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ASSESSING WATER RESOURCES SUSTAINABILITY IN MIDDLE EAST AND NORTH AFRICA

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ABSTRACT

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The Middle East and North Africa (MENA) areas are the driest regions with the most water rare districts on the planet, with a territorial yearly normal of 1,200 cubic meters for every individual (world normal is near 7,000). And also, population and poverty are increasing at an alarming rate, increasing the demand for food, water assets are ending up progressively rare, desertification is a general natural issue, Desalination is an abuse of water assets in the Middle East. The shortages of water are compounded by the degradation of the quality of water. Over-abstraction of groundwater is always meet with high water stress. While farming and the countryside economy are imperative components in the MENA nations, the general commitment of farming to by and large GDP in most nations is low and has been declining. Raising water efficiency in light of the new evapotranspiration (ET) water the board worldview requests something other than changes in water system innovation. It requires coordinated consideration to improving specialized, agronomic, and the executives' measures. Water User Associations (WUAs) incredibly encourage the usage of coordinated measures. Utilizing satellite remote detecting advances, organizers, and arrangement producers can make progressively powerful choices to guarantee a steady supply of water for sustenance and the earth.

Keywords: Renewable water resources, Agricultural Scenarios, Water demand and uses.

FOREWORD

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I would not be able to say 'Thanks' to my husband, parents and my beloved brother. Their love, prayers, and kindness for me are beyond limitations. At the end I would like to dedicate this intellectual effort to my father 'Nitai Das' and my husband 'Palash Saha'.

Oulu, JUNE 2020

Anushree Das

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LIST OF ABBREVIATION

ACU	Agricultural Cooperative Authority
AIC	Agricultural Information Center
AL	Algeria
ADD	Agricultural Development Department
AREA	Agriculture Research and Extension Authority
BH	Bahrain
CWD	Current Agricultural Water Withdrawal
DAWR	Department of Agriculture and Water Resources
DOE	Department of the Environment
EG	Egypt
EPA	Environmental Public Authority
FAO	Food and Agricultural Organization
GDI	General Directorate of Irrigation
GDP	Gross Domestic Product
GWA	General Water Authority
GRWA	General Rural Water Authority
IWA	Irrigation Water Demand
IR	Iran
IQ	Iraq
IL	Israel
JO	Jordan
KW	Kuwait
LB	Lebanon
LY	Libya
MA	Morocco
MCM	Million Cubic Meters
MENA	Middle East and North Africa
MEW	Ministry of Electricity and Water

MLA	Ministry of Local Administration
MMAA	Ministry of Municipal Affairs and Agriculture
MOA	Ministry of Agriculture
MOH	Ministry of Health
MOMRA	Ministry of Municipal and Rural Affairs
MOAW	Ministry of Agriculture and Water
MOP	Ministry of Planning
MOWE	Ministry of Water and Electricity
MPW	Ministry of Public Works
MWE	Ministry of Water and Environment
MWI	Ministry of Water and Irrigation
NIA	National Irrigation Authority
NWRA	National Water Resources Authority
NWD	New Water Demand
OM	Oman
QA	Qatar
RDA	Regional Development Authorities
RSW	Renewable Surface Water
SA	Saudi Arabia
SWCC	Saline Water Conversion Cooperation
TN	Tunisia
TR	Turkey
UAE	United Arab Emirates
WB	World Bank
WMCC	Water Management Coordination Committee
WWTP	Wastewater Treatment Plants

1 INTRODUCTION

The Middle East and North Africa (MENA) is actually a regional group of countries characterized by primarily its culture and history, and covered Africa, Asia and Europe Territories. Most of the countries of MENA region experiencing very rapid population expansion and the over the past half century the region’s population has already quadrupled. For extreme aridity, the population in many regions is allocated very unevenly along with countries and also within them. The relative water availability determines the population density and distribution. However, the MENA countries vary significantly in economic, resources, geographical size, standard of living and population. In the MENA region rural economy and agriculture is a major activity in relation with the people’s number it employs, and it provides a large part of GDP in many MENA countries (Khater 2009).

In MENA region most of the countries fall under semiarid and arid climatic conditions. Decades ago, the region mostly ran out of resources of renewable freshwater in feeling that it been incapable to meet up its requirement for food from the available freshwater resources within its boundaries (Qadir et al. 2009). The MENA region covers 6 percent of the total current world population, but the amount of world’s freshwater resources is only about 1 percent (The conservation 2018). In the MENA region the countries mostly depend on the seasonal rainfall, they have only some rivers, and some of the rivers contain runoff from another countries, depend on fragile, aquifers. The amount of annual renewable water resources in MENA countries is somewhat equivalent to 1.42 percent of the whole world’s annual water resources (The conservation 2018)). In several MENA countries the water withdrawals have already exceed and in some other countries the water condition is at limit or very soon will be. It I clear that the scarcity of water will stay dominant nation in MENA region. The main causes of the water quality degradation are pesticides and fertilizer contamination, industrial and municipal wastewater dumping into waterbodies, deposits of solid waste along the banks of river, saline intrusions in aquifer systems and these also affecting the resources productivity, the quality of life and public health. In the MENA region water shortages compounded by pollution and degradation of water quality (Baconi 2018). In MENA region groundwater can be found in several aquifers system many major aquifers are shared among two or more MENA countries because these countries have the same geologic history and some of the hydrogeological units are vertically interconnected. With very little or no surface water resources, most of the MENA countries depend substantially on groundwater to meet up their water demands. At present, the groundwater contribution in MENA region is about 42% and 55% water's main source is groundwater abstraction. In some region the groundwater abstraction level has already exceeded the normal level of annual groundwater recharge (Baconi 2018).

The countries which are surplus with water supply are mainly based on the flows of surface water (Syria, Iran, Egypt, Lebanon), but the countries that are based on groundwater resources have considerably higher stress of water at present-day. The MENA region's growing and large population, though, in Egypt the aggregate supply of water will become ever more constrained (an estimation in 2025, 591 m^3 /capita/year) contrasted along with Iraq (2300 m^3 /capita/year) (Sowers 2010). Assuming there is no change in the availability of water, the growth of population in MENA region for 2025 will rise the water stress, as the availability of water is projected to decline per capita in range of 35 percent to 75 percent (Sowers 2010). The high-water stresses and the water scarcity are met up with depletion of groundwater and causing groundwater mining. Bahrain is challenging a severe water crisis, and the most important limiting element in future freshwater supplies availability is contamination by means of saline water, because of excessive withdrawal of water from aquifer system. Increasing the amount of cultivated land around and in Oases in Egypt caused a remarkable decline in groundwater table also decline of spontaneously flowing wells. This type of project needs supply of extra water by pumping for irrigation. Increasing costs of pumping are under-mining the existing economic viability as well as the projected schemes of irrigation. In Libya coastal aquifers over-exploitation caused seawater intrusion and water quality deterioration along the coast (Tropp 2016). In Saudi Arab development of agriculture resulted more than 35% depletion of non-renewable ground water resources (Denicola et al. 2015). In Yemen, the abstraction from aquifers named Wadi go beyond the renewable recharge. This type of overdraft creates aquifers extremely unsustainable for future advancement. In Tunisia, seawater intrusion caused by the exploitation of shallow coastal aquifers and pushed cultivators to deepen wells and modify the equipment of pumping (Atlantic council 2019). In these ways, the resources of groundwater in MENA region are seriously over-exploited. This type of over-exploitation can cause further destruction of groundwater reserves through leaking pollutants and saline intrusion (Tropp 2016).

In MENA region agriculture is the most dominant consumer of water. Among several sectors of water-use in MENA region the growing competition for the water with good-quality has decreased the allocation of freshwater to agriculture (Bahri 2008). The water that carried away from agriculture redirected to some non-agricultural utilizes. In MENA region the produces wastewater volume from these utilizes has risen with urbanization, population, economic development, enhanced living conditions and rising in foreseeable future. The productive use of increased generated wastewater in agriculture has also increased because most of time farmers do not have the reliable alternative water sources for irrigation (Keraita et al. 2008). Though irrigation along with treated wastewater in MENA countries requires to be a frequent practice, greater amounts of inadequately or untreated treated wastewater are now utilized in agriculture. These practice of using treated wastewater also helping to increase the concerns for public health protection and also the environment. In MENA region there are inter-related and complex many issues which support the lack of progress and investment in the sector of agriculture. Investments in MENA agricultural farms however need advancements in policies, market access, strategies, institution, and infrastructure (Keraita et al. 2008).

The main objective of this study is to create an index intended for categorizing the MENA countries based on availability of arable land resources and their renewable resources. the water resources availability will be compared then with the demand of water required to expand the area for cultivation. It is really very important to mention that in this study there will be the only assessment of the availability of renewable resources to sustainably cover up the grown demand of water for agriculture, by setting apart other factors of agriculture that also limit the sector. The main theories are this index will theoretically map the development of potential agricultural by taking into consideration the supply of water as a main part to allow the enlargement of agricultural cultivation in MENA region.

2 LITERATURE REVIEW

North Africa and the Middle East is a local embodying about 22 (Twenty-Two) countries in the North America and Middle East. The Middle East and North America (MENA) area sometimes is known as the Greater Middle East or as the Arab World. In general, 19 (Nineteen) countries are included as the part of MENA countries. Sometimes 16 (sixteen) countries are included as part of the MENA. But It is important to say that there is no such a standardized list of the countries which are included in the MENA area. Generally, it involves the region from the Morocco (the Northwest Africa) to the Iran (Southeast Asia) and down to the Sudan (Africa). Typically, the following countries are included in the MENA: Bahrain, Algeria, Iran, Egypt, Iraq, Jordan, Israel, Lebanon, Kuwait, Libya, Oman, Morocco, Saudi Arabia, Qatar, Tunisia, United Arab Emirates and Yemen. Sudan and Ethiopia are also included sometimes (FAO 2018).

In total 6.56 million square km or about 5% of the global surfaced landmass are included as the part of the Middle East region. From the entire 18 countries about 71 percent of this region is represented by the tree largest countries (Turkey, Iran and Saudi Arabia). On the other hand, the smallest 7 (Palestinian, Bahrain, Qatar, Lebanon, Israel, Kuwait and Armenia) represent only 1.5 percent (FAO 2018). The complete region of the Africa is about 30 million square kilometers or about 22 percent of the globe's surfaced landmass. In general, the total 5 largest countries (Algeria, Congo, Sudan Libya and Chad) stand for 34 % of this region, on the other hand, 5 smallest countries (all are islands: Comoros, Cape Verde, Sao Tome, Mauritius, Seychelles and Principe) represent a little more than the 3% (FAO 2018).

2.1 Water Resources

'Water', entirely all forms of lifecycle really need it. For the development of sustainable socioeconomic the freshwater reliable supply is a pre-requirement and also for human prosperity and sociopolitical stability. The MENA areas are widely known as the most water scare areas in the globe, with per capita the amount of actual renewable resources is about 1,120 m^3/year, and this amount is far underneath than the water safety threshold of 1750 m^3 (World Bank 2018). Additionally, the MENA countries always uses more water resources what it obtains every year and more water resources than the renewable water resources. The freshwater resources in MENA countries are below huge pressure and also facing significant dangers to the sustainability because of increased population, overexploitation. 12 out of the globe's 15 water scare countries are in this area and the situation is getting worsen gradually, it is been projected that in future the water availability will be dropped significantly in those countries (Michel et al. 2018).

2.1.1 Renewable Freshwater

The availability of the freshwater in these areas is significantly low compare to the other countries, the problem happens where the water is available at the nationwide, but it is highly flexible in space and time. According to the world bank (2007), the areas are facing vulnerability mainly include Morocco, Tunisia, Lebanon. Mainly hyper-aridity happens in where the renewable water resource are significantly low, as listed Bahrain, Libya, Kuwait, Qatar, Oman, Saudi Arabia, Israel, Yemen, and United Arab Emirates.

