Water scarcity in Jordan: Sustainability issues and information drought

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Abstract

Jordan is considered a landlocked country in the Middle East facing water scarcity. (Dabbas, 2017). The renewable freshwater resource averages about 680 million m^3 (MCM) and about 465.31 MCM of that consists of groundwater; excessive use has led the country to have one of the lowest levels of water resource in the world. This research aims to provide an understanding of the main factors that were responsible for the water scarcity in Jordan and what management approaches the country has taken to preserve the fresh water resource. The research has explored the effects of water scarcity on the people living in Jordan. Moreover, it has also shown the importance of the use of Geographical Information System (GIS) in the planning process for conserving and monitoring freshwater supplies, and how inadequate GIS data will have a negative effect on decision making in a country with scarce water resources. Based on these findings, it was concluded that although there have been new regulations to limit the misuse of water in Jordan and new plans for producing and supplying additional fresh water to the country, through extraction from the Disi aquifer and the Red Sea to the Dead Sea conveyance, there should be more done in order to solve the problem of the diminishing freshwater availability. This paper provides some recommendations.

Introduction

Water provides sustenance to all living beings, it is a quintessential resource that they cannot go without. According to the UNICEF Progress on Sanitation and Drinking Water – 2015 update and The Millennium Development Goals MDG, "in 2015, it is determined that 663 million people in the world do not have access to clean water." (That is equivalent to 18 times the population of Canada). Water scarcity is a global phenomenon that will be the major crisis facing the earth; this could either arise due to human activities or natural causes. Frank R. Rijsberman (2006) conceives water scarcity of an area as "when a large number of people in an area are water insecure for a significant period of time."

It is estimated that freshwater ecosystems occupy only 0.8% of the earth's surface (Abell, Robin, et al., 2008). "A mere 12 percent of the world's population uses 85 percent of its water, and these 12 percent do not live in the Third World." (Maude Barlow, 2001) This shows that although there is enough water to sustain all humans on earth, uneven distribution and water wastage, pollution, and mismanagement can cause a strain in fresh water supplies in many countries around the world. Precisely 43 countries and about 700 million people by 2014 were suffering from water scarcity, including the kingdom of Jordan (UN water topics: Water scarcity, 2014).

The Hashemite Kingdom of Jordan is in the Middle East and has a small surface area of roughly 90,000 km2, 64.350 km2 comprised of desert and only 620 km2 of semi-humid area (MWI, 1997). It has a population of about 8 million, which is growing at an exponential rate of 3.05% per year.

("Jordan Population", 2017). In 2017, it is estimated that the population of Jordan will be increased by 666 persons daily (includes birth rate and refugees) (United Nations Department of Economic and Social Affairs: Population Division, 2015). This is causing an imbalance in water availability, as the water demand rate is exceptionally high compared to the water supply, affecting all sectors of the country. The east of Jordan is a vast desert, which makes up about 75% of the country's area (Isehunwa S., Nair D., Hulse T., Stowell D. 2017).

The country's water supply comes mostly from over-exploited aquifers and groundwater sources. Combined with the high demand driven by the expanding population, pollution, water wasted, climate change (increase in drought and evaporation), and unequal distribution of a limited water supply, this has led the country to become one of the poorest in water resource in the world today (Raddad, K. 2005).

Nations all over the world are beginning to utilize water resources beyond their carrying capacity and their sustainable supply. The lack of fresh water impacts the economic sustainability and vitality of any sovereign country, as it can have severe consequences on ecosystem management, energy, agriculture, industry, tourism, and public health. There should be a greater call for action to emphasize that better management of scarce freshwater resources involves better monitoring of available resources and their use.

For regional groundwater management, higher spatial resolution is required to monitor and map to find measurements of the estimated amount of groundwater resource that is available. Viewing the sources and changes in water availability, will allow decision makers to adapt to better management procedures that are necessary for preserving the existing water supply.

"Geographic Information Systems (GIS) can be defined as a complete computerized system designed to assist the gather, handling, modeling and presenting of spatially based data for resolve, plan and manage sophisticated problems" (Mohammed Otair, 2013). GIS is an important method to better understand and analyze a map of the country for decision makers and planners to pursue possible development in water resources for areas that require improvement in management or accessibility or groundwater vulnerability mapping. However, the GIS is inefficiently used and it is difficult to access spatial data information in Jordan, as the researcher was able to find out in the summer of 2015 while doing field research and creating maps in Madaba, Jordan. The lack of good data results in lack of good GIS modeling of the resources, and therefore inaccurate or erroneous decision-making for resource planners.

Water resource availability can make or break a country; therefore, it is important to utilize the fresh water resources sustainably. This paper would show how Jordan became the second most water scarce country in the world, and how the information availability or lack of it is going to affect decision making. The paper will also seek to answer the following questions: firstly, what are the reasons that Jordan is in this predicament? This would be achieved by tracing the history that led to the water scarcity, discussing the water sources, the methods that make water to be significantly utilized in the country such as irrigation and the effects of the scarcity. The paper would also seek to answer the question of what Jordan is doing and what management processes are being used to mitigate and conserve water? is water scarcity in Jordan due to a poor water management system? If this is the case, is the system not transparent enough? The working

hypothesis of this thesis is that a better use of GIS for data collection, modelling and planning will improve the water management system in Jordan.

Methodology

For this research paper, a mixed research method has been used for collecting and interpreting information. The secondary data was obtained to analyze the water scarcity and determine if there is inadequate availability and access to data information in Jordan. This consists of different academic sources, such as peer-reviewed articles, public documents from government institutions, and case studies.

In addition, for the primary data collection the researcher conducted an interview with Mr. Raouf Dabbas, the senior advisor in the Ministry of Environment of Jordan for the past 10 years. Mr. Dabbas is an invaluable source of information on the current strategies and demands on water management and scarcity in the Kingdom of Jordan. Mr. Dabbas was also the Prime minister's advisor on environmental issues from 2003 to 2007 attending high level environmental meetings and representing Jordan. In addition, he is an environmental lobbyist and activist that participated in many international forums. Dabbas is a member of the Green Growth Knowledge Program (GGKP) Advisory Committee, board member of several environmental and cultural NGOs, Vice President of the Friends of Environment NGO in Jordan, and the Federation of Jordanian Environmental NGOs and working with youth and rural communities building environmental awareness and developing Green Business. (GGKP, 2017). The interview questions have been reviewed by the program level ethical review committee which provided clearance in March 2017.

Literature Review

History: Colonial Effects

"The history of water use in Jordan has been one of poor control and often wasteful use, within recent years, consumption consistently in excess of sustainable supply, and the shortfall being met by over extracting from renewable groundwater supplies or extracting water from non-renewable groundwaters." (Nortcliff S., Carr G., Potter R. B., Darmame K., 2008). The Jordan Basin was part of the Ottoman Empire; after the First World War when the Ottoman Empire collapsed, France and Britain broke up the region into individual nation states by the mandate of the League of Nations (Elmusa, S. S.,1998). The countries were carved out on the map to what is now known as Iraq, Jordan, Israel, Syria, and Lebanon based on France and Britain's interests. Aside from that, the land was divided without considering the people of the region's ethnicity, religion and ancient tribal differences as well as disregarding the application of specific quotas for sharing water basins, eventually leading to interstate disputes. Woodrow Wilson's confidante, Colonel Edward M. House has even predicted that the way the lines were drawn to divide the countries in the Middle East will create a breeding place for future wars (Roberts, S., 2007). Not only does it create implications for civil issues but also causes conflicts when dealing with resources. For example, Labrador's borders were created mainly around water resources. The border between Quebec and Labrador has created territorial disputes between those provinces since the border was following rivers and watersheds. (Hillier J.K. 1997). However due to European colonial powers, Jordan and other middle eastern countries borders were not drawn out with consideration to water resources such as Labradors border.

