

Water Shortage in MENA Region: An Interdisciplinary Overview and a Suite of Practical Solutions

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ABSTRACT

The chronic water shortage in the Middle East North Africa (MENA) region is a perplexing issue, undoubtedly because various operational sectors, multi-institutions and stakeholders are inextricably interconnected. In the light of climate variability and the unprecedented population growth rate, the per capita water resources and biocapacity will continue plummeting, and the demand-gap will seriously expand. Existing water quantification agreements have been deemed inefficient to solve the problem of naturally diminishing water resources and thus require immediate re-assembling. Most scholarly endeavors, including key international organizations, NGOs, and “Think Tank” policy briefs have limitedly addressed water shortage in contexts of regional politics, mass media, and, importantly, from social psychology perspectives. Therefore, a thorough analysis and interdisciplinary approach is required to find a feasible and suitable framework of solutions and from a multi-perspective podium. A synthesis of cross-sectorial bottlenecks that are crucial to water management is presented, and a suite of practical recommendations are introduced to water authorities and governments. This study argues that in the shadow of the region’s political instability, the clash of ideologies and its repercussions, and issues of national security and sovereignty, regional cooperation on water issues remain prognostications. In this essence, governments of MENA countries are urged to develop measures to substantially increase the water supply through innovative approaches. Such measures include enhancing the capacities of water harvesting, maximizing the storage capacities of the built dams, and deploying groundwater recharge techniques. Furthermore, seawater and brackish water desalination through clean energy technologies is a contemporary solution with socio-economic and multiple benefits. Multi-billion water projects might not be suitable approach in the absence of external funding and the aforementioned hurdles. Further research is required to address the social economics, and environmental aspects of desalination and the socio-economic feasibility of privatizing drinking water utilities and price polarization.

Keywords: Water Conflicts; Renewable Energy; MENA Region; Interdisciplinary Approach

1. Introduction

The Middle East North Africa (MENA)¹ region has undoubtedly been attractive in the eyes of the international community for decades due to the so-called “low hanging fruits” of natural resource opportunities, but also for a number of present yet past-driven geopolitical issues. Not surprising, since the region is the home of over 50% of the world’s proven oil reserves and approximately 40% of world’s proven natural gas reserves [1]. The leadership of many industrialized countries obstinately regards the region to be of immense political importance and indispensable to the economic growth and energy

security [2]. The region, on the other hand, is endowed with renewable energy cornucopia, particularly solar, hydropower and wind power. The Middle East receives 3000 - 3500 hours of sunshine per year while North Africa alone has the potential to supply all energy needs of Europe from renewables [3]. Due to land use regulations and restrictions in Europe, the desert of MENA is another attractive opportunity to deploy large scale renewable energy projects. Although the region is a net importer of water in virtual form and in various degrees [4], the region has been exporting industrial commodities to many parts of the world. The region has been an attractive tourist destination, especially to Tunisia and Egypt [5]. Furthermore, the region accommodates vast and rich historical archives of previous civilizations [6]. It has also been remarked that MENA contributed to the de-

¹The term “MENA” region refers to following countries alphabetically: Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Palestine (OPT), Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, and Yemen.

veloped world with numerous number of skilled workers². From a world trade security perspective, the region has the life arteries of the world's oil trade: Suez Canal and Hormoz Strait. For instance, 40% of the daily oil exports pass through Hormoz Strait. The enormous oil shale and natural gas discoveries in Jordan, Israel, and Lebanon, respectively, have made the region even more attractive in the eyes of foreign energy utilities [7].

The key political challenges in the region include: the Arab-Israel dispute in Middle East, Iran's foreign affairs and regional politics, and the social awakening in MENA region that has given birth to newly elect political leadership (Muslim Brotherhood). Surely, the region is teetering on the verge of socio-economic repression due to a cocktail of climate change effects, economic challenges, and post-Arab spring political instability, even in countries that had their regimes toppled. The population of the region is increasing at unprecedented rate, the unemployment rate is overwhelming, poverty and high food prices suppress the poor. Furthermore, potable water shortages and lack of proper sanitization, and extreme climate events such as summer heat waves, frenzy sand storms, and frequent drought are key daunting challenges [8]. Worse enough, the region's consumption of natural resources is more than double what regional ecosystems can support, putting the region on a brink of "ecosystem bankruptcy". Due to the increase in per capita income, population growth, and changing life patterns, the average Ecological Footprint of the region has increased from 1.2 to 2.1 global hectares per capita (gha/capita) while the average biocapacity per capita decreased from 2.2 to 0.9 (gha/capita) [9].

