Water-Energy-Food Nexus in the Middle East and North African Countries (MENA)

Zolfaghari, Mehdi and Jariani, Farzaneh

8 December 2020

Water-Energy-Food Nexus

in the Middle East and North African Countries (MENA)

Mehdi Zolfaghari
Department of Management and Economics, Tarbiat Modares University, Tehran, Iran
Corresponding author: Mehdi Zolfaghari, Assistant Professor of Economics at Tarbiat Modares University, m.zolfaghari@modares.ac.ir
Farzaneh Jariani
Graduate of Theoretical Economics, Tarbiat Modares University, Tehran, Iran

Abstract

The water, energy and food nexus approach was studied and assessed in this research in a period namely between 2009-2018 in the Middle East and North Africa countries and accordingly the results show that the nexus between water, food and energy have not been established in the Middle East and North Africa Region (MENA) as the general perspective of sustainable development and providing the residents of the foregoing region with the food and generally speaking, the important variables do not give any logical and meaningful effect to the behavioural equations of water, energy and food in this region. Therefore, the population growth especially the urbanization one, the economic prosperity and the requirements thereof may cause a pressure increase on the water, energy, food, land and other natural resources and eventually such increase will bug and disrupt the food supply for the MENA region in the years to come and it can also lead to the aggravation and intensification of conflicts, tensions and wars and bellicosity.

The most significant solution for establishing the balance and equilibrium among the population growth, urbanization growth and food supply and also the other effective factors in the MENA region is the establishment and assessment of the water, energy and food nexus and the integral and drastic management and then performing the appropriate strategies that such matter will never be possible except using the social capital (Civil participation and the participation of the entire social processes) and the economic quality (Equipping the economy for sustainable wealth creation and perfect employment) through the decentralized professional working groups which include

the private sector applying the financial sponsorship and legal supports of the then government.

Key Words

WEF Nexus, Water-Energy-Food Nexus, GEE, Middle East, North Africa

Introduction

The Middle East and North Africa regions have invariably played a very important role in the global interaction network (Abbasi et al, 2015) due to the influence geopolitical, economic and cultural factors of the region on the commercial contacts, international agreements, foreign investments and the transit ties or relationships hence any in safety which may happen in the countries locating at the afore-said region can be taken into consideration as a great threat for the safety of the other countries in the world and for that reason the safety crisis (Concerning the water, energy, food, economy, society and so forth) in the MENA region has been invariably taken into account by the superpowers.

The Middle East and the Persian Gulf regions are regarded as one of the low water areas in the world with the water availability average for each person which is only about 1200 cubic meters per annum and with the population growth of 1.8 % and the GDP growth of 1.6 % in 2017 (World Bank, 2019) and approximately 80 % of the whole renewable water resources are wasted in such region (Scardigno et al., 2017). The MENA region involves less than 2 % of the operational freshwater resources in this world having about 6 % of the world population (Zawahri, 2017). More than 60 % of the population in this region is now living in the areas with the water high-stress level or very high one whereas the global average of such stress is about 35 % and also more than 70 % of the Gross Domestic Product (GDP) of this region is now performed in the areas with the water high stress or very high one which the global average thereof is about 22 % (World Bank, 2018).

The population growth and the increasing water consumption both have caused some climatic changes and the MENA region warming since the twentieth century.

According to the predictions the said region will face with the temperature increase (Between 1 to 5 degrees and up to 3 degrees centigrade by 2065) by 2030 and also the rainfall decrease (Between 10 up to 20 %) and an increase in the rate of evaporation together with regular and longer drought and lack of rain (IPCC, 2007). The MENA region has been invariably one of the driest areas (Green Wood, 2014). Such dry spell in the MENA region has started since the 1970s. The recent 30 years period of the shortage of water in the foregoing region can be taken into consideration as one of the most effective and the longest drought. The heating process has begun since 60 years ago and then intensified for about 30 years. The heating process intensity together with a change in the downfall and precipitation patterns all have caused the soil erosion intensity and the environmental degradation which these have actually caused more destructions in the agricultural and animal husbandry infrastructures. One thousand people have lost their job in the rural areas and they have immigrated to the cities for finding job opportunities (Karami, 2016). Therefore, the role of climatic changes and the water shortage both have been invariably taken into account in creating the tension and violence in the Middle East and North Africa regions (Ahmed 2017, Feitelson et al., John Stone and Mazo 2011). The water shortage has caused many tensions and inequalities due to the conflicts on the border resources among the counties of the said region that in such conflicts, one party was accused of consuming more than its own fair share (Green Wood, 2014). The water shortage has also caused some important discriminations in consuming the resources and it has consequently caused creating the domestic tensions within the borders and countries while the rich are now using the cleanest and the most inexpensive water resources but the poor often live in the polluted zones while the available water for them is with the most expensive price and lower quality (Tropp & Jagerskog 2006, Devlin 2014). More than 50 million people have left the MENA region since 2011 due to the conflicts arising out of the water shortage and the health, sanitation and hygiene requirements. A wave of some long wars in the said region and the economic and political crises arising out of the same all have caused the relocation of people between 22 to 24 million ones that such number approximately includes one third of the whole displaced population in the

world. Whilst, the climatic changes, the unplanned development of cities, unstable and unsustainable operation of the water resources have also caused that the challenges of the water management could be effective prior to the recent conflicts and tensions in this region (Diep et al, 2017).

Energy demand involves a very remarkable growth throughout the Middle East and North Africa regions. Like water, the energy demand is subject to change not only with the population growth but also affected by the energy-demanding industries and the lifestyles (Sowers, 2014). Extraction, transmittal, forwarding and conducting the water all need the energy. Also, most of the extraction processes in the different fuel refinement and purification and the water production are now performed by power and electricity. The decrease of freshwater resources is now observed in the most parts of the MENA region due to the increase of demand for energy (Siddiqi, et al, 2011). Energy is needed for producing, transporting and distributing the food and also for extracting, pumping, gaining, collecting, transporting and treating the water (Flammini et al, 2017).

