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Jordan's Water Sector—Alarming Issues and Future

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Abstract

Jordan has, to a satisfactory degree, managed its scarce water resources, especially during the last few decades due to the regional conflicts and refugee waves hosted in the country since 1948. The waves of refugees in 1967, and after), returnees from the Gulf States 1991/92, during the first Gulf war), Lebanon (1970s and 1980s), Iraq (2003 and after, and lastly Syria (2011-2017 have as well severely impacted the management of water resources which has negatively impacted the water sector especially in terms of allocating new water resources to satisfy the needs of the country. In addition, shortsightedness of some water policy-makers has led to the deteriorations in the water resources quantitatively and qualitatively, which has resulted in social and economic discomfort of the population. In this article, the shortcomings in the water sector are addressed, such as setting an end to groundwater overexploitation, providing water to the population in a continuous way, improving water use efficiency in agricultural uses and the way forward is delineated based on a critical judgment of the actual situation of the water sector in order to reach at a more robust water sector with all its positive impacts on the social, economic and political life in the country.

Keywords

Interrupted Water Pumping, Overexploitation, Irrigation Efficiency, Per Capita Water Use, Sector Management

1. Introduction

The prevailing climate in Jordan is semi-arid. Only the highlands in the west and northwest can be characterized as Mediterranean. Jordan receives an average yearly amount of precipitation ranging from 30 mm in the southeast and east to about 600 mm in the northwest (DoM, open files). **Figure 1** shows the distribution