The issue of potable water shortage and the accompanied "national security" and "sovereignty" affairs is undoubtedly a fundamental issue, since water quantity and quality play pivotal role across the various sectors and it is obstinately regarded as a determining factor to the region's economic development and socio-political stability. According to a recently published report by the World Bank, the water demand in MENA countries will quintuple by 2050. The reports stresses that MENA's citizen have a little over 1000 m³/year for use, compared to a global average of over 7000 m³ [10].

The water conflicts in MENA region have remarkably gained academic impetus and it has been a quintessential issue to a number of NGOs, key international organizations e.g. (UN, FAO, WB, and IMF) and from eminent international "Think Tanks" that have assiduously addressed thematic subjects related to water conflicts. The outcomes of such endeavors have, indeed, provided a clear understanding of the problem and provided a set of

²According to the Arab Labor Organization, annually 100 thousand science-seekers leave the region to Europe and North America and only 50% return home. Due to relatively low monthly wages and instability, the region suffers the "brain drain" syndrome.

policies and recommendations through mainly institutional governance and cross-sectorial amendments. The missing links are, however, a broader interdisciplinary approach that encapsulates deeper political issues, mass media influence, accompanied by better understanding of the region's social psychology and ideologies.

Today's problems are very complex and global (such as climate change, poverty, and population growth), thus a better understanding requires new epistemological frameworks and methodological practices that exceed any one discipline [11]. Interdisciplinary studies draw on disciplinary perspectives and integrate their insights through construction of a more comprehensive perspective and coherent research [11-13]. The water shortage and conflicts in MENA region are too complex to be adequately addressed by a single discipline or profession, therefore, the main objectives of this synthesis is to deploy an interdisciplinary approach to target a number of principle issues that, directly and indirectly, influence water balance and potentially create or intensify conflicts in MENA region. The study also seeks to suggest a suite of practical recommendations that would contribute to the frameworks of solutions already presented in the literature.

2. Review of Water-Related Issues in MENA Region

2.1. MENA Population: Social Psychology Perspectives

The population growth in MENA region is growing at an unprecedented rate compared to the rest of the world. The Middle East (ME) is said to be the youngest region in the world [14]. Since the 1970's, the MENA has undergone notable demographic changes and its total population almost tripled from 128 to 359 million people in all Arab countries [15]. By 2050, this region is expected to have a population size of 692 million [15,16]. Poverty and illiteracy among the poor have been one of the main causes of this so-called "*Pine syndrome*"³. Religious, traditions, and cultural heritage have also encouraged people to overshadow the reasons to control birth. The Muslim-Arab societies are said to be submissive to the God's will, characterized by commonly saying "*En Sha' Allah*" meaning ("if God is willing"). This makes them feel ardently subjugated to their environment and the embedded cultural traditions and thus they oppose interference and grudgingly conceive modern societal visions [17,18]. As a result, poor families disregard governmental voices and outreaches to control birth because they are not aligned with the God's will. Further-

³The "*Pine syndrome*" refers to the Aleppo pine tree that annually produces enormous amount of cones even on very poor soils. The same applies to poor families who have many children without any considerations of their economic status.