The Falkenmark Indicator is generally used to measure water stress in a country based on the water usage per capita; a country is categorized under "stress" if the index is between 1,000- 1,700 m^3 per capita, "scarce" if it is between 500-1,000 m^3 per capita, and "absolute scarcity" if it is 500 m^3 per capita and below. (Falkenmark 1989). Today, Jordan water availability per capita is 135 m3/yr, which is significantly below the threshold for absolute scarcity. In contrast to 71 years ago, when Jordan used to be a water rich country that provided 3,600 m^3 /yr of renewable fresh water per capita. (Corps, M., 2014) which is more than is needed for the prosperity and growth of a country.

Water Resources

The water resources in Jordan consist primarily of groundwater (renewable and nonrenewable), surface water (rivers, streams, valleys), and non-conventional water resources (wastewater treatment plants and desalinated water) (Fig. 1). Water supply in Jordan is irregular; in most cities, water is supplied at least once a week and stored in tanks on rooftops. Whereas people in rural areas are especially affected, since the government focuses more on urban areas, people in rural areas receive less amount of water every week averaging once every two weeks. (National Water Strategy of Jordan, 2016 – 2025).

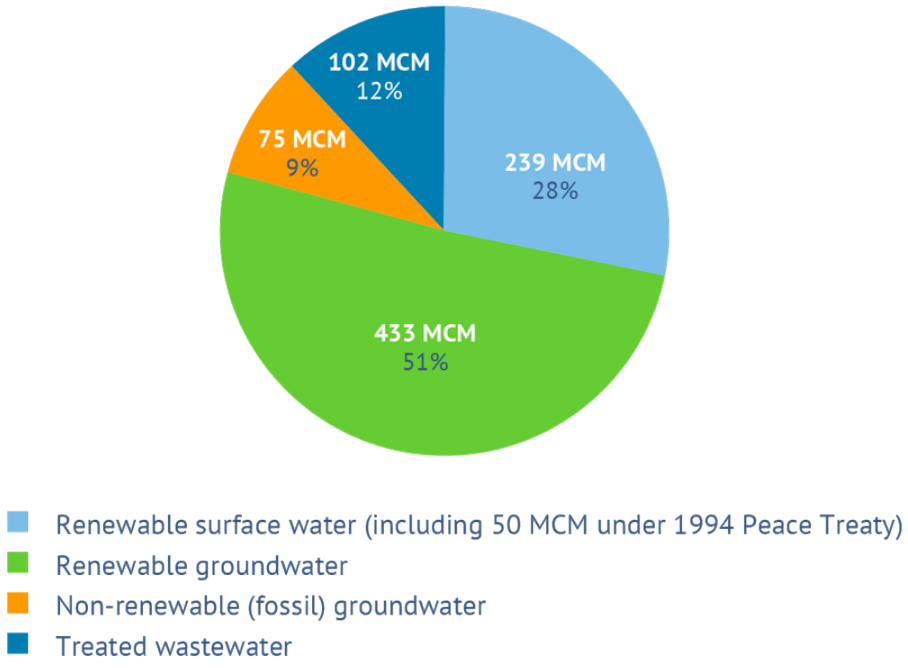

Figure 1: Water Resources available in 2013. Source Water Resources in Jordan - Fanack Jordan. (2015, May 12).

Jordan and Israel resolved their differences on the water in the Jordan basin, by signing a Peace Treaty in October 1994. As part of this treaty, Israel has full access to all the waters of the upper Jordan basin that is approximately 600 MCM per annum. On the other hand, Jordan gets 50MCM from the mainstream in the lower part of the basin, in addition to a more significant share of the

flow of the Yarmouk river. The amount of water which Jordan will now have access to is less than the water distributions of the Johnston Plan that was proposed in the 1950s, that was an attempt to divide the waters of the River Jordan in an equitable manner. The treaty is particularly favorable for Israel. (Beaumont, P. ,1997).

Water Resource: Surface Water

The three major surface water systems in Jordan are the Jordan, Yarmouk and Zarqa rivers (Hadadin, N., Qaqish, M., Akawwi, E., & Bdour, A. 2010). The Jordan river forms a border between Jordan and the West Bank in the south and Jordan and Israel in the North (Fig. 2). The countries around the Jordan river have been exploiting the Jordan river's water by more than 95% of the annual renewable supply (Wolf, A. T. 1995). The water in the Jordan river is saline, therefore not directly suited for drinking (Hadadin, N., et al. 2010).

The Jordan river begins in three headwater streams that have a salinity of 15-20 parts per million (ppm); The first is the Hasbani river which supplies about a quarter of the Jordan's river water, beginning in Syria and part of its outflow is in Lebanon. The other two headwater streams are the Baniyas in the Golan Heights, and the Dan, the largest stream located in Israel (Wolf, A. T. 1995). The lower Jordan river is supplied by springs and runoff from the West Bank, Syrian and Jordanian water and the Yarmouk river. (Villiers, M. D. 2003). The Jordan river flows down from the headwaters into the Sea of Galilee in Israel, continues 105 km in distance downstream through Jordan and finally flows into the Dead Sea, which is -419 m below sea level (the lowest point on earth and the deepest salt lake). (Elana Katz-Mink, 2010) The Yarmouk river is the largest tributary for the Jordan river, it rises in Syria and flows down through Jordan, forming a border and finally feeding into the Jordan river (Lowi, M. R. 1995). Lastly, the Zarqa river is located in the north-eastern part of Jordan (Abdulla, F., & Al-Omari, A. 2008), however it is only suitable for use in domestic and irrigation during wet seasons when it floods, due to the contamination of the river by municipal industrial and agricultural waste. (Hadadin, N., et al. 2010).

Fig 2: Map showing headwaters of the Jordan river flowing through Lebanon, Syria, Israel and

Year	2005	2010	2015	2020
Wastewater for local use	49	67	83	97
Desalinated sea water Aqaba	0	5	5	5
Desalinated brackish water	10	31	40	40
Disi fossil water	83	190	124	126
Peace Treaty	65	90	90	90
Renewable groundwater	387	344	307	275
Surface water	467	594	616	643

Table 1: Water resource Development until 2020. Source Lipchin, C., Amster, A., Pallant, E., & Saranga, D. 2007

Water Resource: Groundwater

There are 12 groundwater basins in Jordan; 2 are already approaching their maximum capacity and 10 are showing a deficit. (Jordan's water strategy, 2009). Wells are being dug deeper and deeper each year, reaching at least 300 m into the deep aquifers to extract enough yield. (Ministry of Water and Irrigation, n.d.).

Other than the environmental impacts of over-exploitation of groundwater, unlicensed wells are problematic in Jordan costing the government 100 MCM per year of unaccounted for water (Shami S. 2014). Out of the 1,318 wells throughout Jordan, only 918 are licensed; laws were placed to put a halt on unlicensed well drillings, the government outlawed the practice for 20 years and violators can face fines in excess of 9,000 CAD and up to two years in prison (Corps, M., 2014).