In MENA region the renewable average annual water resources is about 591,000 Mm^3. It is equal to some 1.41 percentage of the whole world's renewable annual water resources. About 37 percent (222,000 Mm^3) of this water is provided by the region's outsides river flows (Miller 2015). There are also some non-renewable substantial groundwater resources, besides renewable groundwater and surface water and in MENA region countries also have varying right to use unlimited seawater and brackish water. The following Table 1 represents the MENA countries renewable water resources:

Table 1: The Renewable water resources in MENA countries.

Country	Renewable water resources annually ((km^3)	Availability of water resources (m^3/year per capita)		
		1950	2018	2025
Saudi Arab	2.90	813	123	76
Turkey	147.52	6987	2256	1936
Iran	73.55	4432	1198	787
Israel	3.23	2434	510	345
UAE	0.37	2973	87	69
Iraq	121	-	4980	2983
Oman	1.1	2258	453	198
Qatar	0.2	1031	21.98	12
Kuwait	0.19	1287	85	62
Lebanon	3.60	2365	989	765
Jordan	0.87	578	140	61
Bahrain	0.21	-	178	144
Algeria	14.91	1698	455	343
Libya	0.84	763	153	96
Yemen	5.30	982	238	198
Tunisia	4.20	1207	435	386
Egypt	69.34	3276	1100	756
Morocco	30.75	3423	1138	791

Source: UNESCO (2020), ESCWA, World Bank (2020), World Resources Institute (2019).

In 2018, more than 60 percent of countries in MENA region tries had supply per capita a smaller amount than 1000 m^3/year. For MENA countries, it is projected that in 2025, the supply in per capita will be 683 m^3/year which is equal to only 12 percent of the whole world (World Bank 2020). And the main reason behind this is the high population growth. Many countries like Jordan, Yemen, Israel, and Algeria tries to mine the groundwater resources. And obviously, it is not possible to use the non-renewable water resources indefinitely. But mining is often risky due to connections with the flows of river may disturb the surface supplies and may decline the water tables and for this saline intrusion may cause from sea or brackish water (Kather 2009).

2.1.2 Transboundary waters

In the Middle East the major transboundary rivers are the Kura-Araks which flows to the Caspian Sea, the Euphrates-Tigris which flows to the Persian Gulf, The Asi-Orontes which flows to the Mediterranean Sea, and the Jordan that flows to the Dead Sea. In the Middle East region these transboundary river basins cover up 17% of the total area (AQUASTAT 2008). There is also one type of basin named endorheic basin which is that type of basin that doesn't have any outflow to sea, produced by together dominant geological structural conditions and the aridity of climate. It is one of the most important hydrography characteristics of Middle East region. This types of basin either structural, which is entirely closed basins encircled by constant watershed line (exist in Turkey and Iran) or functional, where the basins are open or exoreic but local outflow certainly not goes to the Sea (located in United Arab Emirates and Saudi Arabia). In Africa the major transboundary river basin is: Lake Chad, Congo, Nile, Orange, Zambezi, Niger, Limpopo, Senegal, and Volta. These river basins cover half of entire area of continent but in North Africa Nile is the only one river basin. The water is shared among several countries and operated by the basin organization which group together some or all of states contained one basin (AQUASTAT 2008).

2.1.3 Dams

The total capacity of dam in Africa is about 799 km^3, of which 728 km^3 connects 53 largest dams' capacity which are built in 22 river basins. In the Southern region of Africa more than half of total dams are situated and in North Africa the dam capacity is only about 24%. In North Africa one big capacity dam named Aswan on Nile river is constructed in Egypt and the capacity of that dam is 162 km^3 (Kfouri 2019). In Middle East the total dam capacity is 871 km^3. Iraq, Turkey, and Syria include more than 93% of total capacity of dam and most of this on the basin of Euphrates-Tigris. There are 12 dams which have capacity more than 5 km^3 in Middle East and most of these dams are on the basin of Euphrates-Tigris except The Atinkaya and Hirfanli is constructed on the basin of Black Sea in Turkey (Kfouri 2019).

2.1.4 Non-conventional water sources

In dry countries mainly reuse of water desalination and treated wastewater take place seeking to expand their much-limited resources. Libya, Egypt, Morocco, Tunisia, Algeria are the main countries performing desalination process in reducing production order. In some countries they also lunched irrigation projects specially in peri-urban and urban agriculture which use treated wastewater. In Middle East the amount of reused treated wastewater is 2672 million m^3/year. Among the countries Turkey used 39% of the treated wastewater, followed by Syria, Israel, and United Arab Emirates with 22%, 11% and 9% (Qadir 2017). The total amount of reused desalinated water is 3326 million m^3/year in the Middle East. United Arab Emirates, Saudi Arabia and Kuwait are the largest consumers of desalinated water and around 78% of the total Middle East region. 1043 million m^3 water is used annually by Saudi Arabia, United Arab Emirates uses 961 million m^3 and Kuwait uses 432 million m^3 (Qadir 2017).

2.1.5 Groundwater resources

In MENA region the groundwater system is located with several aquifers systems together with storage capacity and yield characteristics which depend on areal extent and hydrogeologic and hydrologic properties of each aquifers. Most of the time the aquifers systems are of either calcareous facies and/or sandy. And also, alluvium deposits and unconsolidated alongside volcanic deposits exist in MENA region. The formation of water bearing is naturally recharged or non-renewable type or of fossil, according to the hydrologic viewpoint. Naturally recharged most of the aquifers are somewhat replenished because of the limited rates of precipitation prevailing in MENA region (Lezzaik 2018).

The MENA region's geological history dates back more than five hundred million years BP (Pre-Cambrian). The rock of the basement is exposed in big surfaces in MENA region, mainly in west and south of Algeria, Libya's southern part, east of Egypt and thus forming the African Shield. Along the Red Sea coast, it is also revealed Arabian Shield's forming. Three hundred million years ago during the Paleozoic, on the basement rock very thick layers of sandstones and sand were deposited and that one was suitable for storage of groundwater (MWRI 2015). Extra layers of Nubian sandstone and sand covered a huge surface from Libya and Egypt's Western Desert to North Sudan during the period of Mesozoic. Again, some low permeable limestone's thick layers deposited around 120 million years BP ago in the Arabian Peninsula. In the Quaternary (Recent and Pleistocene) and Tertiary, contrasting series of sand and calcareous rocks deposited in several areas creating Al-Hamada in Morocco and Algeria, altogether with limestone in Iraq and Egypt. The Atlas region actually belongs to Mediterranean region and described by formation wherever other rocks and clays, such as dolomites and calcareous rocks belonging to lower Jurassic, is dominant. These types of formations can find in high plateaus in Algeria and Morocco and in Upper Atlas in Tunisia (MWRI 2015).

The similar rock unit often form producing aquifers in MENA region's two or more states because of that geologic history similarity. This is the main reason that the following aquifers are shared in two or more MENA region's countries (MEDD 2018):

- The Paleogene aquifer in Arabian Peninsula
- The Nubian Sandstone in North African countries and Egypt
- The Basalt aquifer in Jordan and Syria
- The Grand Erjs in Morocco, Tunisia and Algeria

Many hydrogeological units are vertically also interconnected in MENA region.

The majority people of the MENA regions depend on significantly on the amount of groundwater to meet up the growing demands of water with no or little surface water resources. The following table (Table 2) represents an estimation of annual average groundwater withdrawal and recharge. The dependency of regions on groundwater is stated as of ratio of withdrawal of groundwater in relation with recharge of annual groundwater along with ratio of withdrawals of groundwater to total water demand in 2018.

Table 2: The Groundwater Resources in MENA countries.

Country	Average annual recharge of groundwater (km^3)	Withdrawal of annual groundwater		
		Total amount (km^3)	Recharge (%)	Demand 2018 (%)
Saudi Arab	3.90	15.10	395	86.88
Turkey	21.00	8.10	39	22.12
Iran	43.00	30.00	71	42.32
Israel	0.55	1.35	251	73.32
UAE	0.15	0.89	689	78.92
Iraq	15.00	0.32	2.5	0.82
Oman	1.21	1.76	176	90.32
Qatar	0.056	0.71	222	75
Kuwait	0.22	0.40	191	69.91
Lebanon	0.76	0.33	45	18.00
Jordan	0.44	0.67	171	52.57
Bahrain	0.11	0.29	267	92.42
Algeria	1.81	2.99	178	65.11
Libya	0.79	3.74	587	97.22
Yemen	1.55	1.43	98	64.40
Tunisia	4.32	1.69	39.50	60.76
Egypt	5.32	4.56	92	7.13
Morocco	9.19	2.88	34	25.22

Source: UNESCO (2020), ESCWA (2020), World Resource Institute (2019).

2.2 Withdrawal of water

The following table (Table 3) represents the annual water withdrawals by sector-wise in MENA region's countries. Even Though the use of domestic water per capita in developed countries can go beyond 155 m^3/year, to maintain the health of human a reasonable supply may be per capita 45-85 m^3/year. It is estimated that, by 2025, there are five MENA countries which will hardly cover the basic needs of human if the renewable resources are completely mobilized (Mualla 2018). Elsewhere, the supply of renewable resources would even exceed the basic requirements of human by varying the amounts.

Table 3: The water withdrawal by sector in MENA region.

Country	The amount of total water (km^3)	Annual water withdrawal		
		Industry	Domestic	Agriculture
Saudi Arab	18.00	1.0	9.0	90.0
Turkey	36.60	11.0	16.0	73.0
Iran	71.02	2.0	7.0	91.0
Israel	1.73	9.0	31.0	60.0
UAE	2.13	10.0	27.0	63.0
Iraq	43.81	6.0	3.5	90.5
Oman	1.33	4.0	6.0	90.0
Qatar	21.98	4.14	1.48	94.38
Kuwait	0.55	2.0	38	60.0
Lebanon	1.32	5.5	29.5	65.0
Jordan	0.99	4.1	23.4	72.5
Bahrain	0.33	4.5	33	62.5
Algeria	4.79	17.3	26.6	56.1
Libya	3.88	5.1	9.9	85.0
Yemen	2.97	1.0	7.7	91.3
Tunisia	2.77	4.4	16.4	79.2
Egypt	64.67	8.8	7.6	83.6
Morocco	12.36	3.3	6.1	90.6

Source: World Bank, World Development Indicators Database and ESCWA (2019), World Resources Institute (2019).

However, in the MENA region not all the supplies of renewable water based on their variability and location can be mobilized at satisfactory cost. Actually, the amount of economically accessible water is very much lower than the mentioned estimates. The largest user by irrigation, perhaps more than 85% of total usage region wide (Tolba 2017). Although, the water is mainly utilized for irrigation, the demand is expanding for water in urban areas rapidly. Most of the MENA regions are highly urbanized and the demand of industrial and domestic share is so much higher than the other parts of most of the developing world.

In MENA region most of the countries can be classifies as middle income and urban population percentage that has safe and sound drinking water access is almost close to 100%. In contrast, only 66% of the rural areas people have the safe access of drinking water. Despite attempts to slow the growth rates of population in the MENA region, projected upcoming growth rates is still very high by the standards of world. In urban areas it is projected that the proportion is about to increase 60% to 70% and for this in urban areas renewable water supplies share need to increase from 10% to more than 20% by maintain the overall present use rates (MRMEWR 2016). The expanded efficiency in reallocation and irrigation could provide enough renewable water to meet up the demands in most of the countries of MENA region. But it is really difficult to reallocate from irrigation because of the involved costs, but most of the MENA countries continue financing the new supplies even as preserving allocations to comparatively very low-return agriculture (MRMEWR 2016).