Citizens of the Middle East and North Africa regions are now severely relying on the agriculture and farming as the food resource and income and the relation among water, energy and food (WEF) is very significant for the sustainability and the continuous growth of the said region. The countries have been already changed from semi-arid to arid and many of them are now taking the water shortage and the most variable rainfall rate caused by the geographical conditions and climatic changes in stride. The agricultural sector consumes and takes a large share of water (World Bank, 2018, Waha et al., 2017). At the moment, about 75 % of the water resources of the afore-said region have been allocated to the farming and agriculture (Scardigno et al., 2017). Water, energy and food are necessary for the human being's health, poverty, destitution and indigence decrease and also the sustainable development. The global and worldwide predictions show that any demand for the freshwater, energy and food in the decades to come will remarkably increase because of the population growth, economic development, urbanization, growing and rising demands for the food, various diets, resources reduction and the shortage of them (Hoff, 2011). Currently,

the agriculture has allocated about 70 % of the total amount of freshwater resources in the world and it is among the biggest water consumers. Water is used for preparing the farming and agricultural products, for the entire foodstuffs supply chain, farming materials, transportation and also for the whole and various kinds of energy (FAO, 2011 a). Yet, producing the foodstuffs and the supply chain applies and consumes about 30 % of the entire global energy (FAO, 2011 b). If such conditions get intensified in the near future therefore, we will need about 60 % more food by 2050 so that we could supply more nutrients and then produce the foodstuffs with the better quality. Also, it is expected that the energy consumption of the world will increase toward 50 % by 2035 and 80 % by 2050 (IEA, 2010). It is predicted that the total water consumption will increase for 50 % in the years 2025 and in the developing countries (A developing country, a low and middle income country (LMIC), less developed country, less economically developed country (LEDC), or underdeveloped country) and it will increase for 18 % in the developed countries (A developed country, industrialized country, more developed country, or more economically developed country (MEDC)) (Flammini et al., 2017).

With regards to this matter that the water, energy and food safeties considering the population growth, climatic changes, environment and economy are of serious ties with each other and one of the most prerogative challenges in the said region was the provision of the water, energy and food safeties without the reduction of the natural resources accordingly the water, energy and food nexus approach (WEF) was provided for meeting the peoples' requirements and interests, economic growth coping with the climatic changes, inequality growth and the social dissatisfaction (Hoff, 2011).

The water, energy and food nexus approach (WEF) is an approach that will be effective and drastic for achieving the water, energy and food safeties and consequently meeting the human beings' needs. Now, 844 million ones can't access to the healthy drinking water, 1.1 billion people are deprived of achieving the energy (50 % of them are now living in Africa) and about 815 million people are deprived of any secured access to the food. Therefore, the concept of such nexus is to ensure the

sustainable operation of the resources avoiding any wastes or to prevent wasting them. Recognizing the interwoven relationships among the water, energy and food parts establishes some principles for creating one new approach and in order to implement very integral management among the water, energy and food parts and consequently among the entire parts (Stephan et al., 2018). The water, energy and food nexus is an endeavour towards balancing the consumption of the ecosystem different resources (Energy, Water, Land, Soil) and the social and economic factors. There are also some clear interactions among the water, energy and food which these may lead to the co-operations, synergies among the different parts and sections and the beneficiary groups. For example, it is estimated that about 30 to 50 % of the produced foodstuffs of the world may change to the garbage and rubbish and this means wasting about 1.96-1.47 hectares of the farming land in the world, 1.25 – 0.75 billion cubic meters of the water and 1.5–1 % of the energy in our world (Aulakh and Ragmi, 2013). Motivations for the nexus approach include the economic efficiency, resources efficiency and the livelihood improvement options (Bazilian et al, 2011).

One of the biggest challenges that we are facing therewith is the growing deficiency of the resources for a vital resistance and sustainability. According to the announcement of the United Nations Organization, the people will need about 30 % more water, 45 % more energy and 50 % more foodstuffs by 2030. The water, energy and food stabilities (WEF) have changed to an important area for the environmental studies (Yuan et al, 2020). In the recent world, we see that about 780 million people are deprived of any access to healthy water and 1.5 billion ones from any access to the power and electricity. Also, the farming lands are known as the main resource of livelihood for the maximum poor of the world (Tidwell and Moreland, 2016). Based on FAO's report, the agricultural sector has to increase its products for 60 % in order to provide the increased population with their food by 2050 that as a result, the water consumption need in the agricultural sector will increase by 10 % (FAO, 2014). Based on the International Energy Agency, the energy consumption rate will increase by about 50 % by 2035 and as a result of the growth in demand, the competition for the resources will increase. Assuring the water, food and energy supplies and providing

safety with each of these three parts without the natural resources decrease will be known as a big challenge of the world (Birol, 2010).

The social and political instabilities are usually created by the resources deficiency which may cause some irreparable environmental damages, too. Focusing on one of the parts related to the water, energy and food nexus without considering the relations among them may cause some serious dangers unwanted consequences (World Economic Forum, 2011). Since the water, energy and food nexus approach is a landscape of the sustainable development and is trying to establish the balance between the various goals and objectives including the peoples' and environment's interests and requirements (Hoff, 2011). Accordingly, with regards to the importance and necessity of the existence of safety for the water, energy and food nexus in the above-said exclusive and strategic MENA region and the inevitability of the participation and alignment between the processes in society and government and also providing the existence of an appropriate quality in the economy and so this matter can be a suitable background for the existence of WEF nexus safety in the MENA region and for producing a sustainable wealth and complete employment. We have studied the relations between the WEF nexus factors and the institutional variables in this essay including the social capital and the economy quality of the countries locating at the afore-mentioned region. It should be noted that we have applied and used the economic growth variable in similar studies. Since the major exporters of oil and gas are in the Persian Gulf and North Africa Regions thus such variable can merely express the quantity of economy and not the quality thereof.

The Nexus between Water, Food and Energy in the Middle East and North Africa Regions

The unprecedented increase of the global population, growth of the middle-class communities and increase in their purchasing abilities, climatic changes, economic development and prosperity, international trading and the concerns into the health and environment all play a very salient and outstanding role in the importance of reducing the growing stresses relevant to the vital resources such as water, energy and food

(WEF). The lack of systematic managerial strategies, supplying ability of such resources can threaten the growing demand. Predictions for the healthy water availability and also the food and energy availability, the soil and air qualities are among the worrying things and the matter of concern. These warnings are hinting and referring to one significant result namely “Business as Usual” which is no longer stable and durable. As a matter of fact, such alarms are asking for a very fundamental change in the method of understanding and managing the resources: Getting away from the traditional approaches “Silo” to the more integral systematic approaches. While, such a change is fostered in the different global stages, the development is completed sporadically and any tendency is focusing on the special and individual aspects (Daher and Mohtar, 2015).