Year	Number of wells
before 2007	235
2007	26
2008	45
2009	46
2010	57
2011	29
2012	19
2013	141

Table 2: Number of illegal wells closed to year 2013. Jordan Water Sector Facts and Figures, 2013, p.16

Water Resource: Treated Wastewater

Treated wastewater is being used on an increasing scale for irrigation, mostly in the Jordan Valley There are 22 wastewater treatment plants throughout Jordan that discharge about 98 MCM of treated wastewater. This water is used for irrigation in the Jordan Valley in the agriculture sector for fodder crops due to the poor quality of the water (Dabbas, (a), 2017).

Furthermore, approximately 65 % of the total population have access to wastewater collection and treatment systems. Through investment, a shift for better treatment is expected to improve the quality of water. There is a great amount of brackish groundwater in Jordan which consists of a

mixture of salt and freshwater. Brackish water is also used for agriculture, although due to the higher salt content compared to freshwater, it is limited to certain vegetation; main crops of rain-fed uplands include wheat and barley, irrigated land in the Jordan Valley includes potatoes, tomatoes, cucumbers and olives. (Jaber, K. S., & Irvine, V. E. 2017).

External Factors: Transboundary water

Water knows no boundaries and flows across nations. Therefore, cooperation between nations that share water bodies is vital for the preservation of the water resource, since actions carried out in a country will have a major consequence on the other countries that rely on it. This can further destabilize the area, due to cultural tensions caused by the current borders.Most of Jordan's surface water is shared between Lebanon, Syria, and the West Bank. The aquifers however are shared between Jordan and Saudi Arabia as well as Jordan and Syria. (Chen, A., Abramson, A., Becker, N., & Megdal, S. B. 2015).

The decline in the water level of the Jordan river started around 1964, when dams, water reserves and water diversions were constructed by Jordan, Syria, Israel and Lebanon, particularly, the construction of the National Water Carrier in Israel, as well dams built by Jordan and Syria. These projects have dramatically contributed to the reduction of the Jordan River level from 1300 MCM/yr to as low as 200 MCM/yr. (Michael Beyth, N.d.).

Yarmouk river, as mentioned earlier, originates in Syria. The managerial decisions used by Syria are biased as they control the quality and quantity of upstream water. Thus, actions that are carried out upstream in Syria can cause negative implications downstream in Jordan, and even change the entire flow of the river itself. The lack of a basin-wide agreement that manages how water is shared, makes the area especially susceptible to instability from issues ranging from contamination to the evaporation of the river itself. (Lowi, M. R. 1995).

What Led to Water Scarcity:

Population Increase

The drastic increase in population in Jordan was unanticipated, the Kingdom's 2008 water strategy expected consistent population growth, from about 5.87 million in 2008 to over 7.8. But with the influx of Syrian refugees, the population of Jordan in December 2013 already approached 8 million. (Corps, M., 2014). Over the past 10 years, most of the population growth came from non-Jordanians, and represents 1/3 of the current population (Dabbas R. (b) 2017). There are about 1.8 million Palestinians, 500,000 Iraqis, 160,000 other internationally displaced people, (Isehunwa S., et al. 2017), and, as of April 5, 2017, there are 658,015 Syrian refugees. (UNHCR. n.d.). This has added additional pressure on the resources of the country. The rate of water consumption already exceeds the renewable freshwater resources available by more than 20% (Al-Adamat, R. A., Foster, I. D., & Baban, S. M., 2003).

Most Syrian refugees are in the Zaatari Refugee Camp in the North of Jordan, which is now the fourth largest city with a population of 81,000 people. The Zaatari camp also sits directly atop one of the largest aquifers in the country (Florence C. 2015). The graph below shows the level of possible projected water demand in Jordan compared to previous years (Fig. 3). However, this is before the surge in population that was unexpected (Al-Adamat, R. A., Foster, I. D., & Baban, S. M. 2003).

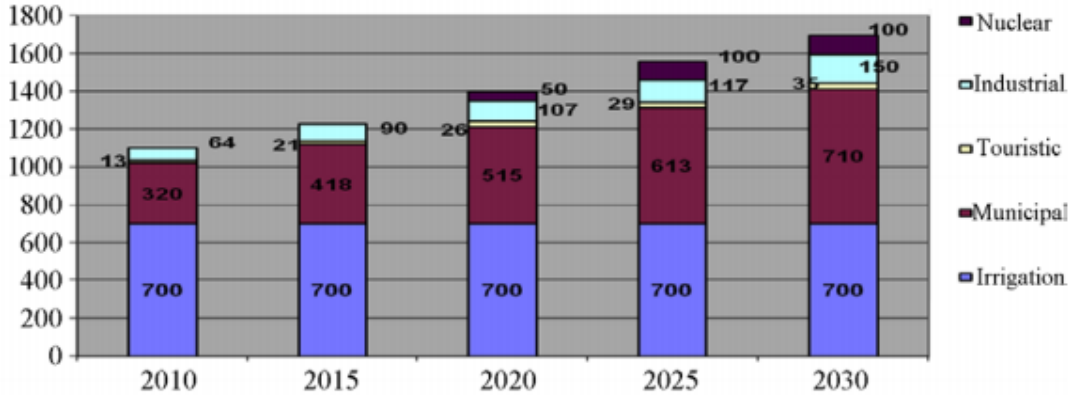

Figure 3: Projected water demand in Jordan. Source Al-Ansari, N. , Alibrahiem, N. , Alsaman, M. and Knutsson, S. 2014

The growth of Jordan's population is also a contributing factor to water shortage. "The population increased by nearly 87 percent over the past decade, with the number of the capital's residents more than doubling…" (Dabbas, (c) 2017).

Climate Change

During the interview with the researcher, Raouf Dabbas mentioned that the earth is experiencing an increase in temperature of an average of 1 degree Celsius, combined with a 20% reduction in annual precipitation in Jordan, this has lead the country to severe water shortage due to persistent drought. In addition, since the Paris agreement, it has cost Jordan 5 billion USD to reduce Greenhouse gases by 14%, which is difficult to achieve for a developing country (Dabbas, (d) 2017).

The table below shows the average distribution of rainfall in Jordan. There is an uneven distribution of rainfall that supplies 80% of the country with less than 100 mm per year and only 5% receives more than 300 mm (Nortcliff, S., et al., 2008) (Fig. 4). Despite the low precipitation rate, Jordan's water supply suffers because about 94.7% of the total amount of water is annually lost to evapotranspiration. In addition, only about 3.0% of the rainfall infiltrates to recharge the groundwater.

	2013(MCM)	percentage from Rainfall	long term	Percentage from long term
Rainfall	8120		8194	99
Evaporation	7689	94.7	7582	101
Runoff	187	2.3	194	96
Recharge	244	3.0	418	58

Table 3: Source Ministry of Water and Irrigation: Jordan's water sector Facts and Figures

