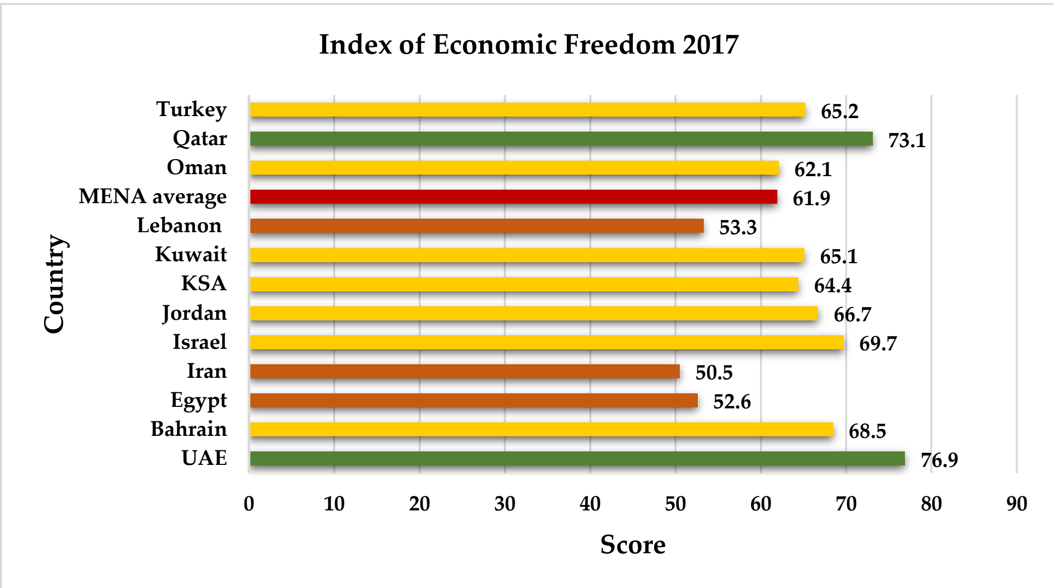


Figure 13. Index of Economic Freedom for the countries of interest within the MENA region in 2017. Countries are categorized as follows: (0–49.9) are repressed country, (50–59.9) are mostly unfree country, (60–69.9) are moderately free country, (70–79.9) are mostly free country, and (80–100) are free country. Note: not listed countries implies data unavailability. The data is acquired from Miller and Kim [75].

With respect to the energy sector, it was found that energy production in the Middle East is highly constrained by water deficiency [44]. For example, drought may significantly affect electricity supplies because of high temperatures which increase electricity demand during the low water supplies [18]. Moreover, rapid growth of population and economy have contributed to intensifying energy consumption in the MENA region [94]. Therefore, energy consumption is expected to increase to 95% in the Middle East for the period from 2012 to 2040 [43].

In order to better understand the differences (with regards to FEW security) among the Middle Eastern countries and to reveal the underlying influential factors affecting such a disparity, a comparison is conducted between the most FEW secure country in the Middle East (i.e., Turkey) and the least secure country (i.e., Yemen). In terms of food security, Yemen lies in an alarming stage of hunger and faces a high poverty rate, which has been exacerbated by the ongoing war and political instability. In contrast, Turkey is characterized by low hunger rate and low levels of poverty. Agriculture can be a major driver of a country's food self-sufficiency (i.e., meeting consumption needs from own production) when suitable environment is available, i.e., appropriate land and water resources. Given that Yemen is considerably below the water poverty line (1000 m^3/capita/year), the agriculture sector there is highly impacted by water scarcity. Limited agricultural area and an exceptionally warm climate aggravate the issue [95]. On the other hand, Turkey is agriculturally much more productive due to the abundance water resources (the highest in the Middle East), farmland availability, and the Mediterranean climate. Moreover, the increasing human fertility and increasing population alongside political unrest are other causes of food security in Yemen.

The other FEW component, energy, is dependent on and convoluted by water availability [96]. Since Yemen is among the arid Middle East countries with limited water availabilities, energy security there is another challenging issue, in contrast to Turkey. Furthermore, Yemen is one of the most vulnerable countries to the risks of climate change effects in the Middle East (e.g., heatwaves, floods, and landslides). The situation is quite different in Turkey, with abundant access to water and secure energy supply. Additionally, Turkey is expected to be less vulnerable to the risks of climate change, and due to its relatively higher liberty and comparatively more free market, Turkey has sustained a decent economic growth in the region.

Adaptation to scarcity in FEW nexus can be managed through reducing demands, increasing supplies, and maximizing storage and transport of resources [18]. Rainwater-harvesting techniques have been used in water scarce countries to increase the efficiency of rainwater usage [97]. Building seawater desalination plants over the Persian Gulf and the Red Sea is one of the most reliable sources of freshwater in the Gulf countries, i.e., Kuwait, KSA, Bahrain, Qatar, and the UAE. However, this solution requires substantial amounts of energy and it can affect the environment of the Persian Gulf or the Red Sea by increasing their salinity levels [98].

In summary, FEW security cannot be achieved if its components are considered as individual entities. In other words, improving one sector while ignoring others will not assist in solving issues related to other systems. A large amount of energy is needed to distribute, treat and use water and concurrently, large portion of water is required to generate and distribute energy. Food production requires intense amounts of water and energy. Fertilizers and pesticides used in agriculture may in turn impact the freshwater and aquatic ecosystems. However, food production can provide biomass energy [99].

5. Conclusions

Food, energy, and water security are emerging issues in the Middle East. It is imperative to study the dynamics behind the FEW security concerns in the region. Therefore, this study introduced the most critical challenges by retracing the FEW security problems that the Middle East has been facing recently. The evaluation suggested that most of the studied countries are facing FEW insecure resources condition. Water availability and natural hazards like drought, precipitation extremes, and heat waves contribute to the stress on water resources in the region. These factors, along with increasing population, can further impact the energy sector in the region. Meanwhile, energy production may affect climate due to greenhouse gases emission. This, in turn, may affect food production in the Middle East.

The FEW security in the Middle East can be classified into two major categories of water-energy security and water-food security. The water-energy security is directly affected by water scarcity, drought, and economic growth. Water-food security is directly impacted by water scarcity, drought, population growth, political unrest, and urbanization. Poverty and migration are the possible consequences of unsustainable FEW management; there is strong linkage and feedback among these components, and no component of FEW changes in isolation. However, water is the scarcest resource in the Middle East. Finally, the lack of consistent management combined with unsustainable use of resources in the Middle East region will probably pose critical FEW challenges in the near future.

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