The food safety and especially the availability of foodstuffs depend on the environmental resources, climatic conditions and the agricultural measures and also on the water resources as a common denominator. In the countries with the water resource limitation, therefore, there is the main concern regarding the safety of the foodstuffs due to the high volume of water which is essential for their production. Countries with the water shortage are interested in relying on international trading for reducing the gap between the water supply and demand (And consequently the foodstuffs) (Antonelli et al., 2017). Presently, the water challenges in the afore-said MENA region are far higher than the old limitations arising out of the water shortage. While the challenges on the water shortage have appeared since one hundred years ago but we see that the new challenges are of their own particular dangers and menaces. These new challenges are as follows:

The complexity of the water, energy and food nexus approach, climatic changes, drought, flood, water quality, surface waters management, water crisis management, conflicts and violence, prevailing upon such challenges all rest on creative and innovative management in achieving and protecting such resources, performing the infrastructural investments and modern technologies (World Bank, 2018). The Middle East and North Africa regions (MENA) are now highly depending on the foodstuff importations and this matter can be also vulnerable and susceptible against the price

shock in the global markets and failure of succeeding in the other parts of the world. This quick study will focus on the literature relevant to the effect and influence of climatic changes on the food safety in terms of any future usage and the changes of foodstuffs importations and for the whole region. The evidence of the blinds are based on the gender and the disability is not taken into account. The completed studies show that this region will remain under the effects and influences of future climatic changes and it may deprive the people of the suitable quantity and quality and also the food safety more than ever. Those studies which have done such assessment involve the reports made by the experts and international institutions including the Organization for Economic Co-operation and Development and the Food and Agriculture Organization (OECD – FAO, 2018) and the World Bank (2018). The quantitative assessments into the climatic changes of MENA region will be considered as a whole so much matter may remarkably make more difficult our understanding of the climatic changes in terms of the regional situation (Jobbins & Henley, 2015). Most of the MENA region countries are now facing a double challenge as disclosed below:

They must use their often small and fragile resource base and yet they face a more and growing dependency of the foodstuffs importations, too. The climatic changes can add to such challenges and then they make the production capacities more limited and then add to the importation requirements. Such challenges are mostly explained to the countries which are the members in the Gulf Cooperation Council and for the Arab countries on the Persian Gulf (That they were known as the Gulf Cooperation Council or GCC in the beginning) that according to this council any dependency on the imports can be higher than 90 % of the domestic foodstuffs requirements and where the product is fecund, prolific (Rich) and also renewable so the water resources will be practically tired out (OECD – FAO, 2018:94).

The mutual dependency among water, energy and food (WEF) is increasing because the demand for one of them will cause a demand increase for two other ones. Several regions of the world are now facing with the WEF safety challenges which this matter puts some effects on their sustainable economic growth. There is also some evidence which shows that the climatic changes, social, political and economic issues can be

effective on the availability and demand for the water, energy and food in addition to the water shortage (Miralles – Wihelm et al., 2018).

The WEF systems are fully interconnected: Food production needs the water and energy. Pumping, water refinery and supply needs the energy, too. Producing energy needs the water (Mohtar and Daher, 2012). These three systems are also placed under some forces which can cause the intensification or they can help reduce the pressures between them. The national strategies for managing a system are often edited and codified independent of two other ones therefore they have not been able to pay attention to the interconnection and reunion of these three factors. Such a thing can sometimes lead to some contradictory and inconsistent strategies and then increasing the competition for the same resources. While the arguments relevant to the "Nexus" have been taken into account over the past few years in the arenas including the politics and science but the need for increasing the knowledge and awareness and integral planning still exists among the involved institutions. We can meet such need through a quantitative framework and using the tools which can lead us to the cooperation increase and integral planning (Daher and Mohtar, 2015).

Water safety is sometimes taken into consideration as a part or subdivision of food safety. According to the Food International Organization, the water safety can be known as the ability for supplying the sufficient and adequate and reliable water for providing the population with it and for meeting the requirements in the agricultural sector and production in the said sector. In most of the countries especially those countries that have dry and semi-dry climates such as the countries in the MENA region, water used for the irrigation can be one of the most important factors in supplying and providing the food. The food and water safeties have been recently applied jointly and together in most of the various fields and aspects (Scardigno et al., 2017).

The relative water shortage in the Middle East and North Africa Regions, the water has been invariably known as a resource of opportunities and threats in these regions. Achieving the water safety and as a result, the economic, social, environmental welfares and the path of peace and sustainability will have a drastic and great influence

in the economic growth, upgrading the social capital, environmental improvements and betterment of the political conditions in this region. The development process of these conditions will rest and depend on the population control, consumption demand control, governance practices and methods, water resources management especially the groundwaters, coordinating the nexus of water, energy, food and then utilizing and operating the water resources sustainably and the climatic changes. In this region, gaining water safety is more important than coping with the water shortage (World Bank, 2018). The water shortage will mostly increase in the whole Middle East and North Africa countries due to the demand increase and over the subsequent few decades and most importantly, most of the countries in the said region can run out of the fossil waters by 2050 except some measures and actions could be taken for controlling the unstable water condition. The influence of such a growing shortage is remarkable in the agricultural sector it is predicted that production in some countries may decrease by 60 % by 2050. In the ascending trend and process, a decrease in the dependency of the agricultural and energy sectors to the water and a change to the renewable energies can reduce the water shortage whilst this matter can decrease the Greenhouse Gas Emissions (Borgomeo et al., 2018).

The foregoing region has been especially challenged by the different factors including the high variability of the biogeographical features, intense population growth over the past few decades and the fundamental economic transitions and also the armed conflicts in some of the countries existing in the afore-mentioned region. The predicted changes in the climatic conditions may intensify the challenges related to the water and energy safeties in the said region. Major effects of climatic changes involve some outstanding temperature increase in the summer which will cause an increase in the number of warmth waves and primarily in the urban structures. The general reduction of rainfalls has been anticipated in most of the countries locating at MENA region and inevitably the drought has increased which accordingly an increasing number of dried talismans will be created. One integral Nexus Concept of the water and energy can provide us with a very hopeful and promising outlook for the betterment of environmental, climatic, human and political safeties in dealing with

the energy and water shortages and their mutual relations. However and at the moment only a very small number of countries in the MENA region have implemented such a concept. The strategies of reduction and conformity (Adaptation) will act with regards to the water and energy shortages including the efficiency increase in using the resources and assessing the integral technology on the power production and stronger self-reliance into the renewable/solar technologies (Lange, 2019).

On the other hand, comparing the velocity and the rate of economic development of countries in the Middle East and North Africa with the developing countries shows that the countries in MENA region had some poor economic performance over the past 20 years for two reasons as disclosed below and despite their favourable geographical and strategic locations:

1- Most of the countries can't effectively apply or obtain the existing technologies

2- They are economically inefficient.

Therefore, the international structural adjustment plans which have been focused on privatizing and releasing the business only show very limited success in the said region (Brach., 2010).

With regards to the structural problems of countries in the Middle East and North Africa including the water shortage, governance practices and methods, poor management regarding the water, energy and food resources and the climatic changes, poor technology all have changed the water, energy and food nexus management to a strategic challenge in the afore-mentioned region so that the inadequate supply of water, food and energy can presumably impose some double and multiple damages in the near future to the social capital and economic growth of the considered countries. Accordingly, the need for creating mutual contact among the social capital, economic growth and the water, energy and food nexus will be something inevitable and binding. So, the factors related to the WEF nexus and their relation with the institutional variables of the social capital and the economy quality will be studied in this essay and then a new scenario will be provided based on the performed analysis: The case study for the WEF nexus in the Middle East and North Africa countries from 2009 to 2018.