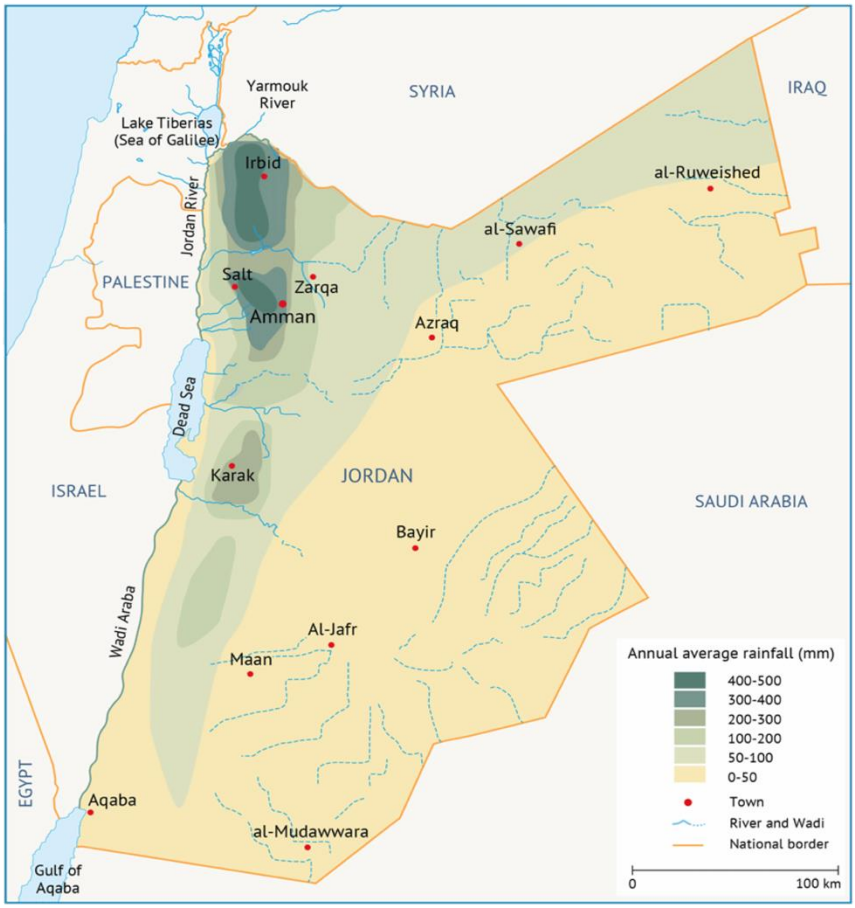

Figure 4: Annual Average Rainfall in Jordan. Source "Geography, Climate and Population of Jordan" 2015.

Urbanization

As the population grows, so do the urban areas. Approximately 83.7% of the population of Jordan is urban, with an increase in the annual rate of 3.79% adding further stress to the water resource in the country (Central Intelligence Agency, 2016). Urbanization called for an increase of water supply networks, however records show that water losses in Jordan due to water supply network leakage reach about 50% (Al-Ansari N., at al. 2014). This is due to the leakage from old and unused pipes or by theft (either by not having in home access to the network or by those who live in poverty). The total leakage every year nationwide is about 76 billion liters which is enough to supply water to 2.6 million people (Corps, M., 2014).

Contamination

The quality of water in Jordan is also under threat. 70% of spring water in Jordan is biologically contaminated, due to different sources of pollution, salinization and an increase in the use of agrochemicals. Some of the main reasons for freshwater contamination are due to improperly

disposed waste, exploitation of groundwater (which has increased salinity and reduced the water level by 5m in many aquifers), and unregulated fertilizers and pesticide application (Wardam, B., & Africa, J. 2004). It was concluded in a report aiming to evaluate groundwater-level and salinity trends that Jordan is expected to have less freshwater available from aquifers as groundwater salinity increases. They have also discovered that monitoring data was not available for some areas (Goode, D. J., Senior, L. A., Subah, A., & Jaber, A. 2013).

To prevent pollution of freshwater, it is important to have maps of potential groundwater contamination to view the location of the potentially highly contaminated areas. (B. Dixon, 2005). An attempt was made to develop a new simplified groundwater vulnerability to contamination index (SGVI). Subsurface parameters were excluded because most researchers might not have adequate data available. These analyses showed that the new index was applicable and could be used in areas where subsurface data was limited or not available (Al-Adamat, et al. 2003).

Agriculture

Since the dawn of human civilization, agriculture has been practiced in the Jordan Valley. Evidence from archeological remains show the existence of water storage facilities as well as irrigation networks used by the Nabateans before the Christian era in the Jordan rift valley and few other places. The channeling of water from wadis (valley that is dry except in the rainy season) and rivers were developed through water conveyance systems and irrigation techniques. In the early fifties, a rebirth of a developed irrigated agriculture in Zarqa, Jordan followed (Jordan's Water Strategy & Policies, 2004).

The agriculture sector is vital for the economy of any country and for many people in Jordan, agriculture plays an important role either due to its significant source of income or way of life. The agricultural sector accounts for $1.4 billion or 2.7 percent of the national GDP, and employs approximately 15 percent of the population, by providing jobs for 62,000 farmers (Al-Jaloudy, M. A., 2006). The sector also provides revenues from exports. 85% of agriculture exports are vegetables, 50% of which are tomatoes ("Jordan agriculture exports on the rise" 2016).

Water Source	Sector			Total Figures in MCM
	Municipal	Industrial	Agriculture	
Ground Water	325	32.2	231.3	589
Surface Water	103.8	4.8	150	259
Treated Wastewater	0	1.7	123.3	125
TOTAL	429	39	505	972
Percentage of total	44.1%	4%	51.9%	100%
Rain-fed agriculture consumes around 100 MCM per year.				

Table 4: Water use by sectors in 2014 (MCM). Source: National Water Strategy of Jordan, 2016 – 2025.

Table 4 above shows that the largest demand and use of water is for agriculture (51.9%). A large amount of water is inefficiently used especially in the agricultural and domestic sectors, and if un-sustainably managed water is wasted at a great extent.

Effects of Water Scarcity:

Food security

Excessive drought has been a recurrent problem for farmers and has become chronic with the lack of fresh water and increase in temperatures that is believed to result in a 15-20% reduction in yield for field and vegetable crops in 30-50 years (Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. 2002). Agricultural sustainability and intensive production practices Nature, 418(6898), 671-677, along with the closing of borders in Syria (that was the gateway route for exporting harvested fruits and vegetables to Syria, Turkey and Eastern Europe), has led to a substantial loss for farmers who used to export 250,000 tons of fruits and vegetables every year (Raed Omari, 2015). This output has currently fallen by about 35%, in addition to the disruption of exports to other countries (Jordan News Agency (Petra), 2017). Karl Hille 2016 stated that the "Recent drought from 1998 to 2012 in the Levant region (which comprises Cyprus, Israel, Jordan, Lebanon, Palestine, Syria, and Turkey) stands out as about 50 percent drier than the driest period in the past 500 years".

In 1999/2000, Jordan started to experience intensive drought that cut rainfall in Jordan by up to 70 percent and dropped wheat production from 70,000 tonnes to 9,000 tonnes. ("Enabling the Rural Poor to Overcome Poverty in Jordan." 2007). This excessive loss in production has created a larger gap between demand and supply.

Future Environmental Refugees

The environmental crisis that the Middle East is facing due to the increase in global warming and drought is threatening water and food security. However, it has been obscured by the shadow of political tension in the region. This diversion in attention needs to be called on to alleviate the numbers of environmental refugees soon. Raouf Dabbas believes there is a strong possibility of having environmental refugees in the future since the environmental crisis is affecting the entire Middle East region. (Dabbas, R. (e) 2017) There are currently 550 million people that live in water-scarce countries. However due to global warming, the number could increase to 200 million environmental refugees that are overtaken by sea-level rise and coastal flooding by 2025 (Naser, M. M., 2011).