more, the “son-culture” in which the son/s is the symbol of manhood, have caused many housewives to unnecessarily continue give birth until the first son is delivered to please the husband and his family. This culture, though have been slightly pacified, however still pose formidable challenges in poor pockets and urban slums. Moreover, the rapid growing population in MENA region puts a great strain on the resources of the countries and their capacities; more water and food will be needed, more jobs and housing will be needed [19]. There is little debate today that economic growth can lead to lower birth rates with Europe as an example [19], however there is also ample evidence that improving the social and economic status of rural women (through education and media outreach) would encourage family planning and birth-spacing thus smaller family size [19]. Promoting availability and affordability of contraceptives supported by media campaigns is one approach. Furthermore, encouraging the participation of clerics in elevating public awareness to gradually relinquish the “son culture”, to promote family planning, deemed necessary. Clerics, to-date, have played a fundamental role in influencing and steering mass public attitudes and behaviors in many MENA countries. For example, there now over 450 religious channels in MENA countries with the aim to “spread the word of God and Islam”. Generally speaking, there is a wealth of evidences that mass media play a fundamental role in influencing public perceptions of environmental and societal issues [20]. The stringent role of social media in the MENA’s social uprisings has been recently highlighted and reported [21].

2.2. Climate Change and Adaptation

The MENA region, based on global and regional climate models, is expected to be drier with higher near-surface air temperature thus with threatening consequences on all vital sectors [22]. A study of climate change’s impact on water resources, based on a high-resolution regional model, shows a decrease in precipitation of on average 4% between 2040 and 2069 in the Middle Eastern countries included in the model [23]. An increase in precipitation is predicted for Kuwait (30.7%) and Qatar (27.9%) while Jordan (-16.6%) and Lebanon (-14.7%) will see the largest decreases. Despite the high increase in precipitation in Kuwait and Qatar, which already have extremely low water resources, no improvement in water availability is expected. With the current population projection of the United Nations, Jordan’s annual per capita water resources are expected to decrease from 110 m³ to 56 m³ by 2050. The rather high water availability in Lebanon is projected to decrease from 900 m³ to 725 m³, putting Lebanon below water scarcity levels. Consequently, groundwater will continue to be a vital source of drinking water [24]. Surprisingly enough, during the

years 1993, 2003 and 2013, the Middle East witnessed extraordinary intensive downpours and snow storms originating from Siberia causing vast destruction to the fragile low-capacity infrastructures [25]. However, these extraordinary climate events instantly send messages to the governments of the region to conduct water-infrastructure refurbishment in order to maximize the benefits of such storms (good-rainy-year) using water harvesting and groundwater recharge techniques. This is vital since precipitation is modeled to decrease, however, intensive rain showers probably become a climatic characteristic of the winter season. The MENA region is threatened by desertification and degradation of ecosystems due to global warming and the over-use of natural resources [5,9], which will exacerbate the problem of water scarcity. Desertification is expected to threatens 14% of Algeria’s and 52% of Morocco’s land base while in Egypt, 30% to 40% of total irrigated land is affected by salinization [26]. Since landscape water plays eminent ecological roles, landscape water management and vegetation rehabilitation using e.g. harrowing and furrowing techniques and establishing natural reserves, would pacify the effect of desertification and promote ecological stability and diversity. In this regard, the MENA governments are argued to establish a set of regulations that contemplate the ecological use of water [9].

2.3. The Agriculture Sector: From Traditional Practice to Economic and Efficient Practice

Typical irrigation practices in MENA use 10,000 cubic meters of water per year for every hectare. That same quantity of water would meet the basic (drinking and hygiene) requirements for 1000 people [27]. In Jordan, 75% of the water is used for agriculture whilst this sector contributes only 2% to national GDP [28]. Over-production of agricultural products in Jordan, such as tomato and citrus, accompanied by market distortions usually results in product low prices. Consequently, farmers trash their products on streets as a form of grievance [29]. One major problem is that irrigation is favored over household use, and commercial farming (especially for export crops), over (generally smaller) farms producing for local markets [27]. Astonishingly enough and during the past 25 years, the Gulf States (particularly Saudi Arabia) have consumed quantities of non-renewable water for agriculture use enough for 500 years without the need for seawater desalination [30]. Saudi Arabia shares two-third of the *Al-Disi* aquifer with Jordan. Satellite image shows green circles that resembles forage production (Pivot irrigation) on the Saudi Arabia’s territory (**Figure 1**). Due to the sandy texture of the soils, the high infiltration rate doubles the needs of fresh water for irrigation.