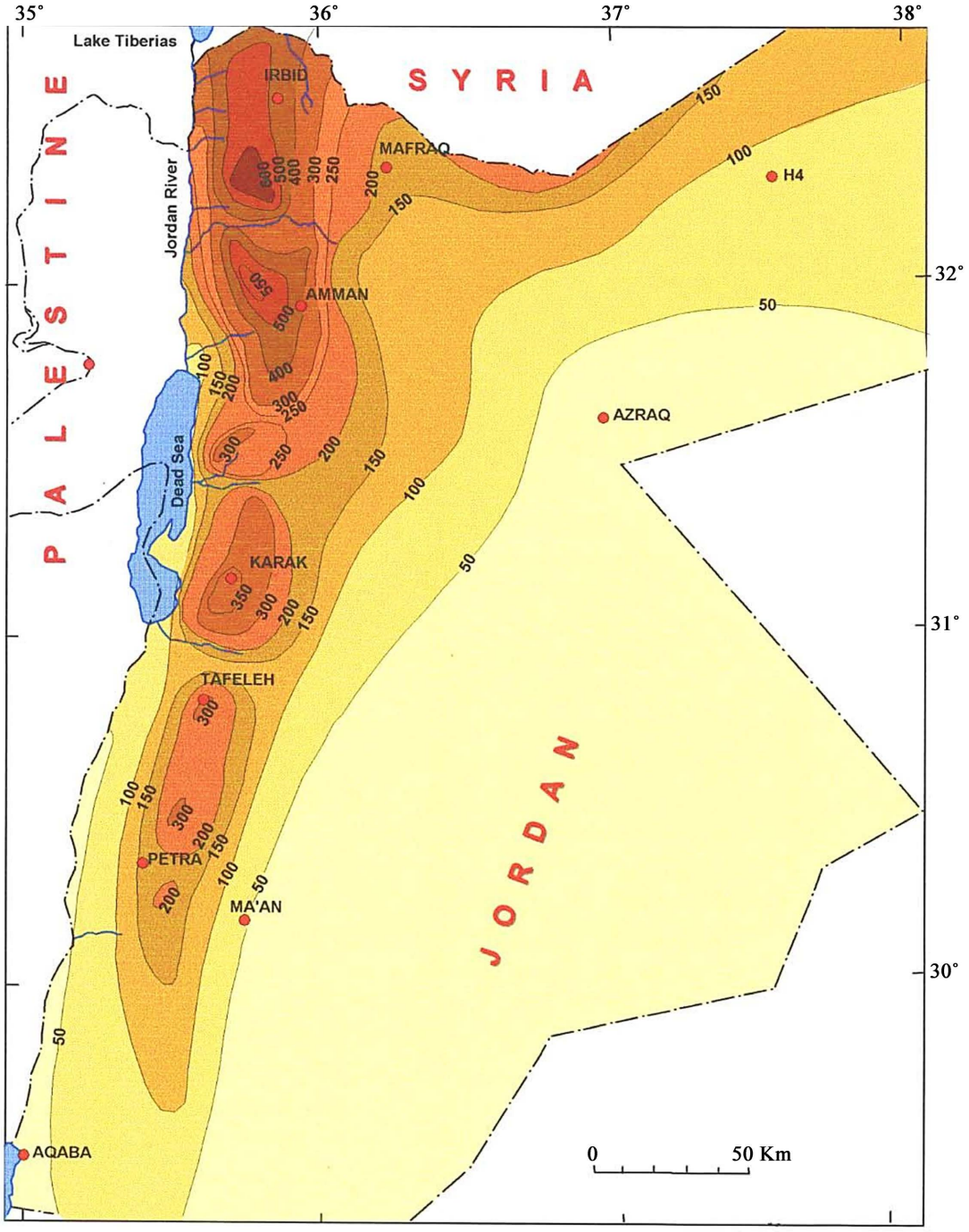


Figure 1. Seven decades average rainfall distribution in Jordan in mm/yr (MWI, open files).

of average precipitation over Jordan.

The evaporation force of the climate in Jordan is very strong: in the cooler north-western areas, it is about 1800 mm/yr; in the southeast, it goes up to 4200 mm/yr (NWMP, 1977). This is respectively, three and 140 times the amount of average annual precipitation. **Figure 2** shows the distribution of potential evaporation rated in Jordan.