Management Process

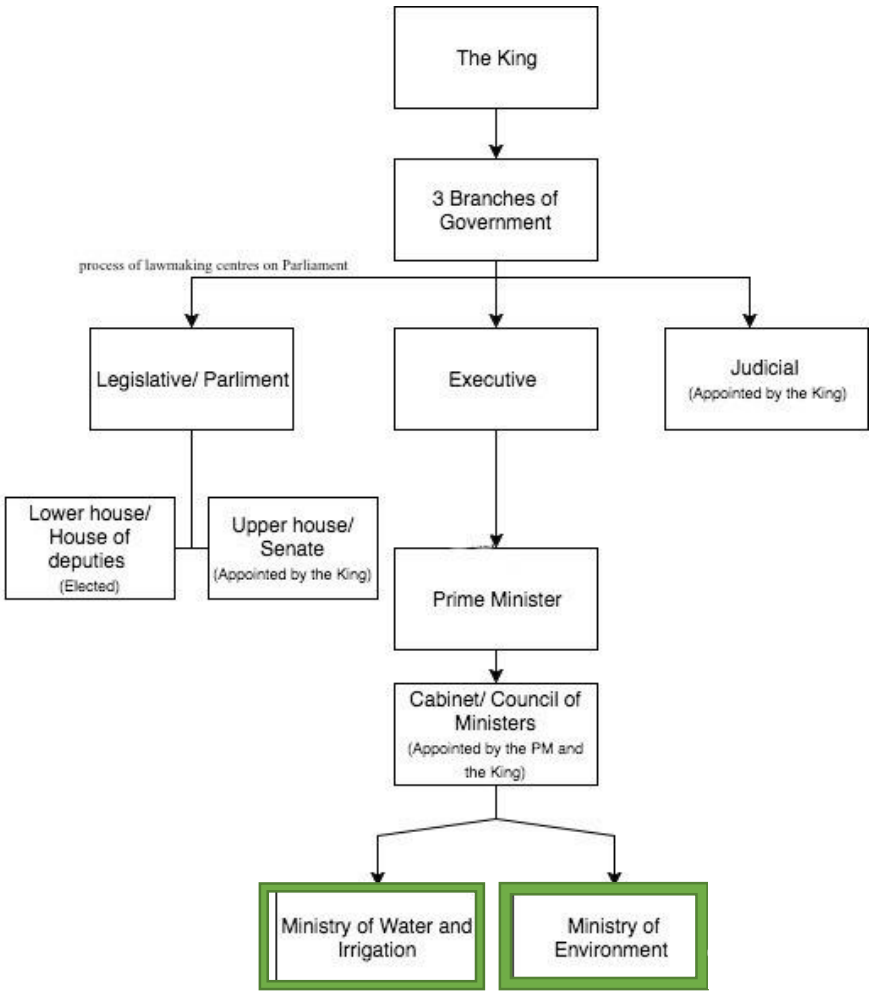

Figure 5: Illustration of the governing structure in Jordan. Source: Bickerton, I. J., & Irvine, V. E., 2017.

The King is the chief executive. The three branches of government starting at the Legislative/ Parliament have the monitoring and law making power. The Executive consist of the Prime minister and the Cabinet (that are responsible for the internal and external affairs of the country). The third branch of the structure is the Judicial. The Ministry of Water and Irrigation and the Ministry of Environment are responsible for water management in Jordan. To establish a better management of water in Jordan, policy is required to be assessed and improved. Therefore, it is important to understand the process and source of jurisdiction. According to Raouf Dabbas, the two main departments that deal with water sustainability in the government are the Ministry of Water and Irrigation and the Ministry of Environment. The Ministry of Water and Irrigation (MWI) is responsible for /water sustainability, due to the water sector being the most vulnerable sector in Jordan it is therefore the most important. The Water Authority of Jordan is controlled by the MWI and is authorized to manage the groundwater resources that are at risk by monitoring and approving groundwater pumping licenses. (Ministry of water and irrigation, 2012). The Ministry of Environment is responsible for monitoring and protecting water in its natural form.

Raouf Dabbas states that "there are many efforts, projects and programs being implemented to reduce the impacts of water scarcity in Jordan. Everyone is responsible and everyone is expected to do their part. NGOs and governmental agencies have been working for many years on building awareness and capacities in the field of water demand and supply management in various sectors including agriculture, tourism, industrial and the general public…". He also believes that they can save water by introducing water saving devices and developing downstream water management behavioral changes. However, governments prioritize large projects practices to supply side management of water aiming to obtain more revenues from increasing the number of consumers. "Donors and the government generally prioritize large, discrete projects, such as new wells or water treatment plants" (Corps, M., 2014).

The Jordan Water Authority (WAJ) was created in 1988 by the executive branch of the government when they acknowledged the need for a more integrated approach to national water management. WAJ is responsible for the water and sewage system. (Ministry of Water and Irrigation, n.d.). Their strategic plan is to "Improve water and wastewater systems through further development of the water and wastewater treatment and networks, optimizing the use of energy, reducing non-revenue water, and continuing to produce water of the highest quality."

However, focusing and investing in solutions such as developments of more networks, treatments and increasing energy to produce more water is merely a temporary solution that does not deal with the cause of the problem. And in time only speeds up the extraction of underground water and does not solve the excessive water loss.

According to Raouf Dabbas, the Ministry of Water and Irrigation and the Ministry of Environment are focusing on regulating and enforcing water effluent treatment and reuse as well as monitoring the surface water quality. "We have all witnessed the effect water shortage is having on Yemen. This unfolding Yemeni apocalypse was predicted decades ago by hydrologists and environmentalists as a result of the dramatically diminishing water availability in the country. Linkages between water availability and security are considered essential and a major factor impacting national stability..." (Dabbas, (f) 2017).

There are also other measures the government is taking to encourage water saving and conservation. These measures include smart water tariffing, water harvesting in houses and in watersheds areas and valleys, introducing drought tolerant agriculture, and drip irrigation for watered crops. (Dabbas R. (g) 2017). There are two major projects to supply the country with more freshwater; the Disi Project, and the Red Sea to Dead Sea Project.

Current Infrastructure: The Disi Project

Al-Disi is a fossil aquifer which has accumulated over 30,000 years and is shared between Jordan and Saudi Arabia. Saudi Arabia has a desert climate that does not have any surface water (rivers, lakes, streams) relying completely on aquifers that were formed during the last ice age (Abdulla ali alibrahim, 1991). However, through over pumping of groundwater they have been able to turn deserts into farmland, which eventually has led to negative impacts.

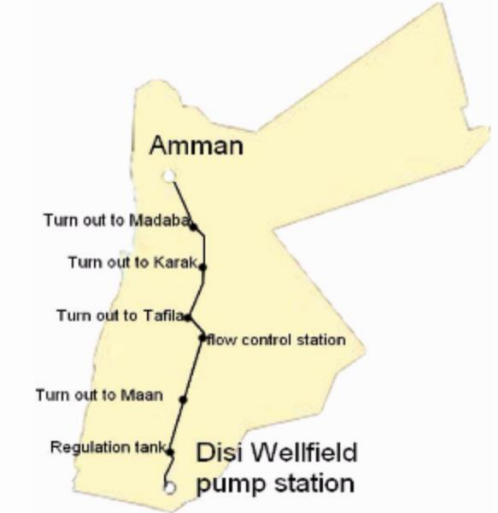

Figure 6: Disi Pipeline. Source Ferragina, E., & Greco, F. 2008.

A relatively recent agreement has been reached to extract water from the Disi aquifer on the border between Jordan and Saudi Arabia by connecting the aquifer to the capital city Amman with a 325-km pipeline (Nortcliff, S., 2008). The construction began in 2009 and the pipeline was launched in 2013.

Nonetheless, Jordan has been extracting water from the Disi since the early 1980s for the use in Aqaba. For future use, it has been reserved for municipal purposes in Amman and has reduced the use of the fossil water for irrigation (Jordan's Water Strategy & Policies, 2004). Possible environmental effects of the Disi Project include: the exploitation of the huge non-renewable reservoir is susceptible to change the local microclimate and aggravate erosion, with negative repercussions on the flora and fauna of the fragile desert ecosystem (Ferragina, E., & Greco, F. 2008).