Research Backgrounds

- **FAO:**

FAO has presented its own quantitative analysis in order to assess the performance of the water, energy and food nexus management as an approach for the sustainable development using the required data in relation with the natural resources condition and the social and economic aspects. In such analysis, the matrix of relations among the water, energy and food has been applied and used as a tool for recognizing the synergy and cooperation of this nexus, in terms of the human ecosystem and system in the different scales. Any specified relation in those matrixes presented by FAO is predominantly and more related to that special country's topology and less with the other countries. The information shown regarding the topology of the country can be specifically appropriate with that special reported relation in the considered matrix. Such a method can help in recognizing a set of WEF nexus relations. We have used the existing indicators and through creating the specific time indicators which are not available and or the existing indicators and using the geographical condition of the countries for measuring such relations.

1- Exact relation assessment (Qualitative Method) and

2- The nexus quick assessment (Quantitative Method)

- **National and Regional Studies:**

(Huang et al., 2020) For studying the interactions of the local nexus among the water, energy and food focusing on assessing the intensity among the nexus factors using the Synchronic Equations Model (SEM) in 30 provinces of China from 2005 to 2016 which showed discovering the mutual relations among the factors that are efficient on the WEF nexus in order to assess and the method of performance of it can be remarkable and effective for the behavioural viewpoint of such interactions. Furthermore, the important factors and the main parts dominating on such nexus will be specified through the coefficients gained from each equation. Whilst, the nexus common points and the feedback chains all will be determined in the system of equations, too.

(Yang et al., 2020) Concerning the function method of water, energy and food nexus in the developing countries (Based on the experimental studies done in China) using the Structural Vector Auto Regression (SVAR) method from 1997 to 2016 show that there are two kinds of behaviour in relation with the water, energy and food nexus in China: The water, energy and food nexus with the use of nuclear energy together with natural gas. Transferring the energy from water can be compatible for the various types of energy for the mutual effect of the water and energy sectors in the WEF nexus there in China while the transference from the water to energy can be different. The food production has always had some negative effects on energy production while transferring the energy from the food can be different for the various types of energies. Conducting between the food and water supply was not sufficiently taken into account especially the effects of water supply in producing the materials had been very poor. Therefore, a new policy has been presented within the framework of WEF relation in China. The research findings are important to help to understand the local and domestic mechanisms and presenting the water, energy and food solution and the political consequences can be appropriate and beneficial for achieving the better effects of the said policy.

(Yang et al., 2020) We present an indicator titled Linked Indicators for FEW Availability (LIFEWAY) through studying the FEW sustainability for 42 developed and under developing countries in 2014 based on SDGs studies aiming to design an integral indicator or one indicator for measuring the sustainability achievements of one country and for comparing the FEW sustainability in the different geographical regions. Conclusions can confirm that the LIFEWAY indicator is remarkably together with the Gross Domestic Product and it can be applied for the FEW sustainability of a country. This can be used for analyzing the special subject matters and allows developing the regional and national solutions.

(Taniguchi et al., 2017) have analyzed the safety measures based on the rate of resources, production and the diversity of the resource of every factor for assessing the water, energy and food resources for thirty two countries in the Asia – Pacific regions using the Self-Production Ratio and as a divided consumption based on the

production rate namely from 1960 to 2012. The surface waters and groundwaters for the water, energy, power, geothermal energy, solar energy and biomass for producing the energy and grains, corns and cereals, vegetables, fruit, meat and fish as a food. Findings of such research can show the higher diversity of the water resources in the United States of America and Philippines and the lower diversity of the food resources in the United States of America, Canada and Indonesia. Also, such safety actions including the water safety can explain a new hydrological insight for the Asia and Oceania regions.

(Endo et al., 2015) About 37 projects selected in Asia, Europe, Oceania, North America, South America, Middle East and Africa studied the current status of research on the water, energy and food using a quantitative method and applying the data existing in the academic publications. They recognized about four types of research of the nexus research subject matters including the water and food, water, energy and food, climate. Among them, about six projects (16 %) were of a close relationship with water and food and about 11 projects (30 %) with water, energy and food and 12 projects (32 %) with water and energy and about 8 projects (22 %) with the climate. They also determined the local patterns in the nexus studies. North America and Oceania were interested in focusing on a special type of nexus, water and energy (46 %) and climate (43 %) while made lower concentrations on the energy and water (70 %).

- **The Middle East and North Africa Studies**:

(Antonelli et al., 2017) in his researches which began from 1980 to 2010 using the FAO, indicators argue that the virtual water trading in MENA region namely the virtual transfer of the consumable water for producing the agricultural products from the producing countries to the regional ones has provided the said region's economy with the economic safety of water and food over the past 25 years. This study also is indicative of this matter that the virtual water imports have become more than double and such increase has been appropriate to the population growth in the said region. The food products have allocated the largest share of the virtual water currents to themselves while the agricultural products and the high consumption foods are among

the main groups of the agricultural products, therefore, the MENA region is outstandingly dependent to the water resources existing in the other countries.

(Abbasi et al., 2015) Since the multilateral relations between the water resources and food safety remains in the main core of the sustainable development in the Middle East and North Africa hence they have dealt with the multi-dimensional analysis of about two indicators which are related to the water safety and food one using the Correlation Matrix and Scatter Plots Matrix of Correlation and in their studies from 2014 to 2016. About 5 factors such as the Poverty Index, Water Capacity, Use, Access, resources and Environment and 3 factors including the Global Food Safety Index, Availability, Affordability and Food Quality and Safety were analyzed. Results are indicative of this matter that there is a positive correlation among the Water Poverty Index, Global Food Safety Index and the correlation between these two indicators and with regards to the different aspects can show more relation with the Availability and Food Quality / Safety. Integrating the water standards in food security can be considered as a very useful step for organizing the water, food and energy management and a drastic approach for achieving food safety in the MENA region.