In several MENA countries water withdrawals have already been surpass renewable supplies: Yemen and Libya. Other countries seem to be essentially at the maximum or almost immediately will be: Israel, Egypt and Jordan. Some countries deal with severe regional shortages even if they are overall in surplus. And it is really expensive the use of local mobilizing surpluses because the costs of transfer and due to physical and social strains, the full mobilization is always impracticable (Qadir 2017).

2.3 Scarcity of water

In semi-arid and arid countries of MENA region the water scarcity is a most important constraint. All available resources on water, in many MENA countries, that can be utilized for economic reasons, have now been established or in procedure of development (Irin 2015). The overall potential analysis concentrating on water withdrawals estimation as contrasted to total amount of available water resources (commonly called the index of water stress) specifies that more than 75% of MENA region's countries are categorized under very high-water stress. And the more crucial matter is that availability of current per-capita water has dropped lower than the line of certain water shortage of 500 m^3/year in more than 50% of the MENA countries. Moreover, it is estimated that by the year of 2025, more than 80% of the MENA countries will crossed the threshold of water poverty. It is clear that, the scarcity of water will stay the most dominant state in the countries of MENA region (Irin 2015).

2.4 Agricultural overview in MENA countries

2.4.1 Major systems of farming

There are eight major systems of farming that has been established and broadly defined and those eight major farming systems are listed in the following Table 4 (FAO 2019):

Table 4: Major farming systems in MENA region.

Major systems of farming in MENA countries				
Farming systems	Total land area (% of the total region)	Total agric. popn. (% of the total region)	Main livelihoods	Poverty prevalence
Dryland mixed	4.0	15	Sheep, cereals, off-farm works	Extensive (for small scale farmers)
Rainfed mixed	2.0	18.5	Cereals, legumes, tree crops, off-farming works	Moderate (for small scale farmers)
Highland mixed	7.0	31	Legumes, sheep, cereals, off-farming works	Extensive
Irrigated	2.0	18	Vegetables, fruits, cash crops	Moderate
Pastoral	23.0	10	Goats, sheep, barely, off-farming works	Extensive (for small scale farmers)
Coastal artisanal	1.0	1.0	Off-farming works, fishing	Moderate
Sparse (arid)	62.0	5.0	Sheep, camels, off-farming works	Limited
Urban based	<1.5	6.0	Poultry, horticulture, off-farming works	Limited

Source: FAO Database.

2.4.1.1 The system of irrigated farming

Based on the semiarid and arid nature in Middle East and North Africa, the farming system of irrigation has constantly been of vital importance in making considerably output of the region’s agriculture. The irrigation system consists both small-scale and large-scale systems. The system of large-scale irrigation consists an agricultural total population of approximately 16.0 million[3] and about 8.3 million ha of irrigated farming land: causing the densities of high population and actually very small sizes farms. Poverty prevalence is moderate within both sub-systems (Elhadj 2018).

The large-scale irrigation (Sub-system) areas primarily linked to the water resources of perennial surface, like Euphrates valleys and Nile, but traditional qanat and karez systems intensification also preceded to the development of the irrigates areas of large-scale system wherever the amount of water (sub-surface) is plentiful. Recently, the accessibility of pumping technologies and deep drilling has allowed the development of new-found areas drawing the subterranean aquifers. The schemes of large-scale systems are found within all zones and involve export cropping and high-value cash, fruit cropping and intensive vegetables (CEDARE 2016). The water uses patterns vary significantly but, all over the region, centralized managing systems and the inappropriate water pricing policies have caused that the water is rarely used efficiently. Considerable environmental and economic externalities have arisen from extreme utilization of aquifers of non-recharged while, the application of excessive irrigation water has caused in increasing soil salinization, the groundwater table problems (CEDARE 2016).

The small-scale sub-system irrigation also happens across the whole region widely but not the same as important as system of larger schemes because of involved people numbers, or in food amount and the other produced crops, and in remote and arid mountain areas it is a major element for many people survival (Elhadj 2018). Along the tiny perennial streams this type of sub-systems typically develops, or where the spate irrigation and flood is feasible. Sometimes it additionally draws on boreholes and shallow aquifers, even though these hardly penetrate to depths perceived in the schemes of large-scale systems. Within the system of small-scale irrigation vegetables, fodder and mixed cereals are the major grown crops. These land areas also deliver vital focal spots for activity of socio-economic, but extreme local communities' competition for constrained water resources among other users and rural farmers is developing progressively more evident (Elhadj 2018).

2.4.1.2 Rainfed and Highland mixed farming system

The farming system of rainfed mixed covers 18% of the total agricultural population although occupies 2% of the total land area and this resulting extreme high population densities. 14 million ha land is cultivated area, involving vines and tree crops. Although the system is principally rainfed, an expanding area is profiting from the accessibility of pumping and new drilling technologies, that made it feasible to make use of supplemental winter irrigation (FAO 2018). The farming system of highland mixed contains land area of 74 million ha but this is not the important system in terms of number of population because in agriculture nearly 27 million people engaged. The land area for cultivation is about 22 million ha. It comprises two, sometimes sub-systems overlapped. The first one is led by rainfed legume and cereal cropping, olives and fruits on terraces, with vines and the second one primarily based on livestock raising on managed communally lands (ICARDA 2011).

2.4.1.3 The farming system of dryland mixed and sparse (arid) and urban based

The agricultural population of dryland mixed farming system is 13 million and the total cultivated land area is 17 million ha. The sizes of farms are larger, and the density of population is also lower than the main other arable systems. But here the drought risk is so high and the considerable insecurity for foods exists (MOA 2016). The farming system of sparse (arid) covers 60% of the total region and comprises the vast zones of desert. The agricultural population is about 5% of the region’s people and 1.2 million ha land is used as irrigated cropland to produce fodder, vegetables, dates, and palms. A small population throughout the region nearly people of 6 million are involved in livestock products and horticulture production – notably poultry, vegetables, and fruits (MOA 2016).

2.4.2 Water management and Irrigation

Actually ''the area underneath the water management'' refers to those area where water except direct rainfall utilized for the agricultural production. And the word ''irrigation'' represents to those areas which are equipped to provide the water to crops. In MENA region the countries make distinction between the areas underneath irrigation, sometimes that one is the summation of partial/full control irrigation zones, equipped lowlands, spate irrigation, and the other forms of management of water, that actually are non-equipped lowlands. And it is difficult the distinction between water management and irrigation. In MENA countries, in calculating the available water for irrigation, some of the countries consider only renewable water resources (surface water and ground water) such as Syria and Lebanon, on the other hand some of the arid countries depend on non-conventional or fossil water sources such as Saudi Arab, Turkey, Jordan, Bahrain. In Iran, the biggest irrigation potential is centered, depend only on the renewable water resources (FAO 2017). United Arab Emirates and Syria assess that the irrigation potential is much lower than equipped irrigation area at present. The reason behind this may be the ever-increasing water demand for industrial and domestic purposes, depletion of groundwater and low availability of water of non-conventional sources. In Middle East region the irrigation potential is about 18.8 million ha and the area equipped intended for irrigation is about 23.5 million ha. But more than 72% area is concentrated for irrigation in Iran, in Iraq 16%, and in Turkey 21%. Partial/full control irrigation covers 23.3 million ha in Middle East region (Berndtsson 2016). 15.5. million ha area are under water management in Africa where more than 41% of the area that are under water management is concentrated in Northern Africa. 55% of the irrigation area in concentrated in Egypt (IDS 2019). In North Africa mainly Spate irrigation is used. Algeria use both ground water and surface water with some other sources of water and on the other hand Libya, Tunisia and Egypt began using treated wastewater. Surface water is the main source for irrigation in MENA region (IDS 2019).

3 STUDY AREA

3.1 Geography and climate

Climate and geography not only the main determinants of the availability of water and accessibility, also helps to exert the constraints on the agricultural productions. The MENA regions endures and enjoys various climatic conditions. The following Figure 1 represent the MENA region:

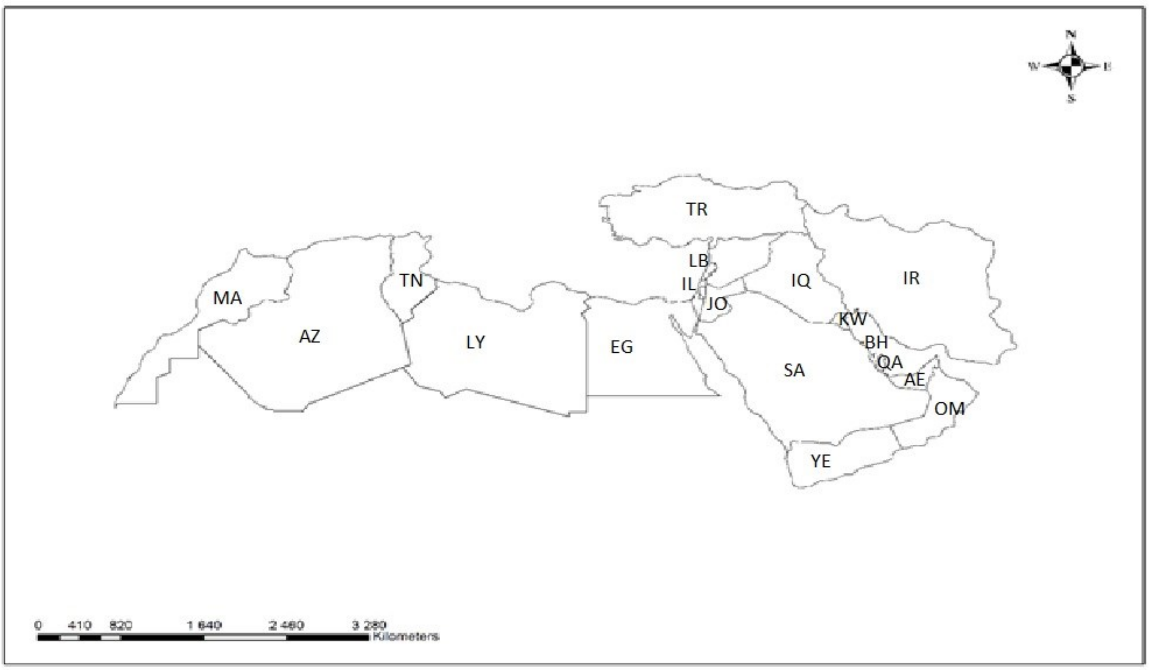


Figure 1: MENA region.

The economics always must manage the problematic combination of very high and low annual precipitation. Rainfall occurs generally during winter and the dry period of the summer lasts for 6-9 months (FAO 2018). The land of the MENA regions is divided as arid, semi-arid and hyper-arid (MWRI 2015). Based on the climatic and geographical conditions the MENA regions can be arranged into four areas. Table 5 describes the climatic and geographic characteristics and agricultural overview of the sub-regions identified.

Table 5: The MENA Region's geography, climate and agricultural overview.

	Countries	Climate	The total Area (km^2)	Area of cultivable land (Thousand ha)	The total cultivated area (Thousand ha)	The total cultivated area (% of the total Cultivated area)
Arabian Peninsula	KW, BH, QA SA, OM, YE, UA	Hyper-arid and Arid	32000380	59879	2846	6%
Near East	JO, IL, IQ, LB, TR, SY	Semi-arid and Arid	1644050	48605	38990	87%
Iran	IR	Semi-arid and Arid	1834240	52023	19371	38%
North Africa	EG, AZ, MA, LY, TN	Hyper-arid (south), semi -arid (north), Arid	5843980	66542	29139	45%

Source: WRI 2015 and FAO 2015; 2012.