Planned Infrastructure: The Red Sea to Dead Sea Project

Jordan and Israel have worked together on developing a project to increase the supply of water in both countries by building an underground pipeline that would cost $5 billion JOD to move water from the bay of Aqaba (the Red Sea) into the Dead Sea. This would allow the replenishment of the declining water levels of the Dead Sea as well as producing electricity to invest in more desalinated water (Villiers, M. D., 2003). The pumping station would start in Aqaba (Red Sea), the water pumped out will be transported in an underground pipeline which would go through reservoirs, desalination, and hydropower plants.

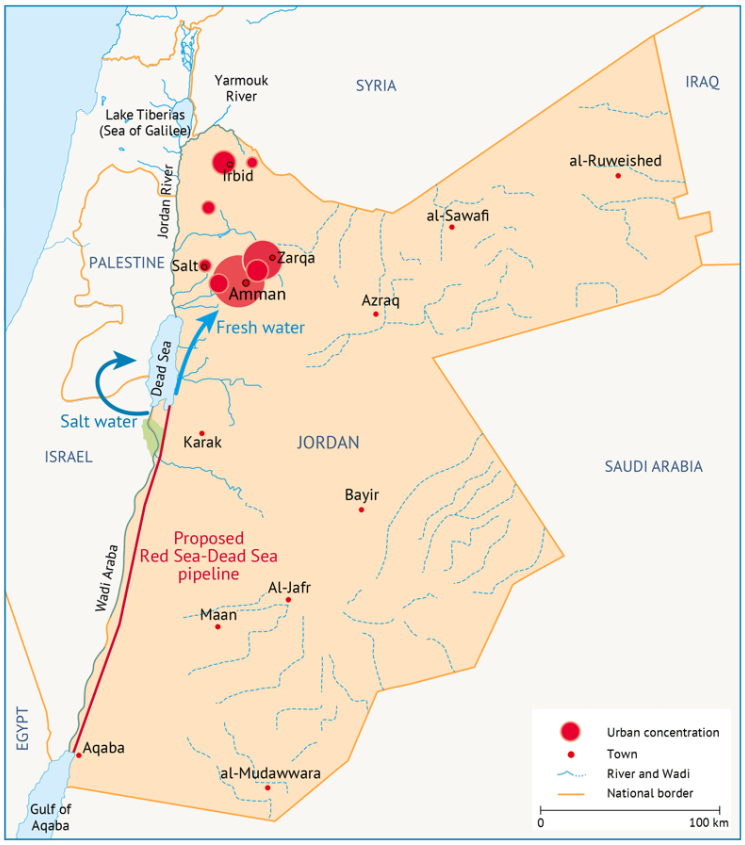

Figure 7: Red Sea to Dead Sea Project illustrating the pipeline. Source: Altz-Stamm, A., 2012.

Possible environmental impacts of the Red Sea to Dead Sea Project includes: having water pipes underground is susceptible to damage, due to severe hydration pressures (Paul F. Hudak, Barry Sadler and Bruce A. Hunter, 2000). Increased pressure on the Dead Sea bottom by the greater volume of the lake could increase the likelihood of earthquakes (Mohsen, M. S. 2007). "The future challenges in meeting the growing demands for water are beyond the capabilities of individual countries" Alkhaddar, R. M., Sheehy, W. J., & Al-Ansari, N., 2005) suggesting that water scarcity is achievable by suitable management and cooperation between countries.

Aquifers and rivers in the Middle East may not have been exploited to the extent they have been, had Jordan, Syria, Lebanon, Palestine and the state of Israel had a water boundary treatment plan to protect and manage the water that is shared between the countries, akin to the United States and Canadian Boundary Waters Treaties agreed to by the International Joint Commission. The Commissioners appointed for the treaty in the United States and Canada must follow the treaty regarding any decisions, reviewing problems or resolving disputes unbiasedly without being affected by the interest of the government's country they are representing (International Joint Commission, 2008). The Commissioners also discovered that a country that shares water that lacks a treaty would be able to divert and use the shared water that is within their jurisdiction however they like, as they have been doing in the Middle East. (Dwivedi, O. P. 1974).

Geographical Information Systems

A case study entitled "Feasibility Study for a National Spatial Data Infrastructure in Jordan." it was recommended that Jordan should adopt the World Geodetic System (WGS84) as well as the Universal Transverse Mercator (UTM) map projection, since the Jordanian agency does not utilize a uniform datum or projection (IDRC/ESRI Canada, 2011). In addition, by embracing a national data model, it would better facilitate and enable data sharing opportunities. It also encourages the participation of various stakeholders (groups and institutions) since the design and implementation of a national Spatial Data Infrastructure SDI is too important a task to be left to just one organization.

"With Esri technology, you can build dashboards to monitor reservoir levels and withdrawals in real time and manage new permit applications. Spatial analysis gives you insights into demand, whether commercial, residential, or agricultural, so you can perform public outreach where needed." (Balance supply and demand. n.d.).

When information is needed annually for water budgeting, calculations, and for revising plans of water management, using ground surveys to map irrigation would not be feasible since it is one of the most basic methods for collecting data. Thus, remote sensing data and geospatial techniques can be used instead. By enhancing spatial, spectral and temporal resolution of remote sensing data and the availability of different sources of earth observation systems support the development of geospatial techniques to further manage water resources efficiently. This could be applied to map vegetation, and measure evapotranspiration and consumption use through medium and high resolution data. (Al-Bakri, J. T., 2016).

According to Nortcliff, S. 2009, data and the monitoring system are important to future strategies for the management of freshwater resources, as it draws data base information on the country's fresh water resource, and the usage of water that is shared between different regions and sectors. Based on a study by the 2011 SDI Team (that consists of Interdisciplinary Research Consultants (IdRC) in Amman and at ESRI Canada Ltd in Toronto), it stated that the challenges that the GIS managers faced in Jordan were: the lack of funding and capacity building, a data centric approach with a focus on outputs rather than a focus on policies, challenges with human resources (recruiting experts in GIS is expensive due to the limited salary, and the 300-400 students/yr. who have trained in introductory GIS lack proficiency), and the limited data exchange in real time. (IDRC/ESRI Canada, 2011)

To speak from a holistic standpoint, water scarcity is not the only issue that can be resolved with GIS. Excessive human loss due to car accidents have even grown faster than the population. (Al-Masaeid, H. R., 2009). If better GIS data were presented, by collecting and viewing information on a map to input and locate where the most accidents occur frequently, pavement conditions or which side of the road to drive etc. To help manage roadways it is necessary to have an understanding of where improvement is needed. Therefore, by increasing GIS data availability for the government and public to view the current system and reinforce future management strategies would thus increase the reconstruction of poor road structures, safety measures, and public transit as a result decrease the money spent on recovery from accidents and together increase revenue.

Recommendations

As a result, it is therefore recommended that the government should also invest in solutions that include: a comprehensive agreement from the governments and stakeholders is required for the Jordanian Spatial Data Infrastructure to be successful. It also suggests that a National GIS Data Model is required. The 2011 SDI Study Team recommended that the National GIS Committee lead the process of creating metadata standards for Jordan, based on the ISO 19115 international standard (as used in Canada and many other countries). Metadata databases are inventories of geospatial data bases and related maps that allow data searching, better planning and decisions to be made on future data and map information investments. (IDRC/ESRI Canada, 2011).