The highly subsidized oil in Gulf States and the endeavor to nationalize strategic crop production especially



Figure 1. Google Earth image of forages production through pivot irrigation systems in Saudi Arabia using *Al-Disi* fresh water.

wheat and forages resulted in a disastrous use of the non-renewable fresh water. In Egypt, the agriculture sector where the majority of the poor reside, subsidies to irrigation have been justified as it provides aid to the poor [8]. However, it has been proven that such an income redistribution instrument only benefit the rich households, not the poor [8]. On the other hand, the Israeli agriculture model consists mainly of diverting water from Palestinian villages to Israeli settlements for intensive export-oriented agriculture systems. The Palestinian farmers therefore abandoned their lands and worked as day-labor in Israeli settlements [8]. Although Israel uses modern and efficient irrigation techniques, this diversion water marked political intentions to probably gain political weight in the peace process negotiations and national security issues. The poor farmers in MENA region generally exhibit low education profile and they perceive agriculture as a socio-traditional heritage rather than pure economic practice. Therefore, they accept only grudgingly to change their old-fashioned and the inefficiently inherited practices from previous generations. Furthermore, due to lack of knowledge, farmers use excessive quantities of fertilizers and pesticides, which have led to soil contamination and seriously threaten groundwater qualities. Another noteworthy trend in agriculture is the expansion of urban areas on the expense of highly fertile arable land. For example, Jordan has lost over 100 thousand hectares of highly productive and fertile lands especially in the North (Irbid city) and Middle (Amman the capital) in just 40 years. Overall, manufacturing- and service sector-led growth, rather than agriculture-led growth, become predominant in most pro-poor Arab countries [31]. It has been suggested that improving food security in MENA region is not only important for improving livelihoods of MENA's people but also likely to be the

key for a peaceful transition [32]. The agricultural sciences are developing remarkably. In this essence, organic mulching, using composted municipal solid wastes and animal manure, have shown to increase the water holding capacity of soils and double the production rate, thus, reduces demand for chemical fertilizers [33]. Using extracts of some poisonous weeds and biological control for pest management are some modern techniques to substitute extensive use of pesticides.

2.4. Waste Water Management: The Forgotten Sector

The total volume of wastewater generated by the domestic and industrial sectors in MENA region estimated at 13 billion m^3 /year, of which 6 billion m^3 is treated for reuse [34]. Treated wastewater, used predominantly in agriculture, can provide a reliable alternative source as wastewater produced is linear to water consumed. Issues regarding treatment processes and infrastructure capacity, due to the varying quality of wastewater and increase of quantity, have resulted in non-effective treatment of wastewater [34]. For instance, 57% of wastewater from MENA countries is partially treated or not treated at all, however, the volume of wastewater collected and treated in the MENA countries varies from country to country [34,35]. Due to lack of financial resources, municipalities relied on traditional "waste stabilization ponds" to treat wastewater and municipal liquid wastes. Effluent from these plants are sometimes mixed with freshwater resources and used for irrigation causing serious contamination problems from the high concentrations of chloride and nitrate [36]. The overflow of stabilization ponds also leads to untreated water polluting the downstream lands and probably the groundwater resources [36]. In many MENA countries, however, the shift to mechanical treatment using "Activated Sludge" accompanied by secondary and tertiary aeration ponds have considerably improved the quality and quantity of the treated wastewater. Nonetheless, the projected increase in MENA population will naturally increase the quantities of wastewater; therefore, wastewater treatment plants require addressing the design limitations, increase their capacities, and overcome the regulatory obstacles regarding the use of wastewater in agriculture or groundwater recharge [34]. The lack of technical data on wastewater qualities and quantities pose another fundamental challenge to successful development of wastewater sector [34-36].