3.2 Economy and population

The population of the MENA regions is nearly now 500 million, the population increases annually an average 2.1 percent from 2004 to 2016 where the world average rate is increasing 1.2 percent per year and this is the fastest rates in the world. Egypt, Turkey and Iran are the most populated countries and cover more than 50 percent of the total population of the regions. 73 percent of the total population is urbanized (World Bank 2016).

Income rate in MENA regions is rising, over the last 10 years it grows annually 2.6 percent and reaching average of $7,600 in 2016 per capita. In 2016, United Arab Emirates stated that the highest income is $59,885 per capita whereas the lowest income rate was in Yemen and the income rate was $1,135 per capita. The total region's GDP was about 5.2 percent of the economy of the world's where the top spot occupied by turkey and then Saudi Arabia and Iran (World Bank 2016). The following Table 6 represents the population and economic overview in MENA countries:

Table 6: Profile of economic and population growth in MENA region.

Country	GDP in 2018 (billions of $US)	Average annual GDP change, % (2004-2015)	Projected annual-average GDP growth, % (2015-2024)	Population in 2018 (millions)	Average annual population growth, % (2004-2015)	Projected annual population growth % (2015-2024)
Saudi Arabia	648	6.3	4.6	26.8	2.1	1.1
Turkey	855	4.9	4.8	80.3	2.3	1.3
Iran	432	3.4	3.3	79.3	1.8	1.3
Israel	279	4.5	3.9	7.5	1.9	1.6
UAE	339	4.1	4.5	5.5	4.1	2.5
Iraq	186	11.2	6.7	31.8	2.9	2.3
Oman	72	5.4	4.5	3.2	2.6	2.3
Qatar	191.4	7.9	2.5	2.8	2.1	1.6
Kuwait	154	4.5	2.9	2.6	2.9	1.3
Lebanon	45	5.4	3.3	4.2	1.7	0.4
Jordan	33	5.6	4.6	6.5	2.9	1.7
Bahrain	41	5.3	3.3	1.7	4.9	1.6
Algeria	187	3.1	3.8	39.1	1.7	1.9
Libya	61	7.0	8.9	6.0	2.2	1.9
Yemen	31	1.9	3.2	24.9	2.9	2.2
Tunisia	45	4.0	4.5	10.8	1.6	0.9
Egypt	256	4.6	4.3	85.2	3.1	1.6
Morocco	112	4.4	4.2	31.9	1.8	0.8

Source: WWDP (World Water Development Report) 2017, World Bank (2020).

Poverty is not as acute in the MENA region as in many other regions of the world, more than 40 million people survive per day on less than $2. The poverty associate’s 15 percent of the overall population according to this measurement and it is around

50 percent for Yemen (World Bank 2014). Unemployment in the MENA regions is still a major problem with an increasing population and very limited economic divergence (Akhtar et al. 2017). The unemployment rate is nearly 18 percent in Tunisia and Yemen while the unemployment rate is less than 5 percent in UAE and Kuwait (ILO 2013).

3.3 Water resources status

In the MENA region most of the countries facing very minimal water usage efficiency combines with scarcity of water. The efficiency of water use is about 40% according to FAO (2012). The countries like Bahrain, Libya, United Arab Emirates, Jordan and Kuwait experiencing Extreme water scarcity situation according to World Water Development Report (WWDR 2014). WWDR ranked 182 countries based on the annual per capita availability of total renewable water resources and the more than half MENA region's countries categorized in the lowest possible 10%. The actual cause behind this most of the renewable water resources are in use and many MENA regions countries using their non-renewable water resources for their industrial, agricultural and domestic purposes (FAO 2014). The following Table 7 represent the water status in MENA countries:

Table 7: Present status of water in the MENA countries.

Region/Country	The amount of the total internal renewable water resources (km^3/yr)	Surface water: internally produced (km^3/yr)	Ground water: internally produced (km^3/yr)	Total renewable water resources per capita (m^3/yr)
Saudi Arabia	2.90	2.35	1.98	119
Turkey	147.52	4.9	3.8	80.3
Iran	73.55	98.50	50.01	1966
Israel	3.23	0.29	0.60	281
UAE	0.37	0.18	0.10	59
Iraq	121	36.00	1.25	3299
Oman	1.1	0.95	0.82	391
Qatar	0.89	0.01	0.56	21.22
Kuwait	0.19	0.00	0.02	11
Lebanon	3.60	98.34	50.41	1330
Jordan	0.87	0.39	0.49	181
Bahrain	0.21	0.008	0.00	183
Algeria	14.91	14.00	1.81	481
Libya	0.84	0.31	0.49	115
Yemen	5.30	3.99	1.62	230
Tunisia	4.20	3.12	1.51	485
Egypt	69.34	0.62	1.29	862
Morocco	30.75	21.00	11.00	991

Source: WWDP (World Water Development Report) 2017, World Bank (2020).

The countries like Israel and Jordan according to FAO are over-exploiting the water resources between 20% and 10%. Because of this the levels of water are dropping, the resources of groundwater being mined, intrusion of saltwater and salinization are appearing, and the supply of domestic water does not meet the quality standard. In many countries of the region the real situations are even worse. The withdrawals of fossil groundwater for irrigation has far exceed that the total renewable resources in some of the MENA region's countries like Bahrain, Yemen, Qatar Kuwait, and Libya. The reduces river flows and the falling of groundwater tables will not impact only the economic and social dynamics but will also reduce services and goods of ecosystems and close the river systems. Because of the extreme scarcity of water, in the region most of the countries will find that it is really challenging to cope with the increased demand of water as well as from downstream and upstream countries.

3.4 Water quality

Between the water quality and quantity, a critical and direct link exists because of the water scarcity. In MENA the water quality comprehensive data is not available, the studies of World Bank revealed that water quality deteriorating becoming the most serious issue in most of the MENA countries. Although the trustworthy comparative information is not actually available, several examples of problems of water quality are quoted. Dumping the industrial and municipal wastewater into lakes and rivers, the deposits of solid water along riverbanks, from unsanitary landfills the uncontrolled seepage, contamination because of excessive use of fertilizers are the main cause of freshwater resources degradation and enforce health risks. The following reasons are the principal sources of pollution (Sowers et al. 2015)

- Leaching from badly functioning and maintained cesspools, washing of waste and fecal matter into water bodies, untreated municipal waste and wastewater
- Discharge of municipal sewer system directly into water systems, untreated industrial waste and wastewater
- Runoff and seepage of non-biodegradable pesticides and fertilizers
- Runoff and seepage from unhygienic and dirty landfills where the most the solid waste of the regions dumped

Contamination from these sources continuously declining the quality of water and affecting the resources productivity, public health and most importantly the quality of people's life (MEDD 2009). Groundwater seldom actually regenerates after contamination and although in some extent rivers are self-cleansing, declining quality raises the costs of treatment to users of downstream and may prohibit reuse of some purposes. In several countries one of the critical issues is intrusion of seawater into coastal aquifers and secondary salinity and waterlogging are the widespread challenges in most of the irrigated areas. Consequently, in the MENA region water shortages are compounded by pollution and the degradation of quality of water (MEDD 2018).

4 METHODOLOGY

4.1 Country Classification Framework

The renewable water resources consist of groundwater and surface. When the agricultural water requirement is less than the rate of renewability then it is considered sustainable water usage. For assessing the potential for future agriculture, a variable known as the new agricultural water demand (N_{WD}) is specified (Abou Zaki et al. 2018). This variable comprises of the sum of irrigation water demand (I_{WD}) and current agricultural water withdrawal (C_{WD}), as follows:

$$N_{WD} = I_{WD} + C_{WD} \tag{1}$$

Here, Irrigation water demand (I_{WD}) indicates the amount of increased water utilization volume which is needed to expand the farmed area, as well as both rain-fed and irrigated areas and current agricultural water withdrawal (C_{WD}) represents the current water expenditure in every single country. For the comparison of new water demand (N_{WD}), groundwater resources (R_{GW}) and the renewable surface water (R_{SW}) for every country, an index (Table 8) was utilized for the classification of the chosen countries based on the available renewable resources and calculated increase. The estimation of groundwater resources (R_{GW}) and renewable surface water (R_{SW}) based on the available FAO data. The countries are classified into six classes (I-VI) based on the cultivable area for development and accessible water resources (Abou Zaki et al. 2018).

Table 8: Country Classification.

Class I	If $N_{WD} \leq R_{SW}$ and $N_{WD} \leq R_{GW}$	New water demand is less than both renewable surface and groundwater resources
Class II	If $N_{WD} \leq R_{SW}$ and $N_{WD} > R_{GW}$	New water demand is less than renewable surface water resources but larger than renewable groundwater resources
Class III	If $N_{WD} > R_{SW}$ and $N_{WD} \leq R_{GW}$	New water demand is larger than renewable groundwater resources but larger than renewable surface resources
Class IV	if $N_{WD} \leq (R_{SW} + R_{GW})$	New water demand is less than the summation of surface and groundwater resources
Class V	if $N_{WD} > (R_{SW} + R_{GW})$ and if $C_{WD} < (R_{SW} + R_{GW})$	New water demand is larger than the summation of surface and groundwater resources, but the current water demand is less
Class VI	if $C_{WD} > (R_{SW} + R_{GW})$	Current water demand is higher than the summation of renewable surface and groundwater resources

Source: Abou Zaki et al. 2018

To assess the accessibility of every source compared to the requirement, N_{WD} was compared to both R_{GW} and R_{SW} in the classification. The countries which are belong to class I, it is possible to farm all cultivable area utilizing either two water resources (R_{SW} and R_{GW}), because both sources are greater than N_{WD}. Class VI represents the worst condition where the both water sources (R_{SW} and R_{GW}) are lower than current water demand (C_{WD}). The water resources are in an unsustainable situation and some reforms are required to stabilize the current demand for the countries belong to the class VI. The rest of the classes (II, III, IV and V) indicates sustainable conditions N_{WD} is lower than R_{SW}, R_{GW}, or their sum (Abou Zaki et al. 2018).

4.2 Calculation of Crop water demand

The amount of water which is essential to meet the rate of evapotranspiration for thrive of crops is known as water demand of crops. The amount of water which is lost through the plant leaves as well as to atmosphere is known as the rate of evapotranspiration. The water demand of crop always refers some optimal condition under which crops grown and those are:

- Actively growing
- Shading completely the ground
- Diseases free
- A uniform crop
- Favorable conditions of soil

Under the given environment the crop thus reaches its full production. It is essential to assess the water demand of the crops planned to be grown-up.

Here I am going the use CLIMWAT 2.0 (Figure 2) and CROPWAT 8.0 (Figure 3). CLIMWAT 2.0 is a database of climatic parameter that is used in together with the CROPWAT 8.0 program. CROPWAT 8.0 which is a decision support apparatus established by the Water and Land Development Division of FAO. CROPWAT 8.0 for Windows is a PC program for the count of harvest water prerequisites and water system necessities dependent on soil, atmosphere and yield information. Moreover, the program permits the advancement of water system plans for various administration conditions and the estimation of plan water supply for fluctuating yield designs. CROPWAT 8.0 can likewise be utilized to assess planters' water system prepares and to evaluate crop performance under both rainfed and inundated conditions.