A Brief Review on the Situation of Counties Locating at the Middle East and North Africa

According to the classifications made by the world bank the Middle East and North Africa countries include 14 Asian countries (Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, West Bank and Gaza and Yemen) and 7 African countries (Algeria, Djibouti, Egypt, Libya, Malta, Morocco, Tunisia). Despite this matter that the countries in this region have enjoyed the main oil and gas resources of the world but they are of different economic, social and environmental features which such difference has been stated using the descriptive statistics as disclosed below:

Table (1): Water, Energy and Food

Population using at least basic drinking-water services (%)		*Electric power consumption (kWh per capita)*		*Cereal yield (kg per hectare)*	
Mean	93.095	Mean	5483.144	Mean	4488.675
Standard Error	0.713	Standard Error	404.633	Standard Error	387.455
Median	96	Median	2670.730	Median	2318.900
Mode	100	Mode	-	Mode	2000
Standard Deviation	10.077	Standard Deviation	5577.474	Standard Deviation	5066.625
Sample Variance	101.543	Sample Variance	31108221.024	Sample Variance	25670689.296
Kurtosis	4.699	Kurtosis	0.147	Kurtosis	7.329
Skewness	-2.209	Skewness	1.161	Skewness	2.607
Range	48.506	Range	20688.308	Range	27496.000
Minimum	52	Minimum	193.804	Minimum	634.100
Maximum	100.506	Maximum	20882.112	Maximum	28130.100
Confidence Level(95.0%)	1.405	Confidence Level(95.0%)	798.176	Confidence Level(95.0%)	764.842

Table (2): Economic Indicators

Total renewable water resources per capita (m3/inhab/year)		*Electricity production from oil, gas and coal sources (% of total)*		*Population growth (annual %)*	
Mean	639.924	Mean	93.752	Mean	2.558
Standard Error	62.226	Standard Error	0.799	Standard Error	0.167
Median	302	Median	99.026	Median	2.039
Mode	282.4	Mode	100	Mode	
Standard Deviation	880.005	Standard Deviation	11.020	Standard Deviation	2.359
Sample Variance	774408.935	Sample Variance	121.436	Sample Variance	5.563
Kurtosis	3.006	Kurtosis	6.535	Kurtosis	4.714
Skewness	1.963	Skewness	-2.540	Skewness	1.059
Range	3381.014	Range	54.922	Range	18.681
Minimum	4.314	Minimum	45.078	Minimum	-4.537
Maximum	3385.328	Maximum	100	Maximum	14.145
Confidence Level(95.0%)	122.706	Confidence Level(95.0%)	1.577	Confidence Level(95.0%)	0.329

Urban population growth (annual %)		*GDP per capita growth (annual %)*		*Inflation, consumer prices (annual %)*		*Trademark applications, total*	
Mean	2.746	Mean	0.357	Mean	4.127	Mean	23607.370
Standard Error	0.180	Standard Error	0.836	Standard Error	0.475	Standard Error	3558.426
Median	2.139	Median	0.497	Median	2.904	Median	8830.000
Mode	-	Mode	-	Mode	2.084	Mode	-
Standard Deviation	2.546	Standard Deviation	11.338	Standard Deviation	6.379	Standard Deviation	41802.043
Sample Variance	6.482	Sample Variance	128.541	Sample Variance	40.698	Sample Variance	1747410824.278
Kurtosis	4.549	Kurtosis	76.955	Kurtosis	14.501	Kurtosis	7.505
Skewness	0.672	Skewness	5.765	Skewness	1.636	Skewness	2.901
Range	20.860	Range	184.158	Range	70.122	Range	199246
Minimum	-6.515	Minimum	-62.378	Minimum	-30.856	Minimum	230
Maximum	14.345	Maximum	121.780	Maximum	39.266	Maximum	199476
Confidence Level(95.0%)	0.355	Confidence Level(95.0%)	1.649	Confidence Level(95.0%)	0.938	Confidence Level(95.0%)	7036.543

Table (3): Social Indicators (Legatum Prosperity Index)

Social Capital		*Economic Quality*	
Mean	49.869	Mean	49.063
Standard Error	0.654	Standard Error	0.856
Median	49.955	Median	45.549
Mode	47.975	Mode	-
Standard Deviation	9.247	Standard Deviation	12.112
Sample Variance	85.506	Sample Variance	146.691
Kurtosis	-0.080	Kurtosis	-0.750
Skewness	-0.384	Skewness	0.143
Range	45.260	Range	52.824
Minimum	22.629	Minimum	19.877
Maximum	67.889	Maximum	72.702
Confidence Level(95.0%)	1.289	Confidence Level(95.0%)	1.689

Table (4): Environmental Indicators

CO2 emissions (kt)		*Average monthly precipitation*		*Average monthly Temperature (°C)*	
Mean	126397.652	Mean	13.948	Mean	23.207
Standard Error	12182.176	Standard Error	0.827	Standard Error	0.267
Median	62006.094	Median	10.016	Median	23.414
Mode	517.047	Mode		Mode	-
Standard Deviation	172281.987	Standard Deviation	11.424	Standard Deviation	3.697
Sample Variance	29681082984.986	Sample Variance	130.499	Sample Variance	13.667
Kurtosis	3.833	Kurtosis	2.300	Kurtosis	-1.129
Skewness	2.186	Skewness	1.400	Skewness	-0.086
Range	718939.043	Range	63.714	Range	13.213
Minimum	462.042	Minimum	1.533	Minimum	15.820
Maximum	719401.085	Maximum	65.247	Maximum	29.033
Confidence Level(95.0%)	24022.722	Confidence Level(95.0%)	1.630	Confidence Level(95.0%)	0.528

Studying the statistics stated in the above-said tables show a remarkable variance and distribution from the moderation point and the statistical gravity centre in some of the standards of WEF, economic and environmental indicators including:

-Water, Energy and Food Nexus: Cereal Yield, Electric Power Consumption,

-Economic: Trade Mark Applications, Total Renewable Water Resources Per Capita,

-Environmental: CO2 Emissions

Therefore, the Mena region countries have significant differences in terms of energy consumption, food production, water resources, technology and climate changes, which could lead to greater hunger and tension in some countries in the region. It is worth noting that there is no such strong distribution and distinction in social indicators. In other words, the countries of the Middle East and North Africa are not very different in terms of social capital and economic quality.

Empirical Model

In the FAO approach, the connection of water, energy and food as social, economic and environmental goals interact with the basic sources of energy, water, land, capital and labour through the following drivers:

- Population growth, urban planning, diversity and change of diet, cultural and social beliefs and behaviours, climate change
- Government, sectoral policies and granting benefits, international and regional trade and market, agricultural developments, innovation and technology (See Flammini et al, 2017 for further reading)
- Using the following three behavioural equations in the system of simultaneous equations, Huang et al (2020) examined the structure of water, energy and food bonding in China:

Water equation:	$w_t = f_1(E_t.F_t.X_{Wt})$	(1)
Energy equation:	$E_t = f_2(W_t.F_t.X_{Et})$	(2)
Food equation:	$F_t = f_{13}(E_t.W_t.X_{Ft})$	(3)

In the said equations, the vector Y can be presented as water consumption, energy consumption and food production, and the vector X (as indicators) as the driving factors.