2.5. The Drinking Water Networks and Utilities

According to the United Nations, the total renewable water per capita decreased from 3035 m^3 in 1958-1962 to 1000 m^3 in 2003-2007 in MENA region. This makes the region the world's water scarcest [5,8,10]. Some coun-

tries are below the scarcity level with 12 other countries in state of water crisis (less than 500 m³) and of these 9 are in the state of absolute scarcity (less than 165 m³ per capita)⁴ [8]. This trend will increase the groundwater footprint [37], especially with the introduction of extraction technologies. Furthermore, the water demand gap will quintuple by 2050, from today's 42 billion m³ per annum to 200 m³ per annum with a total cost to close this gap could reach as US \$300 billion - 400 billion a year if no demand management measures are adopted [10]. The dire demand gap is further intensified by the continuous deterioration of the fossil non-renewable ground water quality. Excessive extraction led to higher salinity, sea-water intrusion, sewage liquids intrusion, and intensive agriculture practices with the absolute absence of ground water recharge techniques [28,38,39]. For example, no groundwater in Gaza Strip meets all World Health Organization (WHO) drinking water standards [38]. Due to measured higher underground radioactivity, serious concerns have been raised on the safety of such underground water resources for domestic use [40]. Many, if not most of the countries in the MENA region, have heavily invested in drinking water infrastructure in recent times. However, most of the infrastructure does not deliver the services as designed, either due to lack of maintenance or poor planning. For instance 30% of water facilities in Iran supply less than one-third of their design capacity and 20% are non-operational [41]. The lack of prompt network maintenance leads to the increase of losses from the networks, but without effective monitoring representative figures are difficult to establish. Non-revenue water at country level has been reported to be as high as 59% for Turkey amounting to 43.4 m³/km/day, 54% for Algeria (53.9 m³/km/day), 40% in Bahrain (59 m³/km/day) and 36% for Jordan (14.8 m³/km/day) [42]. Cities in most MENA countries have water losses over 30% and although it can be argued that the urban water sector uses only 10% to 15% of the region's water, these losses are considerably higher than the average water losses in western countries and may add up to substantial amounts of water [41]. Within the domestic use, MENA countries, in general, have separated bodies for irrigation water and drinking water with no clear guidelines for coordination [27]. Another malfunction in MENA water institutions is that water demand management is deemed a secondary task, meaning such institutions perform pricing measures, to increase revenues, without considering the water end-use by their clients [27]. The poor performance of many water utilities in MENA is, in most cases, due to lack of funding and mismanagement and the tendency to be administered as government departments and not private entities, creating problems such as

⁴Countries with absolute scarcity (Kuwait, UAE, Qatar, Saudi Arabia, Yemen, Libya, Bahrain, Jordan, and the Occupied Palestinian Territory).

unclear responsibilities for operations, low tariffs, difficulty retaining qualified personnel, the lacking of and application of necessary legislation and political interference [41,43]. The idea of mega-hydro projects such as the Red-Dead Sea canal is another complex issue, since it requires enormous funding, which is difficult in the light of EU and US austerity measures, the difficulties to assess post-implementation environmental impacts, and it requires political treaty among the beneficiaries, which is unfeasible due to sovereignty issues [44]. Theoretically, the Red-Dead Sea canal is said to save the vanishing Dead Sea, generate power and drinking water; however, practically, it require US \$10 billion and a decade—in the best case scenario, with no obstacles—to be accomplished [44].

2.6. Corruption: The Plague

According to Transparency International [45], many countries within the MENA region are near the bottom of the transparency index making them very corrupt. Corruption has many forms and exist at all governmental levels. According to Wilson and Damania (2005) [46], corruption is one of the major causes of environmental degradation in developing countries. The corruption plague in MENA region has reached a tipping point that has burst social unrest and street riots in North Africa [8]. Predominantly, corruption is a tool used to dilute the intended effects of governmental policies [46], to increase the low monthly wages especially in service sectors, and a tool used to express social prestige and power. In MENA region, the monocratic regimes and politically well-connected businessmen—“*who earn huge profits by virtue of political connections, which allow them to avoid taxes and charge non-competitive prices*”—in a rentier-based political economy model [8]. Consequently, the poor-rich gap has expanded, public services have been rendered substandard, low political trust has resulted in poor political participation, and economic activities have accumulated in selected urban zones (e.g. capitals) leaving vast rural areas, rambling, under the mercy of the intermittent and modest governmental aid. The poor had no choice but to practice corruption (through bribes), or, in case of water scarcity, digging illegal wells with an over-extraction rate [28]. The lack of political trust is one key hurdle to enforce regulations and laws related to water governance in MENA region. Anti-corruption agencies exist in many MENA countries with some level of achievements to pacify corruption. However, their autonomy is not yet matured.