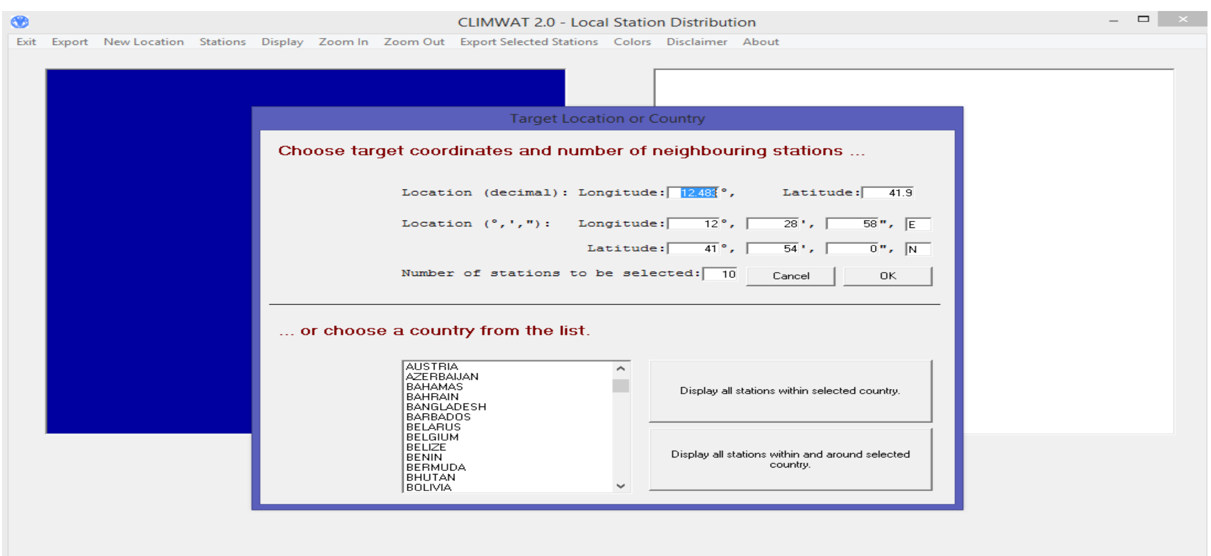


Figure 2: Using CLIMWAT 2.0

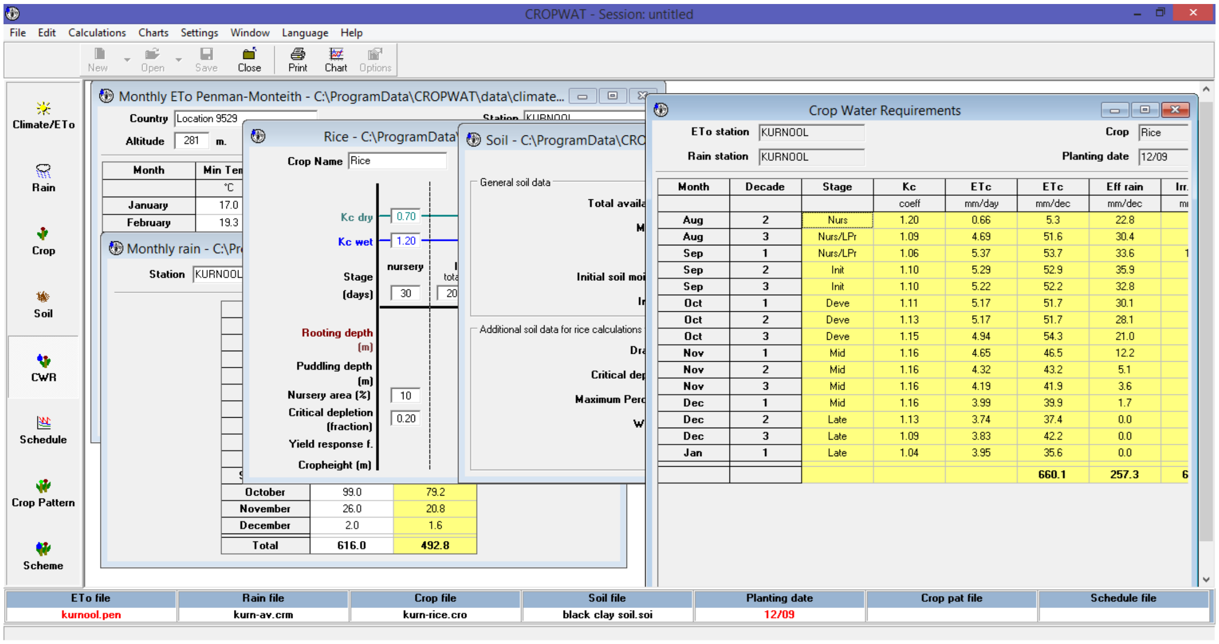


Figure 3: Using CROPWAT 8.0

For this analysis I have chosen three different types of crops as follows:

- Rice
- Sugarcane
- Sorghum

The reasons behind to choose these crops grown in significant quantities in the study area and all the data which are needed for the calculation are available.

4.3 Agriculture Development Scenarios

For this analysis, the cultivated area was divided between irrigated and rain-fed area in the selected countries. Depending on the climate Zones and the amount of precipitation the percentage area of each one varies. We consider that it is possible to increase the cultivable area by expanding the irrigated, rain-fed or combined irrigated rain-fed area. Different production rates and water consumption are required for various farming irrigation methods. This analysis assumed water consumption variation, depending on the various irrigation schemes formed. For this analysis, I have clustered two main categories of rain-fed and irrigated farming schemes. I have considered the total cultivable land area (A_{Total}), as follows (Abou Zaki et al. 2018):

$$A_{Total} = A_{RF} + A_{IR} + A_{PC} \quad (2)$$

Here,

A_{RF} = The current cultivated rain-fed area

A_{IR} = The current cultivated irrigated area

A_{PC} = The potential cultivable area

It is possible to increase the potential cultivable land area by increasing the rain-fed or irrigated area with several water intakes rates (Figure 4).

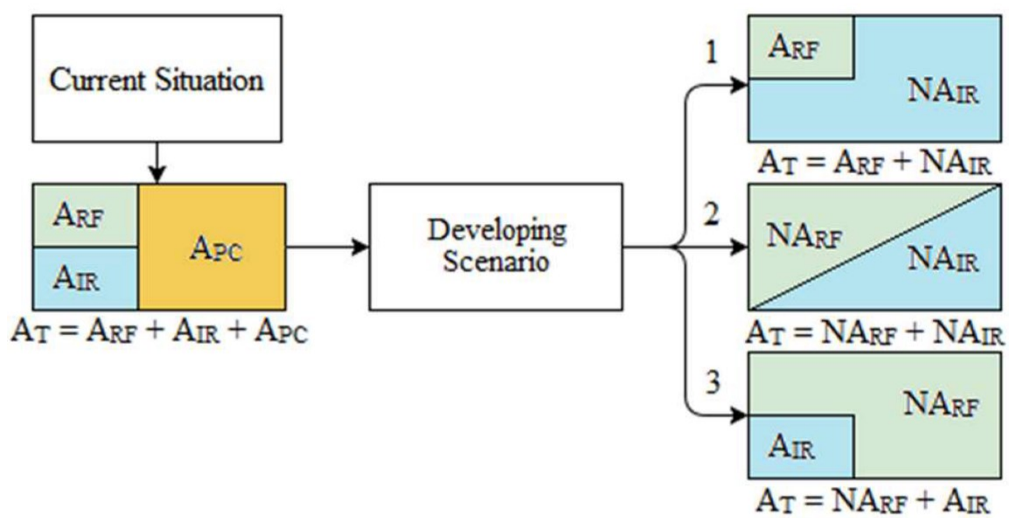


Figure 4: For evaluating the possibility for expanding cultivable area the three scenarios used. In scenario 1, A_{RF} = 0 and in scenario 3, A_{IR} = 0

Source: Abou Zaki et al. 2018

For assessing the possibility of every country to cover the demand of agriculture water three different scenarios of agricultural development are developed. The basis of the scenarios is the demand of water of various irrigation schemes, water consumption variation, and assume that the cultivable land area may be extended by either irrigated, rain-fed or combination of both water supply system. A_{Total} in subdivided into new irrigated (NA_{IR}) and new rain-fed (NA_{RF}) in every scenario. Depending on the irrigation methods that are applied to farm the cultivable land area, NA_{IR} and NA_{RF} varied between three different scenarios by the area (Abou Zaki et al. 2018).

Scenario 1

In a country all the potential cultivable land Area A_{PC} is outfitted for irrigated agriculture. In this scenario, the area of the current rain-fed farmed will stay unchanged, as follows:

$$NA_{IR} = A_{PC} \quad (3)$$

$$A_{Total} = A_{RF} + NA_{IR} \quad (4)$$

Scenario 2

The all cultivable area is partly rain fed (B ratio) and partly irrigated (A ratio). The (A) and (B) ratios are calculated from the available database of FAO from the currently rain-fed and irrigated ratios. I assume that in each country it is possible by the current farming methods to expand comparably to cover up the area of total potential.

$$A = \frac{A_{IR}}{A_{RF}+A_{IR}} \quad (5)$$

$$B = \frac{A_{RF}}{A_{RF}+A_{IR}} \quad (6)$$

$$NA_{IR} = (A) \times A_{PC} \quad (7)$$

$$NA_{RF} = (B) \times A_{PC} \quad (8)$$

$$A_{Total} = A_{RF} + A_{IR} + NA_{IR} + NA_{RF} \quad (9)$$

Scenario 3

By using only rain-fed agriculture the total potential cultivable land is farmed. The irrigated area will then unchanged, as follows:

$$NA_{RF} = A_{PC} \tag{10}$$

$$A_{Total} = A_{IR} + NA_{RF} \tag{11}$$

For each scenario the new water demand can be calculated, as follows:

$$IRG_{WD} = \frac{C_{WDIR}}{A_{IR}} \tag{12}$$

$$RE_{WD} = \frac{C_{WDRF}}{A_{RF}} \tag{13}$$

$$N_{WD} = C_{WD} + (RF_{WD}) \times (NA_{RF}) + (IRG_{WD}) \times (NA_{IR}) \tag{14}$$

Here,

N_{WD} = New water demand for irrigation (m^3)

C_{WD} = Current water demand (m^3)

C_{WDIR} = Current water demand for irrigation (m^3)

RF_{WD} = Annual mean water depth needed for one rain-fed hectare (m)

IRG_{WD} = Mean annual depth of water needed for one irrigated hectare (m)

A_{IR} = Current irrigated area

A_{RF} = Current rain-fed area

5 RESULT

5.1 Country Classification

The countries are classified into VI groups. Among those the class VI countries are thus in an unsustainable condition with regards to water resources, and reforms are needed to balance the current demand and renewal ratio. The other classes (II, III, IV, and V) represent sustainable conditions, with R_{SW}, R_{GW}, or their sum being greater than N_{WD}. Data has been collected from FAO website and classified the countries according to the methodology. The following map (Figure 5) represents the current condition of the MENA countries.