With respect to the previous studies in the field of water, energy and food bonding in the Middle East and North Africa, there is insufficient confidence in supplying food security, providing national and regional security, both now and in the future. Also, considering the importance and necessity of the role of institutional variables in providing and supplying water, food and energy security, no institutional variables have been included in any of the research models. For such reason, in the present article, Pursuant to the FAO approach, two institutional variables of social capital and economic quality, which play a direct and important role in managing and ensuring WEF security, will be added to the above three behavioural equations.

According to the definition of a methodology for calculating the Legatum Welfare Index, social capital pillar measures the strength of personal and social relationships, social norms, and civic participation in a country. The variables used to determine the social capital criteria of the Legatum index are as follows: Social Networks, Personal and Family Relationships, Interpersonal Trust, Institutional Trust, Civic and Social Participation. Also, according to the above definition, The Economic Quality pillar measures how well a state's economy is equipped to generate wealth sustainably and with the full engagement of its workforce. The used variables for measuring the economic quality pillar include Productivity and Competitiveness, Macroeconomic Stability, Labor Force Engagement, Fiscal Sustainability, Dynamism.

According to the said explanations, the equations of this research are:

$$W\_C_t = \alpha_0 + \alpha_1(F\_P_t) + \alpha_2\,(E\_C_t) + \alpha_3 trw_t + \alpha_4 ep_t + \alpha_5 popg_t + \alpha_6 upg_t + \alpha_7 gdpg_t + \alpha_8 inf_t + \alpha_9 cc_t + \alpha_{10} amp_t + \alpha_{11} amt_t + \alpha_{12} tec_t + \alpha_{13} socap_t + \alpha_{14} ecoqu_t + \alpha_{15} arabs_t + \mu_W \quad (4)$$

$$E\_C_t = \beta_0 + \beta_1(F\_P_t) + \beta_2\,(W\_C_t) + \beta_3 trw_t + \beta_4 ep_t + \beta_5 popg_t + \beta_6 upg_t + \beta_7 gdpg_t + \beta_8 inf_t + \beta_9 cc_t + \beta_{10} amp_t + \beta_{11} amt_t + \beta_{12} tec_t + \beta_{13} socap_t + \beta_{14} ecoqu_t + \beta_{15} arabs_t + \mu_E \quad (5)$$

$$F\_P_t = \gamma_0 + \gamma_1(W\_C_t) + \gamma_2\,(E\_C_t) + \gamma_3 trw_t + \gamma_4 ep_t + \gamma_5 popg_t + \gamma_6 upg_t + \gamma_7 gdpg_t + \gamma_8 inf_t + \gamma_9 cc_t + \gamma_{10} amp_t + \gamma_{11} amt_t + \gamma_{12} tec_t + \gamma_{13} socap_t + \gamma_{14} ecoqu_t + \gamma_{15} arabs_t + \mu_F \quad (6)$$

In the above equations:

W_C: Population using at least basic drinking-water services (%)

F_ P: Cereal yield (kg per hectare)

E_C: Electric power consumption (kWh per capita)

trw: Total renewable water resources per capita (m3/inhab/year)

ep: Electricity production from oil, gas and coal sources (% of total)

popg: Population growth (annual %)

upg: Urban population growth (annual %)

gdpg: GDP per capita growth (annual %)

inf: Inflation, consumer prices (annual %)

cc: CO2 emissions (kt)

amp: Average monthly precipitation

amt: Average monthly temperature

tec: Trademark applications, total

socap: Social Capital

ecoqu: Economic Quality

arab: Arab spring

μ: Error terms

Generalized estimating equations (GEE) are applied for estimating the richer analysis of data structure and modeling the structure of within-panel correlation.

All data will be extracted from World Bank databases, World Health Organization, FAO, Legatum and other related databases from 2000 to 2018 for countries in the Middle East and North Africa (Iran, Iraq, Saudi Arabia, Yemen, Djibouti, Oman, Qatar, Kuwait, Bahrain, the United Arab Emirates, Syria, Jordan, Lebanon, Israel, the West Bank and Gaza, Egypt, Libya, Tunisia, Algeria, Morocco and Malta).

Estimation results

Prior to estimating the model, the unit root test was performed using the Augmented Dickey-Fuller test to ensure the durability of the concerned data. Test results showed that all data were at a durable level.

Table (5): Data unit root results

Variables	Result	Variables	Result
w_c	0.0151	Inf	0.0000
e_c	0.0000	Tec	0.0005
f_p	0.0000	Cc	0.0007
trw	0.0044	Amp	0.0000
ep	0.0062	Amt	0.0000
popg	0.0000	Socap	0.0000
upg	0.0000	Ecoqu	0.0000
gdpg	0.0000	Arabs	0.0000

The results of model estimation from the GEE method for each of the behavioural equations: water consumption (w_c), energy consumption (e_c) and food production (f_p) are presented in the following table:

Table (6): Estimation results

Equation Explanatory	Water	Energy	Food
w_c	-	0.09 (0.929)	1.40 (0.162)
e_c	-1.86** (0.062)	-	5.48* (0.000)
f_p	0.49 (0.625)	3.34* (0.001)	-
Trw	-3.93* (0.000)	1.17 (0.242)	-0.99 (0.322)
Ep	-2.59* (0.009)	5.35* (0.000)	-4.70* (0.000)
Popg	5.36* (0.000)	2.34* (0.019)	0.79 (0.430)
Upg	-5.31* (0.000)	1.79* (0.074)	0.14 (0.886)
Gdpg	-0.32 (0.748)	0.43 (0.670)	1.93** (0.053)
Inf	-0.90 (0.368)	-3.88* (0.000)	0.19 (0.848)
Tec	1.77** (0.077)	4.87* (0.000)	-1.44 (0.149)
Cc	3.08* (0.002)	2.48* (0.013)	-0.47 (0.635)
Amp	-4.25* (0.000)	1.24 (0.216)	-0.78 (0.438)
Amt	-3.29* (0.001)	3.92* (0.000)	0.07 (0.943)
Socap	1.29 (0.197)	3.06* (0.002)	3.34* (0.001)
Ecoqu	3.79* (0.000)	11.54* (0.000)	-1.60 (0.111)
Arabs	-0.17 (0.868)	3.23* (0.001)	2.92* (0.004)
Constant	6.03 (0.000)	-9.69 (0.000)	2.08 (0.037)
Wald chi2	348.95 (0.0000)	1067.70 (0.0000)	194.77 (0.0000)
No.	109	109	109

*p<0.05, **p<0.01

Therefore,

- Positive factors affecting on the water equation are: population growth, technology, climate change and economic quality

- Negative factors affecting on the water equation are: energy consumption, water resources, energy production, urbanism growth, rainfall and temperature
- Positive factors affecting on the energy equation are: food production, energy production, population growth, urbanism growth, technology, climate change, temperature, social capital, economic quality and the Arab Spring
- Negative factors affecting on the energy equation are: inflation
- Positive factors affecting on the food equation are: energy consumption, Gross Domestic Production, social capital and the Arab Spring
- Negative factors affecting on the food equation are: energy production

The above-mentioned results show that there is a positive mutual relationship between water and food, and a one-way reverse relationship between water and energy and there is no relationship between water and food.