2.7. Water Quantification Treaties and Politics of Water Policies

The issue of water politics in MENA and particularly in

Middle East is contentious and a perplexing one. This issue encompasses: water treaties, broader political ideologies and foreign affairs, shared and cross-boundary water resources, and the country's development pathway. Due to complexity of these issues, we will briefly examine them and provide the reader with a broader image. A long-standing literature exists to demonstrate the inefficacy of the bilateral treaties to solve water conflicts in the region [47-50]. One possible explanation of the failure of such bilateral treaties is the pre-defined quantification of water resources, which is an ineffective approach due to virtue of precipitation variabilities. According to [47], securitization of water resources prevents the system from adjusting to natural changes or to socio-economic developments, therefore, once such allocations have been fixed, changing them is perceived as a threat to national security. Furthermore, climate variabilities are expected to reduce the available water resources to all parties, thus, and in the light of population and economic growth, fixed quantitative allocations that seem equitable now may be considered inequitable in a few years [47]. Alternatively, we argue that water resource partitioning based on "percentage allocations" of seasonally-monitored surface water quantities would accommodate seasonal climate variabilities and thus render water negotiations and treaties more flexible rather than static and contentious. To date, Israel neither has water nor peace treaties with Syria and Lebanon, and the former countries are currently in war-status with Israel. This is deeply rooted to issue of national sovereignty of occupied territories. The state-in-state Hezbollah in Lebanon—although listed as terrorist organization by Israel, EU and the US officials, is politically and financially connected to Iran's, Hamas organization in Ghaza Strip, and Syrian's regimes. This delta of ideologies precludes any attempts to achieve political stability in the region in the foreseeable future. For instance, the EU-US economic sanctions on Syria and Iran are one compelling measure. Furthermore, Gaza's siege by Israel and the abolish of international aid to Gaza strip for water management purposes was due to Hamas political control over the Gaza territory [51]—Hamas is also listed terrorist organization by the EU-US officials. On the other hand, Turkey's strategic location, economic competence, the relatively high water resources, and its endeavor toward Europe Union accession have collectively re-positioned Turkey to play pivotal role in shaping the region's politics. However, Turkey's support to the Syrian opposition to ouster the Assad's regime has paralyzed bilateral collaboration for the time being. Current social unrest in Syria will further complicate the political disputes between Syria and Israel, especially when the Israeli air force launched two air strikes inside the Syrian territory in 2006 and in 2013. The other important pillar of MENA's water conflicts is that water