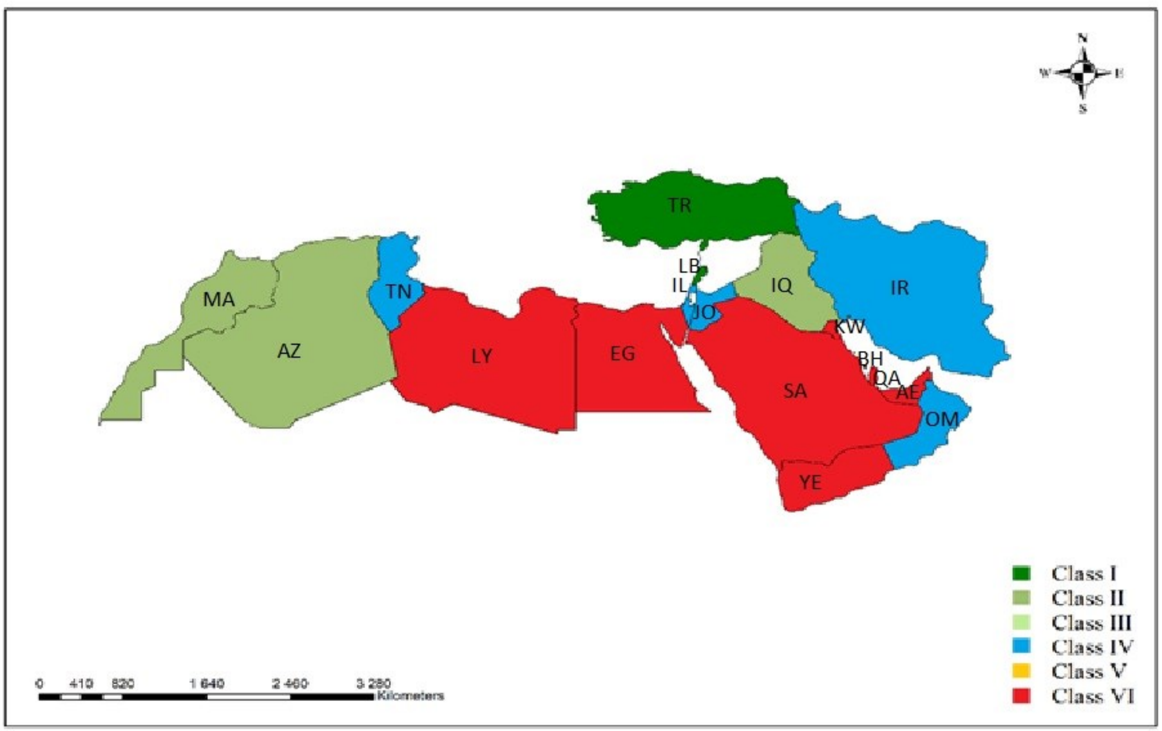


Figure 5: Country classification map of MENA countries.

From the above map it can summarize that many countries of MENA region are now in unsustainable condition. There are only two countries in category I (The countries which are most sustainable condition according to the classification) and those countries are Turkey and Lebanon.

The following figures shows the groundwater and surface water depths as the renewable water resources proportional to the country's area annually. The following graph (Figure 6) represents total renewable surface water resources of the study area countries. Most of the MENA countries hold very little amount of surface water except Turkey, Iran, Iraq and Egypt.

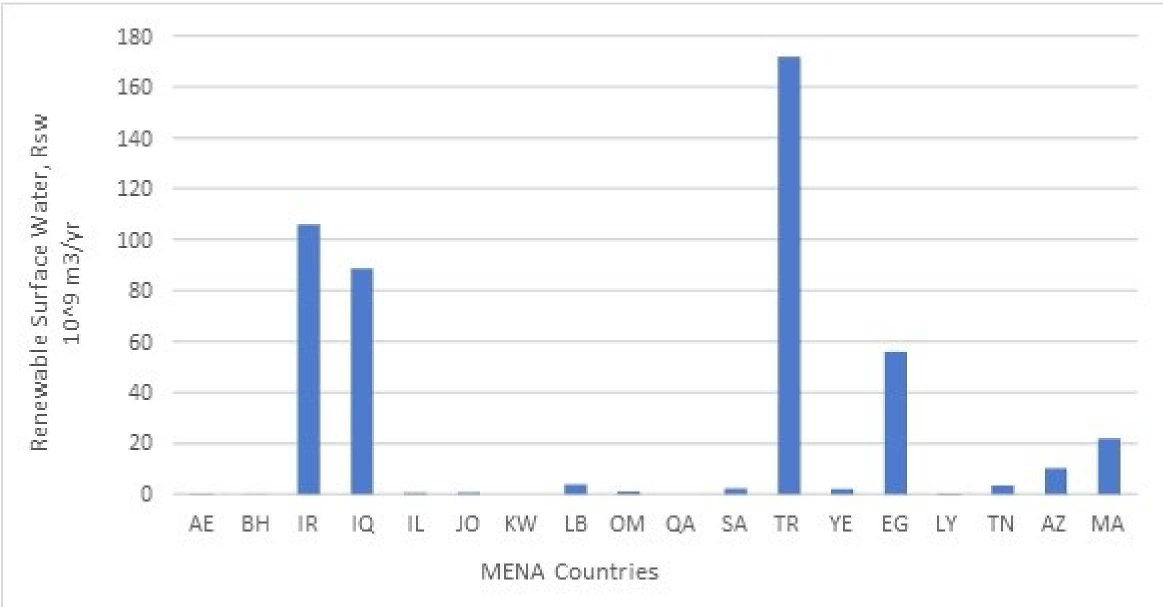


Figure 6: Y-axis represents Renewable surface water resources (R_{SW}) in 10^9 m^3/yr.

This graph (Figure 7) represents the total renewable groundwater resources of the MENA countries. From this graph it can clearly conclude that most of the MENA countries contain lower amount of groundwater resources except Turkey and Iran.

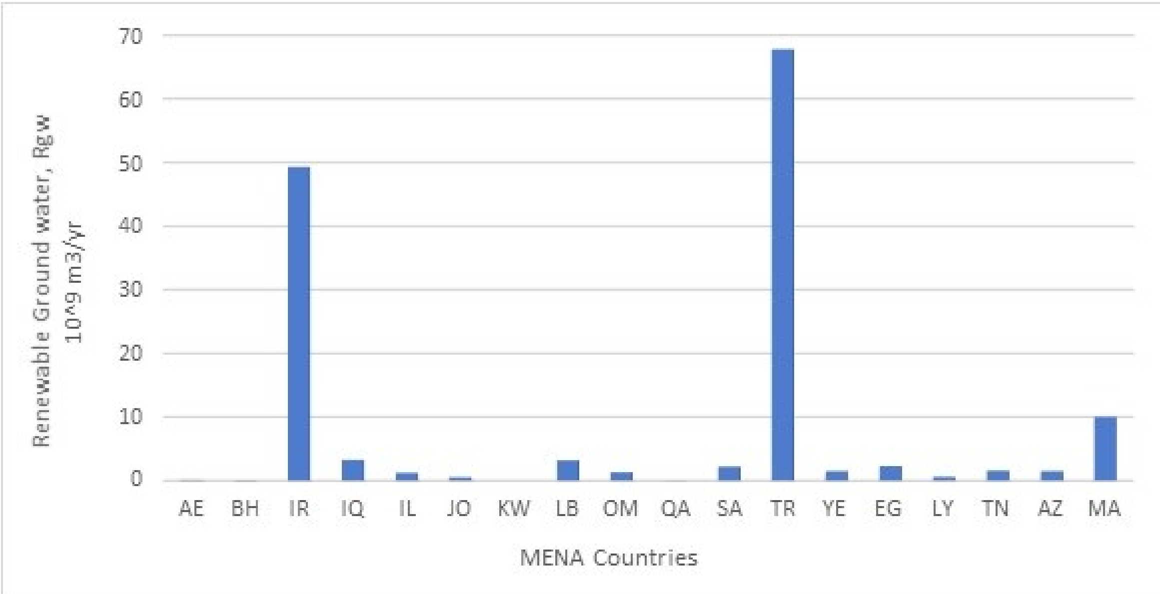


Figure 7: Y-axis represents Renewable groundwater resources (R_{GW}) in 10^9 m^3/yr.

The following graph (Figure 8) represents total irrigation water demand of the studied countries and it is significant that the irrigation water demand is so high in Iran, Iraq, Saudi Arab, Turkey, Egypt among to the other countries.

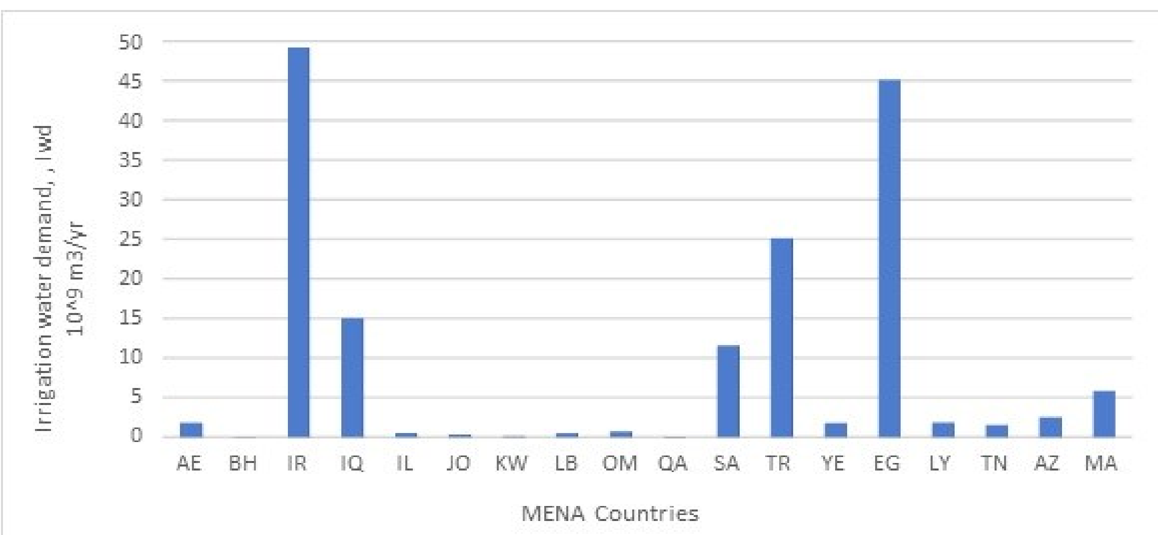


Figure 8: Y-axis represents Irrigation water demand (I_{WD}) in 10^9 m^3/yr.

This graph (Figure 9) shows the agricultural water withdrawal of the studied countries and the amount of agricultural water withdrawal is so much high in Iran, Iraq, Saudi Arab, Turkey and Egypt among the other countries.

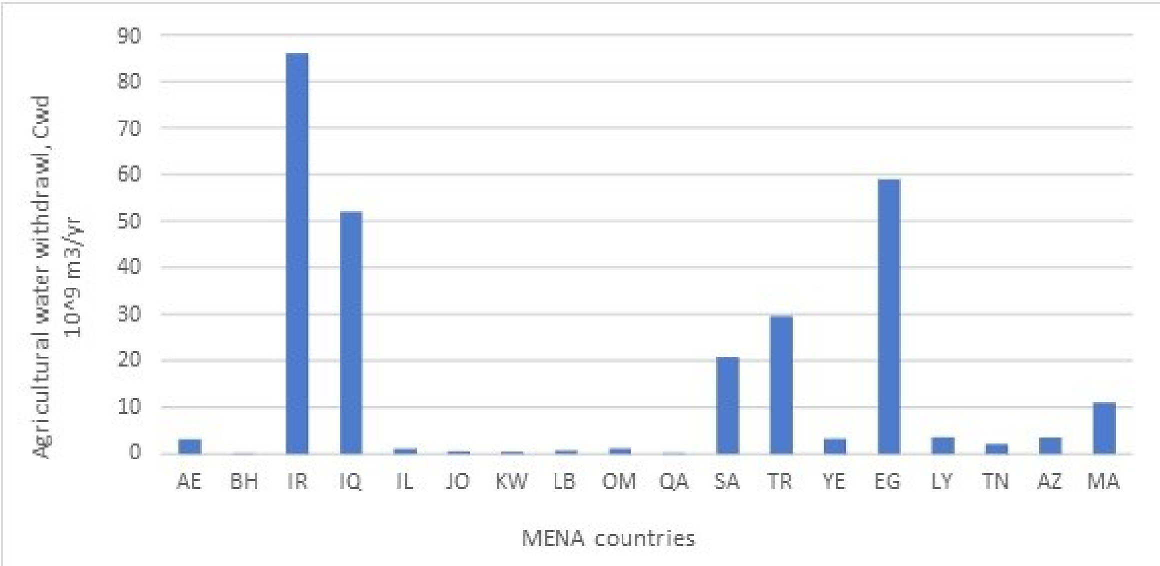


Figure 9: Y-axis represents Current agricultural water withdrawal (C_{WD}) in 10^9 m^3/yr.