With respect to the significant impact of the Gross Domestic Production index on the evaluation of the WEF link and the development of national and regional solutions (Yuan et al, 2020), the growth index of Gross Domestic Production has no significant effect in the water and energy equation.

On the other hand, due to population growth and urbanization pressure in Mena region, and the dependence of countries in such region on the import of virtual water for food production (Anlonelliet et al, 2017), these two variables do not have a significant effect on the food equation. Also in the food equation, other important variables such as technology, climate change, rainfall, temperature and the Arab Spring do not have a significant effect.

Considering the important role of bonding management through beneficiaries' dialogue (FAO, 2020) and the importance of understanding internal mechanisms, the discovery of interrelationships between factors affecting on WEF linkage in order to evaluate and method of its performance (Huang et al., 2020 and Yang et al. 2020) and organizing water, food and energy management for adopting an effective solution to achieve food security in Mena (Abbasi et al, 2015), the significant role of the two factors such as social capital and economic quality in the three equations of water,

energy and food is undeniable. Only the both of these variables have a significant effect on the water equation.

The results of the Hassmann test in the below-mentioned table show that for all three equations of water consumption, energy consumption and food production, the null hypothesis of this test (the appropriateness of random effects) is rejected. In other words, in this model, there is a correlation between the unseen individual effects and explanatory variables and the effect of these factors is constant over time.

Table (7): Results of Model Test

Type of test	Water equation	Energy equation	Food equation
Wu-Hausman test	44.53 (Prob>chi2 = 0.0000)	67.69 (Prob>chi2 = 0.0000)	26.99 (Prob>chi2 = 0.0125)

Summary

The results of the present research show that over the period 2009-2018, the link between water, energy and food as a general outlook of sustainable development and food supply of the residents is not established in Mena region and in general, the important variables are not influenced logically and significantly on water, energy or food behavioural equations in this region.

Thus, population growth, especially urbanism growth and economic development and its related necessities increase the pressure on water, energy, food, land and other natural resources and disrupt food security in the Mena region in the future and will lead to escalating conflict, tensions and wars.

The most important strategy for balancing population growth, urbanism growth and food security, as well as other factors influencing on the Mena region, is to establish and evaluate water, energy and food linkages and integrated and efficient management and to adopt and implement appropriate strategies which this matter will not be possible unless the use of social capital (civic participation and participation in all social processes) and the quality of the economy (equipping the economy for producing sustainable wealth and full employment).

The proposed Scenario

With respect to FAO's approach based on linkage management through beneficiaries' dialogue (scenario development, response options, and credible documents), and given the diversity, complexity, and complex status of the Mena region, the best way to link water, energy, and food and to evaluate its continuous management is the formation of specialized and decentralized working groups, consisting of the private sector and the financial and legal support of governments.

Therefore, the main core of these working groups are located in the provincial capitals, which, will take measure to design and implement different scenarios in each period using the experiences of native people and academic research, and at the end of each period, report on the method of their performance and the arisen results for obtaining the effective feedbacks at the macro level are provided to the competent and legal authorities.

It should be noted that the activity of these decentralized specialized organizations would be effective in order to stabilize and make the WEF linkage effective if they are free from any political orientation.

References

Abbasi, E., Pourjan, B. and Mandegar, A., (2015). A Comparative Study about Communicative Situation of the North Middle East with Central Asia in Comparison with Other Areas of the Middle East. (pp.289-309).

Ahmed, N.M., (2017). Biophysical Triggers of Crisis Convergence in the Middle East. In *Failing States, Collapsing Systems* (pp. 49-59). Springer, Cham.

Allan, J.T., (2017). Water, Food and Trade as an Element of the Water-Energy-Food Nexus in the MENA Region. In *Water, Energy & Food Sustainability in the Middle East* (pp. 45-56). Springer, Cham.

Antonelli, M., Laio, F. and Tamea, S., (2017). Water resources, food security and the role of virtual water trade in the MENA region. In *Environmental Change and Human Security in Africa and the Middle East* (pp. 199-217). Springer, Cham.

Aulakh, J., Regmi, A., (2013). Post-harvest food losses estimation- development of consistent methodology: Introduction. FAO.

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., Stedutof, D., Muellerf, A., Komorg, S.J. Tolh, R., Yumkella, K. K., (2011). Considering the energy, water and food nexus: towards an integrated modelling approach. Energy Policy, 39(12).

Birol F., (2010). World energy outlook 2010. *International Energy Agency*, 1(3):1-23.

Borgomeo, E., Jagerskog, A., Talbi, A., Wijnen, M., Hejazi, M. and Miralles-Wilhelm, F., (2018). The Water-Energy-Food Nexus in the Middle East and North Africa: Scenarios for a Sustainable Future.

Brach, J., (2010). Technology, political economy, and economic development in the Middle East and North Africa. *Review of Middle East Economics and Finance*, 5(3), pp.1-23.

de Strasser, L., Lipponen, A., Howells, M., Stec, S. and Bréthaut, C., (2016). A methodology to assess the water energy food ecosystems nexus in transboundary river basins. *Water*, *8*(2), p.59.

Daher, B.T. and Mohtar, R.H., (2015). Water–energy–food (WEF) Nexus Tool 2.0: guiding integrative resource planning and decision-making. *Water International*, 40(5-6), pp.748-771.

Devlin, J., (2014) Is water scarcity dampening growth prospects in the Middle East and North Africa? rookings. www.brookings.edu/opinions/

Diep, L., Hayward, T., Walnycki, A., Husseiki, M. and Karlsson, L., (2017). Water, crises and conflict in MENA: how can water service providers improve their resilience. *International Institute for Environment and Development, London. http://pubs. iied. org/pdfs/10846IIED. pdf*.

Endo, A., Tsurita, I., Burnett, K. and Orencio, P.M., (2017). A review of the current state of research on the water, energy, and food nexus. *Journal of Hydrology: Regional Studies*, *11*, pp.20-30.

FAO, (2011a). The state of the world's land and water resources for food and agriculture (SOLAW) Managing systems at risk. Rome: Food and Agriculture Organization of the United Nations and London: Earthscan.

FAO, (2011b). "Energy-Smart" Food for People and Climate – Issue paper.

FAO. 2014. The Water-Energy-Food Nexus. A New Approach in Support of Food Security and Sustainable Agriculture.