resources are either shared (especially underground) or crossing borders of ten countries in case of Nile River in North Africa, four countries in case of Euphrates-Tigris, and five countries in case of Jordan River. There are few more rivers with smaller strategic value such as (Shatt AL-Arab, The Orontes, Shebelle River, and Senegal River) with a number of tributaries feeding them. According to [52], water conflicts emerged as a sovereignty issue in Euphrates (2700 km long-upper 40% in Turkey, middle 25% in Syria, and lower 35% in Iraq) and Tigris Basin when all the three riparian countries (Turkey, Iraq, and Syria) put forward their major development projects, which aim to utilize these waters for hydropower and irrigation purposes. Although bilateral meetings took place since 1964, however, due to the disagreement on the terminology and procedures on water allocation, the three countries couldn't agree, to date, on the water allocation of the rivers [53]. Consequently, by treating the rivers as one single unit, Turkey prevented downstream countries to have co-sovereignty on the Euphrates and Tigris rivers [52-54]. The Euphrates was extensively utilized by the Turkish through the Ataturk Dam that was impounded in 1990 and through the Anatolia Project (Guneydogu Anadolu Projesi: GAP) to develop 19 dams and 22 hydroelectric power stations. The Turks blocked the flow of entire Euphrates for one month which heavily and adversely affected the Syrians and Iraqis as well. During the construction of the GAP project Syria supported PKK (Partia Karkaren Kurdistan or Kurdish Workers Party) to force Turkey to reach an agreement on minimal allocation of the Euphrates waters [55]. As a result, Turkey agreed to guarantee the minimal allocation of 500 m³/second flow of Euphrates. Syria, on the other hand, launched several dams on Yarmouk River basin, which surpassed Jordan's ambitious to build *Al-Wahda Dam*⁵ [28]. The river now suffers contamination and over exploitation [28,36]. Regarding Nile River, and according to Prince Khalid Bin Sultan (Honorary Chairman of the Arab Water Council), Egypt's water shortage will reach 94 billion cubic meters by 2050 and Egypt's share of the Nile River is "barely enough". He argues that the Ethiopian 4.8 US\$ billion "Grand Renaissance Dam (GRD)" (12 kilometers away from Sudanese border) is a "political maneuver rather than an economic gain". He stresses that in case of collapse, the prospect dam will threatens Khartoum Capital, with potential negative consequences on *Aswan Dam* [56]. The Ethiopian officials claim that the GRD project aims to: eradicate poverty in the region, to enable Ethiopia to export electricity to Sudan, Egypt, Kenya, and South Sudan, and help control

⁵Jordan invested 50 million to build *Al-Wahda dam* after long negotiations with the Syrian water authorities, the dam's construction completed however is not getting enough in-flow. The project deemed a failure.

flooding risks in the Nile's downstream countries. The Ethiopian officials stress the Ethiopia's right to utilize the Nile resources, and that the GRD is being constructed based on "global high quality standards" [57,58]. To conclude, any country's ability to find a compromise is collided with its ability to jeopardize its sovereignty and development rights. The contentious debate on MENA's water resources may remain hyperactive and no consensus seems to be approachable, even though these countries seem to show verbal commitment to cooperate.

3. Renewable Energy Technologies Are Part of the Solutions

Renewable energy technologies have matured and their prices are plummeting considerably [59]. Renewable energy have witnessed a resurgence the past few years with US \$257 billion poured in deploying various applications standing at 16.7% of the global primary energy mix in 2011 [59]. Therefore, clean energy resurgence in MENA region may solve many of the economic difficulties and it may potentially contribute to solving the water shortage problem. The DESERTEC industrial initiative [60] and the Mediterranean Solar Plan [61] demonstrate the EU's endeavor to utilize the desert resources in North Africa and the Mediterranean region respectively. Arab oil revenues are expected to reach US \$400 billion annually, thus there is a room to transform the regional economies from a rent-seeking behavior to a more innovative and developmental economic model [8]. The MENA region has now approximately 10 million unemployed young graduates with extraordinary energy to engage in labor markets. However, due to projected economic growth, the region would need 75 million jobs within the next eight year to achieve social equity and economic development [62]. Energy transition is anticipated to be led by the Gulf Cooperation Council (GCC) with US \$250 billion investments in clean technologies during the next five years [63]. Mutual benefits for MENA and European energy utilities are feasible through cooperation and technology transfer. The GCC currently manufacture fresh water using intensive fossil energy for seawater desalination through "Reverse Osmosis" and Israel is on the pathway to install several plants along the Mediterranean Sea [47]. Deploying Concentrated Solar Power (CSP) for seawater desalination is one modern approach [10]. Photovoltaics (PVs) solar application can be deployed for brackish water treatment and powering water pumping stations. Deploying renewable solutions to increase water supply will be of multiple benefits and create numerous jobs. For example, a potential desalination plant can be built in Jordan at the Red Sea shore, which would save the 50 million m³ of fresh water extracted from *Al-Disi* aquifer to Aqapa city. Another desalination plant can be built on the Gaza's Mediterranean

shore to serve Gaza's needs of drinking water. Clean energy benefits goes beyond the scope of desalination, it can be used in agriculture sector for soil fumigation and drying up forages for winter use. More innovative use of clean energy involves deploying solar collectors for fermenting municipal liquid wastes to generate methane gas for power production.