The following graph (Figure 10) represents the new water demand for the studied countries, and it is clearly shown that water demand is so much high in Iran, Iraq, Saudi Arab, Turkey and Egypt among other countries.

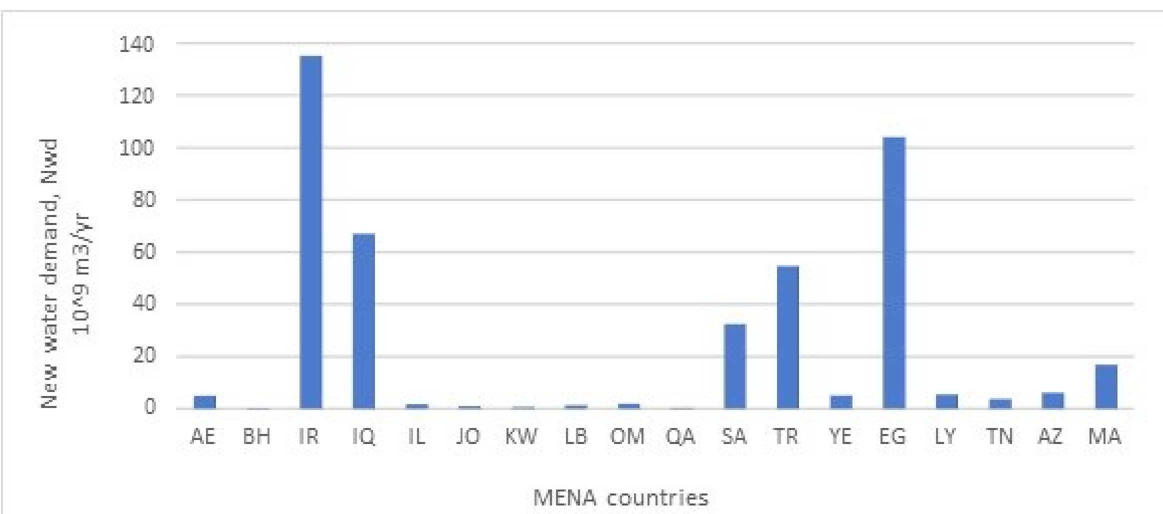


Figure 10: Y-axis represents New water Demand (N_{WD}) in 10^9 m^3/yr.

5.2 Crop water demand along the study area

These are the calculated crop water demand (Table 9). I have chosen the following crops because these crops grown in significant quantities in study area. Data has been collected from FAO website.

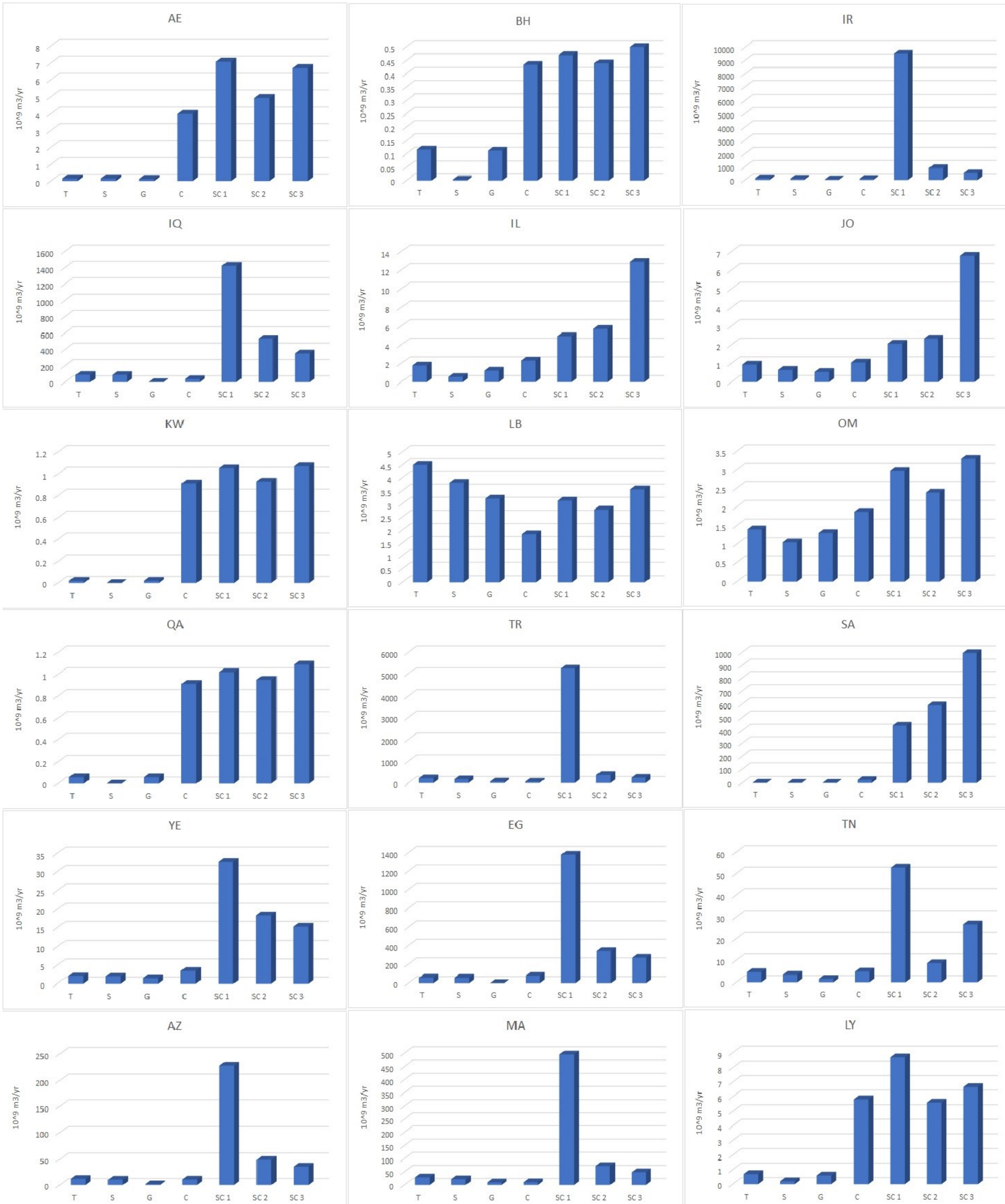
Table 9: Crop water demand.

Countries Name	Crops Name: Rice			Sugarcane			Sorghum		
	ETc mm/dc (season)	Eff. Rain mm/dec (season)	Irr. Req mm/dec (season)	ETc mm/dec (season)	Eff. Rain mm/dec (season)	Irr. Req mm/dec (season)	ETc mm/dec (season)	Eff. Rain mm/dec (season)	Irr. Req mm/dec (season)
AE	1243.7	148.7	1371.3	2483.3	440.6	2036.7	734	140.8	582
BH	1125.7	142.6	1242.1	2219.5	446.8	1772.9	686.6	150.2	534.6
IR	1234.5	151.2	1352.8	2396.9	451.5	1911.6	761.1	155.4	609
IQ	977	150.5	1056.8	1905.7	438.2	1432.9	591.6	144.1	439.6
IL	881.3	142.4	961.1	1653	441.1	1179.9	520.8	149.8	368.7
JO	714.3	147.8	802.6	1355.6	430.1	887.3	408.8	157.9	256.8
KW	1617	146.7	1734.5	3110.1	428.5	2625.3	1064.1	152.5	912.1
LB	690.5	155.1	772.7	1387.1	437.4	923.3	418.3	144.4	266.3
OM	1128.3	153.2	1255.6	2156.6	443.3	1669.8	656	133.9	504
QA	1439.4	152.4	1563.3	2656.1	449.7	2168.4	904.5	1498	752.4
SA	745.2	143.1	827.2	1472.6	431.4	1000.6	409.2	154.8	257.1
TR	550.6	140.6	632.5	1061	440.9	603.1	346.5	151.5	194.5
YE	905	139.1	1028.7	2008.4	399.1	1529.7	489.2	137.7	337.2
EG	894.2	147.9	975.1	1742.4	450.7	1266.9	529	149.3	377
TN	474.3	148.3	1057.3	1930.3	412.2	1453.5	580	147.2	428
AZ	861.6	157.7	942	1671.7	398.3	1198.2	500.9	130.3	348.9
MA	851	143.6	931.4	1662.9	429.6	1189.1	500.8	139.1	348.7

According to the calculated crop water demand (Table 9) it is clear that the crop water demand is really so high in relation with the other variables for all of the different types of crops. Almost all of the MENA countries are actually so dry and there is not enough rainfall to cover the water demand of crops.

5.3 Agricultural water scenarios

Most of the MENA countries lacked the water resources, of both ground water and surface water for completely farming their total potential area of cultivable land by using the system of irrigation. Only Lebanon doesn’t have the limitations on either surface water or ground water in any of the three agricultural scenarios analyzed. Except Lebanon none of the MENA countries have enough the groundwater or surface water resources to expand the total potential area of cultivable land by utilizing current situation. For each scenarios the calculated new water demand is shown below:



Figures 11: New water demand for different agricultural scenarios. Here, T – available total renewable water resources; S – renewable annual surface water; G – renewable annual ground water; C – annual current water consumption (includes industrial, domestic, irrigation); SC1 – water consumption in scenario 1; SC2- water consumption in scenario 2; SC3 – water consumption in scenario 3. The water volume represented with Y-axis in 10^9 m^3.

According to Figures 11, In scenario 1, only Lebanon has available groundwater of surface water to reach the new water demand and thus Lebanon belong to the Class I. The water withdrawal for irrigation in most of the MENA countries annually varied from 1 to 86 (10^9 m^3/year), clearly showed in figure 9 and that's why it's might not be possible to meet the new water demand for farming with the present renewable water resources. Most of the MENA countries belong to the same situation. Many of the MENA countries (e.g. Iran, Iraq, Lebanon, Turkey) can only cultivate some part of their potential area and some countries (e.g. Oman, Tunisia) already overused most of the water for irrigation. The countries (e.g. Yemen, Jordan, Kuwait, Qatar, Bahrain, Israel, Egypt, Algeria, Saudi Arab, United Arab Emirates) have only little amount of surface water and ground water and that's why it's not possible to increase the farm area. These countries need the large-scale projects for irrigation supported by the local government and supported by the legislation and largescale investment. Some of the schemes recently been slowing down in MENA countries, as they confronted with institutional and technological difficulties that have limited returns for agricultural farmers. This type of large-scale projects for irrigation are highly suitable along the major rivers (e.g. Nile) in the dryland. And the project development cost may be will very high, government commitment for long-term projects and it may bring great economic revenue. But this type of agricultural projects schemes will only focus on crops which are profitable and have the market access. Plans must be set for long-term projects which will provide maintenance, infrastructure, and will also improve the agricultural farmer's knowledge.

In scenario 2, farming the total cultivable area was believed by utilizing the similar percentage on a much wider scale, referring to the ratio of total irrigated area of the cultivated total area (Equation 9). In this scenario, none of the MENA countries could depend on groundwater or either surface water except Lebanon. Here, expanding the projects of low-cost irrigation can improved hectare yields. This type of projects has continually been popular along the rivers in the MENA countries whereby using the techniques of basic pump water is lifted and it then irrigates tiny farms especially on the bank of the rivers. To increase the exploitation of the groundwater and surface water resources the introduction of electric pumps and small diesel will be so much helpful in increasing this small irrigation projects. These market-oriented goods and low-cost products can boost up the economic revenue and the productivity on small hold agricultural farmers. Small irrigation community-based projects with some external assistance can develop the scheme of irrigation for many smaller local farms. By taking the advantages of the river ban areas and the system of flood recession can also boost farmed areas and the soil moisture usage. If the partnership between the external agencies and the local farmers assist with technological support and funding, then the small community-based irrigation projects can act effectively.