FAO, (2019). http://www.fao.org/economic/ess/ess-fs/en/

Feitelson, E. and Tubi, A., (2017). A main driver or an intermediate variable? Climate change, water and security in the Middle East. *Global environmental change*, *44*, pp.39-48.

Flammini, A., Puri, M., Pluschke, L. and Dubois, O., (2017). *Walking the nexus talk: assessing the water-energy-food nexus in the context of the sustainable energy for all initiative*. FAO.

Greenwood, S., (2014). Water insecurity, climate change and governance in the Arab world. *Middle East Policy*, *21*(2), pp.140-156.

Helliwell, J., (2001). Social capital—Editorial. *ISUMA—Canadian Journal of Policy Research*, 2(1), pp. 6–7.

Hoff, H., (2011). Understanding the nexus: Background paper for the Bonn2011 Conference.

Huang, D., Li, G., Sun, C. and Liu, Q., (2020). Exploring interactions in the local water-energy-food nexus (WEF-Nexus) using a simultaneous equations model. *Science of The Total Environment*, 703, p.135034.

IEA, (2010). World Energy Outlook 2010. Paris: OECD/ International Energy Agency.

International Panel on Climate Change (IPCC), (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. New York: Cambridge University Press.

Jobbins, G. and Henley, G., (2015). Food in an uncertain future: the impacts of climate change on food security and nutrition in the Middle East and North Africa. *Overseas Development Institute/World Food Programme, London/Rome.*

Johnstone, S. and Mazo, J., (2011). Global warming and the Arab Spring. *Survival*, 53(2), pp.11-17.

Karami, N., 2016. Factors of climate extremes hyperactivity: a study on MENA. *International Journal of Geography and Regional Planning*, *2*(1), pp.11-26.

Lange, M.A., (2019). Impacts of climate change on the eastern Mediterranean and the Middle East and North Africa region and the water–energy nexus. *Atmosphere*, 10(8), p.455.

Legatum Institute, (2019).

Miralles-Wilhelm, F., Hejazi, M., Kim, S., Yonkofski, C., Watson, D., Kyle, P., Liu, Y., Vernon, C., Delgado, A., Edmonds, J. and Clarke, L., (2018). Water for Food and Energy Security: An Assessment of the Impacts of Water Scarcity on Agricultural Production and Electricity Generation in the Middle East and North Africa. World Bank.

Mohtar, R.H. and Daher, B., (2012). Water, energy, and food: The ultimate nexus. *Encyclopedia of agricultural, food, and biological engineering. CRC Press, Taylor and Francis Group*.

Musee, S.B., (2018). Determinants of Improved Water Supply and their Influence on Dietary Intake, Nutritional Status and Morbidity Rates of Pupils Aged 6-13 years in Yatta Sub County, Kenya (Doctoral dissertation, COHRED-JKUAT).

OECD/FAO, (2018), OECD-FAO Agricultural Outlook 2018-2027, *OECD Publishing*, Paris/Food and Agriculture Organization of the United Nations, Rome.

Rasul, G. and Sharma, B., (2016). The nexus approach to water–energy–food security: an option for adaptation to climate change. *Climate Policy*, *16*(6), pp.682-702.

Ringler, C., Willenbockel, D., Perez, N., Rosegrant, M., Zhu, T. and Matthews, N., (2016). Global linkages among energy, food and water: an economic assessment. *Journal of Environmental Studies and Sciences*, *6*(1), pp.161-171.

Scardigno, A., Capone, R., El Bilali, H. and Cardone, G., (2017). Water-food security nexus in Middle East and North Africa Region: an exploratory assessment. *New Medit*, *16*(4), pp.31-39.

Siddiqi, A. and Anadon, L.D., (2011). The water–energy nexus in Middle East and North Africa. *Energy policy*, 39(8), pp.4529-4540.

Sowers, J., (2014). Water, energy and human insecurity in the middle east. *Middle East Rep*, 44, pp.2-5.

Stephan, R.M., Mohtar, R.H., Daher, B., Embid Irujo, A., Hillers, A., Ganter, J.C., Karlberg, L., Martin, L., Nairizi, S., Rodriguez, D.J. and Sarni, W., (2018). Water–energy–food nexus: a platform for implementing the Sustainable Development Goals. *Water International*, *43*(3), pp.472-479.

Taniguchi, M., Masuhara, N. and Burnett, K., (2017). Water, energy, and food security in the Asia Pacific region. *Journal of Hydrology: Regional Studies*, 11, pp.9-19.

Tidwell, V. and Moreland, B., (2016). *Mapping the Energy-Water Nexus around the Pacific Rim* (No. SAND-2016-0412R). Sandia National Lab.(SNL-NM), Albuquerque, NM (United States).

The International Institute for Sustainable Development, (2014). Water-Energy-Food Nexus and Agricultural Investment: A Sustainable Development Guidebook, pp 1-52.

Tropp, H. and Jagerskog, A., (2006). Water scarcity challenges in the Middle East and North Africa (MENA). *Human Development Paper. UNDP. http://hdr. undp. org/hdr2006/pdfs/background-docs/Thematic_Papers/SIWI. pdf.*

United Nations, (2015). https://sustainabledevelopment.un.org/

United Nations Department of Economic and Social Affairs Population Division, Data on Population Growth, (2016). Accessed March 17, 2017.

Waha, K., Krummenauer, L., Adams, S., Aich, V., Baarsch, F., Coumou, D., Fader, M., Hoff, H., Jobbins, G., Marcus, R. and Mengel, M., (2017). Climate change impacts in the Middle East and Northern Africa (MENA) region and their implications for vulnerable population groups. *Regional Environmental Change*, 1 7(6), pp.1623-1638.

Willenbockel, D., Ringler, C., Perez, N., Rosegrant, M., Zhu, T. and Matthews, N., (2016). *Climate Policy and the Energy-Water-Food Nexus: A Model Linkage Approach* (No. 9746). EcoMod.

World Bank., (2018). Beyond Scarcity: Water Security in the Middle East and North Africa. MENA Development Report. Washington, DC: World Bank. © World Bank.

World Bank. 2019. https://data.worldbank.org/region/middle-east-and-north-africa

World Health Organization. 2019. https://apps.who.int/gho/data/node.main.WSHWATER?lang=en

Yuan, M.H. and Lo, S.L., (2020). Developing indicators for the monitoring of the sustainability of food, energy, and water. *Renewable and Sustainable Energy Reviews*, 119, p.109565.

Yan, X., Fang, L. and Mu, L., 2020. How does the water-energy-food nexus work in developing countries? An empirical study of China. *Science of The Total Environment*, 716, p.134791.

Zawahri, N.A., 2017. Water Security in the Middle East and North Africa.