Advocating for more proactive interdisciplinary strategies to enhance coalition between the government, scientists, NGOs and the public, to address the water challenges collectively. Mitigate the high-water loss in the country by restoring old and damaged water infrastructure as well as reducing water leakage in water supply networks. Using the remaining available water more efficiently and effectively. The government should replace the supply side management of water resources with a demand side management aiming to involve consumers in conservation of water resources. Introducing drought tolerant agricultural species as an alternative to the conventional agricultural products which demand a large amount of water, and increasing the use of halophytes. Finally, regarding waste water, better regulation and control of pesticides as well as over effluents from industries and municipality is required before discharge. As well as treating wastewater through absorption to remove diverse pollutants, by using low-cost natural materials, industrial wastes or byproducts (V. K. Gupta, P. J.M. Carrott, M. M.L. Ribeiro Carrott, and Suhas, 2009).

Conclusion

The paper has shown that there should be a sufficient level of information to provide a sound sustainability decision-making tool for group organizations, and the government to find a solution to the urgent water crisis in Jordan. After providing a framework for a better and broader understanding of the source, then Jordan can proceed and implement a better structure of water management. As without adhering to the technological advancements that help guide environmental policy and decision making such as GIS, we run blind, as we have been in Jordan's impending environmental crisis, as environmental crisis does not always preclude a social or economic crisis.

In addition, it is important that Jordan replace its predecessor's reactive management techniques with proactive management solutions that foster a stronger understanding and therefore stronger society in the face of perturbations like water scarcity, since a conglomerate of issues requires a conglomerate of interdisciplinary sources to enact proactive management techniques and properly guide the society towards sustainability. Moreover, mismanagement and water theft from illegal wells and unmonitored groundwater will only exacerbate as people in rural areas become more desperate for water. Therefore, it is important for the government to focus on rural areas as well which includes, among others: equal water supply for rural and urban areas, and increase monitoring of groundwater and illegal drilling for water. Instead of the government merely prioritizing the investment of new projects to increase the water supply in the country, they also need to consider the environmental impacts of their projects and find solutions to one of the key roots of the problem; which is the water that is wasted. Collaboration between interdisciplinary

sectors in the country to collectively tackle water scarcity in Jordan; as well as evaluate and implement supply-side. It is imperative and cost effective to improve the efficiency of water supply network by restoring old and damaged infrastructure and reduce water loss. Improving and introducing new methods in agriculture.

References

Abell, Robin, et al. "Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation." BioScience 58.5 (2008): 403-414.

Al-Jaloudy, M. A. (2006). Country Pasture/Forage Resource Profiles: Jordan.
Committee, Raouf Dabbas. (n.d.). Retrieved from http://www.greengrowthknowledge.org/person/raouf-dabbas

Al-Adamat, R. A., Foster, I. D., & Baban, S. M. (2003). Groundwater vulnerability and risk mapping for the Basaltic aquifer of the Azraq basin of Jordan using GIS, remote sensing and DRASTIC. Applied Geography, 23(4), 303-324.

Al-Ansari, N., Alibrahiem, N., Alsaman, M., & Knutsson, S. (2014). Water Supply Network Losses in Jordan. Journal of Water Resource and Protection, 2014.

Al-Bakri, J. T., Shawash, S., Ghanim, A., & Abdelkhaleq, R. (2016). Geospatial techniques for improved water management in Jordan. Water, 8(4), 132. Retrieved from: http://www.mdpi.com/2073-4441/8/4/132/htm

Al-Masaeid, H. R. (2009). Traffic accidents in Jordan. Jordan Journal of Civil Engineering, 3(4), 331-343.

Altz-Stamm, A., 2012. 'Jordan's Water Resource Challenges and the Prospects for Sustainability'. GIS for Water Resources.

Alkhaddar, R. M., Sheehy, W. J., & Al-Ansari, N. (2005). Jordan's water resources: Supply and future demand. Water International, 30(3), 294-303.

Balance supply and demand. (n.d.). Retrieved April 21, 2017, from http://www.esri.com/industries/water-resources/water-supply

Bickerton, I. J., & Irvine, V. E. (2017, March 13). Jordan. Retrieved April 21, 2017, from https://www.britannica.com/place/Jordan/Government-and-society

Beaumont, P. (1997). Dividing the waters of the river Jordan: An analysis of the 1994 Israel-Jordan Peace Treaty. International Journal of Water Resources Development, 13(3), 415-424.

Central Intelligence Agency. (2016). Jordan. In The world factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/jo.html

Charlotte Florance (2015). A Lost Generation: Where Have 4 Million Syrians Fled? The Daily Signal. Retrieved from http://dailysignal.com/2015/08/26/a-lost-generation-where-have-4-million-syrians-fled/Dixon, B. (2005). Groundwater vulnerability mapping: a GIS and fuzzy rule based integrated tool. Applied Geography, 25(4), 327-347.

Chen, A., Abramson, A., Becker, N., & Megdal, S. B. (2015). A tale of two rivers: Pathways for improving water management in the Jordan and Colorado River basins. Journal of Arid Environments, 112, 109-123.Abdulla Ali Al-Ibrahim. (1991). Excessive Use of Groundwater Resources in Saudi Arabia: Impacts and Policy Options. Ambio, 20(1), 34-37. Retrieved from http://www.jstor.org/stable/4313768

Corps, M. (2014). Tapped out: Water scarcity and refugee pressures in Jordan. Amman: Mercy Corps. Retrieved from: https://www.mercycorps.org/sites/default/files/MercyCorps_TappedOut_JordanWaterReport_March204.pdf

Dwivedi, O. P. (1974). The International Joint Commission: Its Role in the United States-Canada Boundary Pollution Control. International Review of Administrative Sciences, 40(4), 369-376.

El Zabri, Tawfiq (Oct. 2007)."Enabling the Rural Poor to Overcome Poverty in Jordan." The International Fund for Agricultural Development. IFAD.

Elana Katz-Mink,. (2010) Cooperative Management Structure for the Proposed Red Sea-Dead Sea Conduit. 5-6.

Elmusa, S. S. (1998). Toward a unified management regime in the Jordan Basin: The
Esri- water resources. Retrieved from: http://www.esri.com/industries/water-resources

Falkenmark. "The massive water scarcity threatening Africa-why isn't it being addressed." Ambio 18, no. 2 (1989): 112-118.

Ferragina, E., & Greco, F. (2008). The Disi project: an internal/external analysis. Water International, 33(4), 451-463.

Ferragina, E., & Greco, F. (2008). The Disi project: an internal/external analysis. Water International, 33(4), 451-463.

Geography, Climate and Population of Jordan - Fanack Jordan. (2015, May 12). Retrieved April 16, 2017, from https://water.fanack.com/jordan/geography-climate-population/

Gupta, V. K., Carrott, P. J. M., Ribeiro Carrott, M. M. L., & Suhas. (2009). Low-cost adsorbents: growing approach to wastewater treatment—a review. Critical Reviews in Environmental Science and Technology, 39(10), 783-842.

Hadadin, N., Qaqish, M., Akawwi, E., & Bdour, A. (2010). Water shortage in Jordan—Sustainable solutions. Desalination, 250(1), 197-202.