In scenario 3, the situation is also same for all the MENA countries like scenario 1 and 2. It's not possible by expanding the nationwide irrigation method to meet the demand of water supply by utilizing only the available water resources. In MENA countries agricultural farmers have limited skills, knowledge, financial resources and they lack to adopt the technological changes and the development of farming (Droogers et al. 2017). As direct rainfall is the principal thing for faming here, the sensitivity of drought can be decreased, by runoff controlling and soil moisture concentration around the roots of plants the productivity can be increased. There is one technique called plant pits that used to enrich the moisture of soil (Abou Zaki et al. 2018). Management of soil fertility, rotation of crops, increasing uptake of plant water, and controlling of pest and some also other techniques used to boost the agricultural productivity on rain-fed farming. To overcome the periods of drought the techniques of water management and harvesting of water have helped the farmers a lot, also expand the yields, and for supplementary irrigation provide water.

6 DISCUSSION

6.1 Rapid population growth, Poverty, and consumption of water

The population of the region during the period 2000-2030, is expected to nearly double from the present population of 296 million. This will create a significant negative impact in MENA areas with vulnerable soils or fragile soils and the sloping lands and the most importantly water resources. The population of major centers of the MENA areas are going to suffer from different forms of shortage of water and environmental degradation (FAO 2018).

In 2018, The Report Poverty and Shared Prosperity; Piecing Together the Poverty Puzzle, released by the World Bank in which it includes the regional and global estimations of poverty, there are two main reasons for MENA stood out. Firstly, the rate of extreme poverty is only increased in MENA region between 2010 and 2015. The rate of extreme poverty increased to 5 percent in 2015 from 2.7 percent in 2010, almost doubling the extreme poor numbers to nearly 18.8 million who are living on a lesser amount than 1.90 dollar per day (World Bank 2018). Secondly, after several years the regional estimates were first time reported for MENA regions of issues and the availability of poor data. In Syria extreme poverty increased to more than 20 percent from almost zero and the rate of extreme poverty increased more than doubles in Yemen which reach about 41 percent in 2015 (World Bank 2020). Most of the MENA countries is now facing a serios economic problem and that is unemployment. The low rates of economic growth related with the higher rate of population growth, the average unemployment rate is 14% in MENA countries and this is the higher rate than in many other developing countries. Among both adults and youth, the unemployment rate is higher in MENA countries, comparing to other developing countries. More than 60% youth are unemployed in Syria and Egypt. For people aged 20-24, the unemployment rate is higher more than 3 times than the people aged above 40 (World Bank 2007). Most of the MENA countries is highly urbanized, with the population of 57% in the urban areas. Lebanon and Jordan with the 80% urbanization rates ate the countries of most urbanized.

Because of the high population growth and the water scarcity for climate related issues the MENA has become the greatest water scarce region where the population nearly 60 percent don't have any access or has little access to drinkable water (World Economic Forum 2020). The gross domestic product about 70 percent of the regions is subjected to very high or high - water stress, and that is extreme in compared to the average of global rate which is only 22 percent (World Economic Forum 2020). In MENA region the largest water scarcity per capita with an availability of average water of smaller amount than 300 m^3/capita/year. In the future this condition will turn out to be more sever because of rising population and global warming. It is also projected that by 2050, the 14 MENA countries among 21 countries will have fewer amount renewable water resources than 200 m^3/capita/year. In MENA countries the amount of total current water demand now exceeds by nearly 20 percent than the available natural water supplies (Mualla 2018).

According to result of this study it is also clear that the water demand is highly increasing in most of the MENA countries (e.g. Iran, Iraq, Saudi Arab, Turkey and Egypt) and that's why they are facing the serious water scarcity problems.

6.2 Water and Unsustainability

In the world the Middle East and North Africa (MENA) is the most water-scarce region, where 60% or more than that number of people doesn't have any access or has very little access to drinkable water resources. More than 70 percent Gross domestic product (GDP) of the MENA region's is exposed to very high or high water stress, while the worldwide average is about 22 percent (World economic forum 2020). The Middle East and North Africa (MENA) is a well-known hotspot for unsustainable uses of water and unsustainable consumption of water. The overspending of water resources or the unsustainable uses of water in MENA region is mostly driven by irrigated areas expansion, uses of water for irrigation and reduction in the availability of surface water. From unsustainable water resources about more than 30% water consumption is supplied for water consumption (World Bank 2018). It is too difficult to conserve the available renewable water resources and reverse the existing trends of using water resources because the demand of water is highly increasing. Before 1997, the irrigated area and the consumption of water resources were equivalent to the available renewable water resources in MENA region, but after that year the water uses exceeded than the amount of available renewable water. After the year 1997, for irrigation the source of water for new cultivated area was mainly the groundwater and thus the available groundwater were depleted. This causes significant cultivated area reduction after 2006, because of water resources unavailability in MENA region. That dry period changed cultivated area from rainfed to irrigated and that result a tipping fact where the water demand surpassed the potential for available renewable resources and also the sustainable level of renewable water resources. The continuous decrease in river flow and significant groundwater level depletion confirms that this unsustainability is actually in use of renewable water resources in MENA region. In MENA region the practice of intensive agricultural cultivation has resulted the degradation of water levels in major lakes (e.g. Urima, Hamoun) in Iran. (Torabi Haghighi et al. 2020). The depletion of groundwater level because of overexploitation also limits the interaction between groundwater and surface water and in this way reducing the recharge of wetlands. With a continuous depletion rate about annually 0.6 meters, the level of groundwater table decreased about 50 meters in many aquifers in MENA regions (Abou Zaki et al. 2020). In Middle East and North Africa, the surface water is already overexploited and, in some countries, (e.g. Egypt, Iraq) with over abstraction of surface water compromising 20%-50% of the requirement of environmental flow. The withdrawals of excessive surface water have reduced the flows in Jordan river basin and also degraded ecological status of rivers. Some MENA countries (e.g. Iraq, Turkey) has transformed the regime of river's flow by exploitation and uncoordinated and rapid development and also causes 45%-50% decrease in river's flow that reaches to the downstream river in Iraq (World Bank 2018).

6.3 Agriculture and Water situation

This study tries to represent an effort to assess the availability of future and current cultivable area in some selected MENA countries, with regards to future and current capacity of groundwater and surface water in every country. The MENA countries contains 1.4% of the global water resources and the availability of freshwater in 50% per capita is below 500 m^3/yr. The main source of water is ground water in 54% of countries of MENA. The analysis showed that, some of the MENA countries already using more than 100% of their natural resources (e.g. Oman), Egypt is consuming 92%, Tunisia is using 85%, and also the current demand of agricultural water is also so much high than groundwater and surface water resources available. The MENA counties contains vary little amount of both water resources. Depending on the cost of exploitation and resources availability, irrigation source percentage varies within the MENA countries. To meet the calculated new water demand, searching for new water resources needed.

The current consumption of water is more than 85% in some MENA countries (e.g. Tunisia, Libya, Yemen, Egypt) and in Oman the water consumption ratio is more than 100% and this is so high consumption rates compared to the available quantity of water resources. It is important to maintain the renewable water resources sustainability when expanding the farming areas in each MENA countries. It will help to prevent the negative effects on both society and ecology. Our method showed satisfactory evaluation at national level but there may be some issues at local level to be challenged. In all the scenarios, where based on the existing scheme of water supply the current area of potential cultivable land was expanded, the new calculated water requirement was so high to maintain the conditions the natural rechange on a national scale. Only Lebanon has the available groundwater and surface water to meet the demand in different sectors.

The management of agricultural water are in priority already in MENA countries, and through large plot commercialization the expansion of agricultural land areas takes place, and by also subsistence farming. To improve the cropped rain-fed areas the main issue is to manage the soil moisture where motorized pumps and manual spread helps to soil moisture maintaining and to promote low-cost irrigation (Abou Zaki et al. 2018). To increase the irrigation projects of small community-based, schemes of communal pump and the flood recession also helps on a small scale. Big infrastructure projects, like construction of weirs or dams, surface channels and piped irrigation could meet demand of future for irrigation plans on larger scale in some of the MENA countries (e.g. Turkey, Iran, Iraq, Lebanon, Egypt).

The management planning for current irrigated water resources and the current data collection could not cover up all the water use aspects in MENA regions. There is still lacking in the collection of data, especially about the situation of current aquifers and the recharge rates of ground water. In some cases, the FAO data contains model estimates and values. The providing data can varies within countries and are the national averages, especially within various climate zones countries. However, the calculations and the data can be used to get the general conclusion about the availability of water and land in the selected MENA countries.

7 CONCLUSION

The Middle east and North Africa are suffering several environmental risks lately. Renewable water resources are actually becoming progressively scarce and the factors behind this is lack of existence of proper amount of resources of water and the poor management of water resources. In MENA countries the desertification is now-a-days an extensive environmental problem, and the overgrazing and unsustainable practices of agriculture is the main cause of this. In this region 86% water is used in agriculture sector. Yemen, Jordan are facing severe water shortage. Because of groundwater shortage in Jordan the water cost has increased 35% in last ten years. In Yemen, more than 30% population don't have the access to daily food needs. In United Arab Emirates, the water table has fell for the last 30 years about 1 meter/year (The water project 2018). In MNEA region the overuse of desalination plant for water resources is also a serious problem. Although those desalination plants help to produce the water that are needed for the MENA region, but they can create problems for environment and for human health. Economic growth and rapid population, water supplies sharing across the borders, and the climate change effects including rainfall declining, droughts and the much high evaporation rates significantly affected the water supplies systems in MENA region (Arab regional report 2018).

The current research has demonstrated the present water resources scenario and future and present water demand for agricultural sector in MENA region countries throughout the utilization of water resources that are available in the MENA region countries. The analysis considered equally small farming and large commercial for increasing the production agricultural products in the studied MENA countries. The scenarios of water demand, availability of resources, and the increasing of water exploitation were reviewed on national level. The results revealed that, many of the MENA countries (e.g. Lebanon, Iran, Iraq, Egypt, Turkey) could increase their cultivable area, based on establishing some extra technological methods. Most of the MENA countries does not have the sufficient groundwater or surface water. However, each of the country needed to be considered as individual case, when producing management plans for water resources for future. The volume may be comparatively estimated of renewable groundwater and surface water resources, but the increasing cost of exploitation in every source needed to be considered. It is clear that only depending on the groundwater and surface water resources it's not possible to meet the future demands of water, even when thinking their significant abundance.

The scenario along with greatest economic returns, provided used groundwater and surface water percentage, should be selected. For future development, the recommendation should also consider farmer's livelihood, economic sustainability, and most important economic growth for long-term. Expanding the area of agricultural land on countryside scale is also related to many more constrained issues than ones reviewed in this paper. It is admitted that, in the agricultural sector the major developments are directly associated with the ability of society to improve legislations and the plans for water management. This research paper aspires to represent a baseline intended for comparison of renewable water resources and agricultural land availability in MENA region countries, as a prerequisite for agricultural sector expansion with the manner of sustainability.

In MENA region the problem of water resources is the most complex, urgent, and intractable than any other state of the world. It is noted that MENA's declining water resources are a great threat for the economic growth in the mentioned regions. The government and the water users call the immediate actions for the critical situation. Usually the fragmented supply-oriented method for developing water definitely give way to unify the water resource management. Opportunities and challenges for unifying water resource management normally includes alteration of the recent planning exercises to represent the treatment of the water as an economic development and implementation of a complete policy outline, united along with the decentralized administration and also the delivery structures. It can be a partial or sometimes completely new substitute to investment in the innovative supply for improving existing management supplies. The one significant approach to enhance the availability of water supply in the area can be the management of usual groundwater renew and improvement of magnitude through the means of artificial.

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