4. Discussions and Conclusions

The main objective of this study is to provide the readers with an overview of the challenges confronting MENA region with special focus on water shortage. The study deployed interdisciplinary approach due to the profound complexity of MENA water issues. A suite of practical recommendations are presented in the aforementioned sub-sections. These recommendations can be scrutinized by governments, NGOs, and water and agriculture authorities that seek rationale solutions to water and broader environmental issues. The main arguments drawn from this analysis accentuates the daunting political and socio economic challenges confronting the MENA region. The study argues that current bilateral treaties need to be re-addressed to accommodate seasonal variabilities in precipitation. Overall, the member countries of MENA region have no choice but to increase water supply through energy transition and technological tools. However, reducing water demand in agriculture sector through the use of modern irrigation techniques (drip irrigation) and abolishing flooding irrigation style is inevitable. In a lecture delivered at Stanford University, UN Secretary-General Ban Ki-moon outlined three ways to achieve the "Great Transition" by advancing sustainable development, helping people meet their aspirations for democracy and dignity, and empowering women and young people [62]. In this essence, modern public education strategies need to be adopted to elevate public awareness of contemporary environmental issues and clean technologies [64], equip and empower women to play stronger role in family planning and birth control. Population growth and water demand are linearly plotted, thus, any attempts to control population growth will have a positive rebound effect on water demand. Mass media outreach campaigns are influential in changing public attitudes and behaviors if it used in the right direction and for the right objectives [20]. The successful public education profile in Finland, Japan, and Singapore are some examples that demonstrate how education can create environmentally and country loyal citizens.

Although climate variabilities may reduce precipitation and increase the mean annual temperature, however, years of intensive rainfall maybe expected especially after the exceptional years 1993, 2003, and 2013. In this regard, community-based resilience and adaption are strongly recommended. Encouraging water harvesting

from house roofs would satisfy the water needs for two to three summer months. Community associations in rural areas could play a pivotal role in encouraging and funding such community endeavor. Furthermore, and on governmental level, improving large-scale water harvesting techniques and enhancing dams' capacities through the removal of seasonal sedimentation would be beneficial especially in the unexpectedly good rainy years. The agriculture sector in most MENA countries consumes the lion-share of water resources yet only modestly contributes to the national income. Fixing market distortions in the agriculture sector through state-intervention approach is required to elevate the national income in this sector. State owned corporations that monitor the production chain of products and assist in marketing the surpluses will be beneficial. Producing European-standard (e.g. EURO-GAP) quality products will increase the volume of product exportation to Europe. In Gulf states, agriculture policies reform are needed to preserve the groundwater resources by, for instance, reducing the intensively irrigated fodder production that consumes 25% of ground water resources [10]. Privatization and polarization of the water utilities must be analyzed within the country's context; further research is required to assess the economic feasibility and social acceptance of privatizing water supply and demand institutions. In some known cases, privatization of e.g. tele-communication sector (Jordan and Egypt) resulted in a resurgence and highly quality product delivered to consumers. Privatization may enhance competition and lead to lower prices on longer terms. Social acceptance studies accompanied by public referendum help governments decide on privatization option of drinking water utilities. Current bilateral water treaties partition fixed water quantities to beneficiaries. However, revisiting the treaties and distribute water based on percentages of seasonally-monitored surface water resources would render such treaties more acceptable and fair. A solid data bank is required to better understand and document the waste water quantities in all MENA countries. Therefore, water utilities must invest in gathering data to assist in planning and building treatment plants. Information and continuous quality control of the produced treated waste water would help decide the final destination of treated waste water. The region is under-going a political and democratic transformation process. Arab Spring is a myriad force demanding transformative change [8], however, it may take several years to stabilize and achieve its goals. Therefore, the political instability in the region is expected to continue and social transition may colloid with the ideology of the new political leadership and globalization. The politics of the region will most likely change the way the water issues are being negotiated, and equally water scarcity may steer the politics of the region which therefore may take

new unexpected directions.

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