HASHEMITE KINGDOM OF JORDAN Ministry of Water and Irrigation (MWI) Jordan (n.d.) Augmentation of Water Supply for Central and Northern Jordan from Deep Aquifer (Sheediyya – Al Hasa) Retrieved from: http://www.waj.gov.jo/sites/en-us/Hot%20Issues/Project%20Concept_Augmentation%20of%20Water%20Supply%20for%20Amman%20from%20Deep%20Aquifer.pdf

Hille, K. (2016, March 01). Drought in Eastern Mediterranean Worst in 900 Years. Retrieved April 16, 2017, from https://www.nasa.gov/feature/goddard/2016/nasa-finds-drought-in-eastern-mediterranean-worst-of-past-900-years

International Joint Commission. (2008). Annual report for 2008: Boundary Waters Treaty centennial edition.

IDRC/ESRI Canada (2011) Feasibility Study for a National Spatial Data Infrastructure in Jordan. Washington, D.C: infoDev / World Bank.

Jaber, K. S., & Irvine, V. E. (2017, March 13). Jordan. Encyclopædia Britannica, inc. Johnston Plan revisited. Yale F&ES Bulletin, 103, 297-313.

Jordan News Agency (Petra), (2017). Retrieved from: http://www.petra.gov.jo/Public_News/Nws_NewsDetails.aspx?Site_Id=1&lang=2&NewsID=288825&CatID=13&Type=Home&GType=1

Jordan's water strategy & Policies. (2004) Ministry of Water and Irrigation.

Jordan Water Sector Facts and Figures (2013). Available at: www.mwi.gov.jo/sites/en-us/Documents/W.%20in%20Fig.E%20FINAL%20E.pdf

Lipchin, C., Amster, A., Pallant, E., & Saranga, D. (Eds.). (2007). Integrated water resources management and security in the Middle East (pp. 251-267). Springer.

Lowi, M. R. 1995

Maude Barlow, Water as Commodity—The Wrong Prescription, The Institute for Food and Development Policy, Backgrounder, Summer 2001, Vol. 7, No. 3

Michael Beyth, "Water Crisis in Israel," in Water, retrieved from: http://www.gsi.gov.il/Eng/_Uploads/140Water-Crisis-Israel.pdf, 174.

Ministry of water and irrigation. (2012). Retrieved from http://www.mwi.gov.jo/sites/en-us/Annual%20Reports/MWI%202012%20English%20Report.pdf

Mohsen, M. S. (2007). Water strategies and potential of desalination in Jordan. Desalination, 203(1-3), 27-46.

MWI (Ministry of Water and Irrigation) 1997 Water Strategy in Jordan, Amman, Jordan

Naser, M. M. (2011). Climate change, environmental degradation, and migration: a complex nexus. Wm. & Mary Envtl. L. & Pol'y Rev., 36, 713.
National Water Strategy of Jordan, 2016 – 2025

Nortcliff, S., Carr, G., Potter, R. B., & Darmame, K. (2008). Jordan's water resources: challenges for the future. Geographical paper, 185.

Otair M. (2013). The Jordanian Mineral Resources Geographical Information System: A first Step Towards a Computerized Exploration of the Jordanian Mineral. International Journal of Computer Science Issues IJCSI, 10(2). Retrieved from: http://www.ijcsi.org/papers/IJCSI-10-2-3-64-71.pdf

Paul F. Hudak, Barry Sadler and Bruce A. Hunter. (2000). Analyzing underground water-pipe breaks in residual soils. Retrieved from: http://www.wwdmag.com/water/analyzing-underground-water-pipe-breaks-residual-soils

Rijsberman, F. R. (2006). Water scarcity: fact or fiction? Agricultural water management, 80(1), 5-22. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0378377405002854

Roberts, S. (2007, January 27). How the Middle East Got that way. New York Times ,Vol. 139(8), 24.

Raddad, K. (2005). Water supply and water use statistics in Jordan. Proceedings of the IWG-ENV, International Work Session on Water Statistics, Vienna, Austria, 20-22.

Sadik, A.K. and S. Barghouti. 1994. "The water problems of the Arab world: Management of scarce water resources." In P. Rogers and P. Lydon, eds. Water in the Arab World. Massachusetts, USA: Harvard University Press. 4-37.

Scarcity, Decade, Water for Life, 2015, UN-Water, United Nations, MDG, water, sanitation, financing, gender, IWRM, Human right, transboundary, cities, quality, food security. (2014, November 24). Retrieved March 23, 2017, from http://www.un.org/waterforlifedecade/scarcity.shtml

Seyi Isehunwa, Divya Nair, Tom Hulse, Daniel Stowell (2017) Water Scarcity in Jordan Situational Analysis. Blue Initiatives. Subset of Water Issues in Middle East/North Africa (MENA) countries.

Site designed and built by Hydrant (2016, March 22). Jordanagriculture exports on the rise. Retrieved April 17, 2017, from http://www.oxfordbusinessgroup.com/news/jordan-agriculture-exports-rise

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. Nature, 418(6898), 671-677. Abdulla, F., & Al-Omari, A. (2008). Impact of climate change on the monthly runoff of a semi-arid catchment: Case study Zarqa River Basin (Jordan). Journal of applied biological sciences, 2(1), 43-50.

United Nations Department of Economic and Social Affairs: Population Division, 2015

United Nations High Commissioner for Refugees (UNHCR). (n.d.). 658,015. Retrieved April 18, 2017, from http://data.unhcr.org/syrianrefugees/country.php?id=107

Villiers, M. D. (2003). Water: the fate of our most precious resource. Toronto: M & S.

Wardam, B., & Africa, J. (2004). More politics then water: Water rights in Jordan. IUCN Regional Water Programme in West Asia and North Africa, Jordan, Global Issue Papers, Heinrich Böll Foundation.

Water Resources in Jordan - Fanack Jordan. (2015, May 12). Retrieved April 16, 2017, from https://water.fanack.com/jordan/water-resources/

Wolf, A. T. (1995). Hydropolitics along the Jordan River; scarce water and its impact on the Arab-Israeli conflict (Vol. 99). United Nations University Press.

World Health Organization, & UNICEF. (2015). Progress on sanitation and drinking water–2015 update and MDG assessment. World Health Organization. Retrieved from: http://files.unicef.org/publications/files/Progress_on_Sanitation_and_Drinking_Water_2015_Update_.pdf

Zeitoun, M., Messerschmid, C., & Attili, S (2009). Case Study/Asymmetric Abstraction and Allocation: The Israeli-Palestinian Water Pumping Record, Ground Water, 47, 146-160.

Appendix: Interview Questions

- Why do you think water scarcity is an issue in Jordan?
- What do you think the main reasons that led to water scarcity in Jordan?
- What is currently being done by NGOs and the government to reduce the water wastage in the country?
- what can water users or water regulators do to solve the water scarcity problem in Jordan?
- How is the distribution of fresh renewable groundwater resources in Jordan monitored?
- How can we predict how vulnerable Jordan's water is to climate change?
- in the Jordan government what special department deals with water sustainability issues?
- What tactics are being employed to mediate the water scarcity now?
- How much of a priority does the current government put on water sustainability?
- How much of the country's groundwater is dependent on rainfall to recharge? are there critical external sources beyond the borders of Jordan?

"We have all witnessed the effect water shortage is having on Yemen. This unfolding Yemeni apocalypse was predicted decades ago by hydrologists and environmentalists as a result of the dramatically diminishing water availability in the country. Linkages between water availability and security are considered essential and a major factor impacting national stability..." "There are many efforts, projects and programs being implemented to reduce the impacts of water scarcity in Jordan. Everyone is responsible and everyone is expected to do their part. NGOs and governmental agencies have been working for many years on building awareness and capacities in the field of water demand and supply management in various sectors including agriculture, tourism, industrial and the general public…"