Perennial water in Jordan is found mainly in the rivers and wadis of Yarmouk,

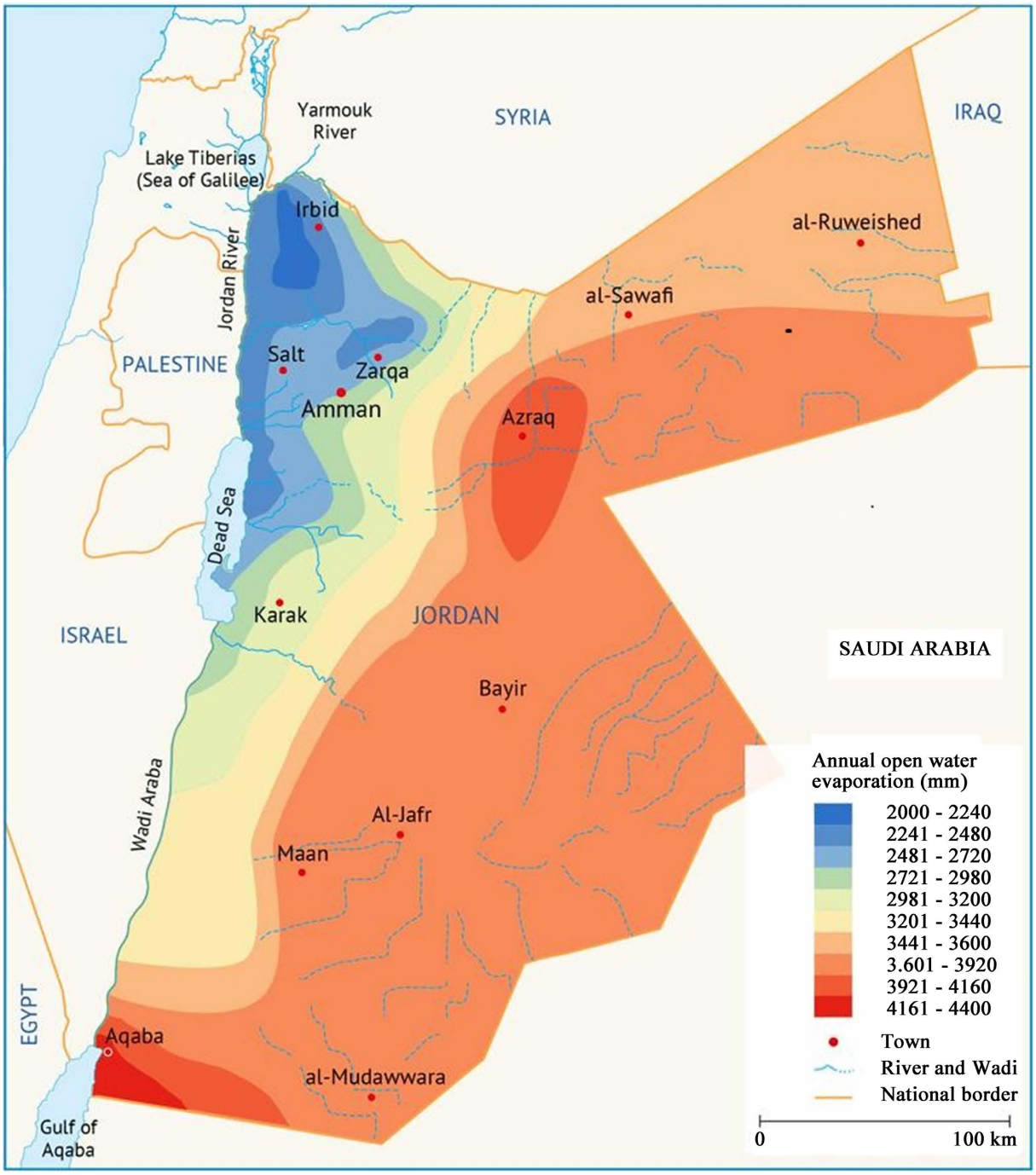


Figure 2. Potential evaporation distribution in Jordan in mm/yr (MWI, open files).

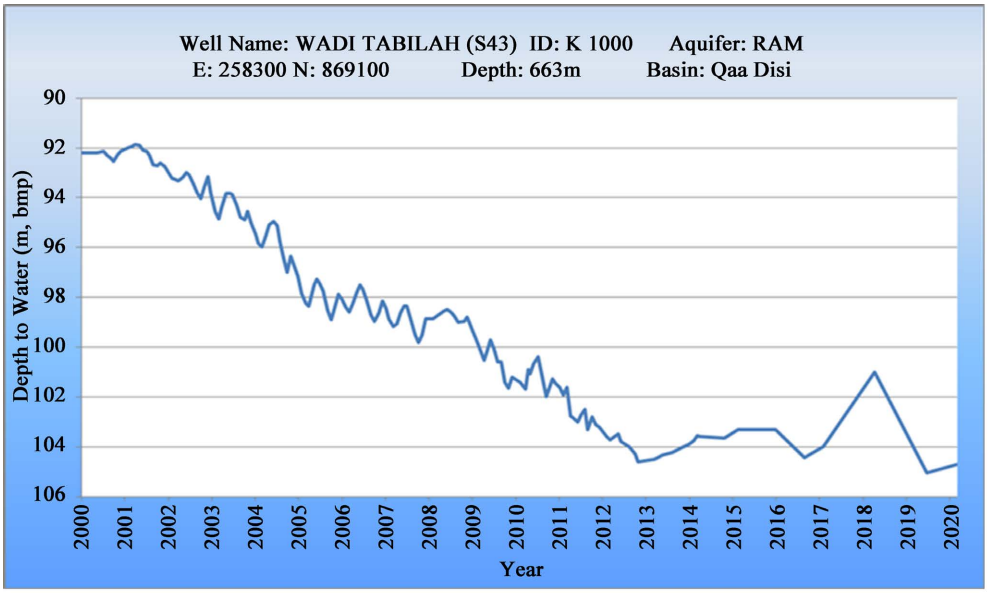
Zerqa, Mujib, Zerka-Ma'in and Hasa. These discharge water during all seasons into the Jordan River, the Dead Sea and Wadi Araba, but its ultimate destination is the Dead Sea (**Figure 3**). These sources, excluding the shared Yarmouk River with Syria and Israel, discharge approximately 160 million cubic meters annually (Salameh et al., 2018).

The groundwater resources of the country are of two origins: recent and renewable or fossil. The latter are non-renewable in technical terms and their

Figure 3. Location map of main cities, river and wadi courses and the Dead Sea, the ultimate destination of most of Jordan's surface and groundwater resources.

exploitation is equivalent to a mining process. The fossil groundwater resources had infiltrated into the aquifers tens of thousands of years ago, when the prevailing climate was more humid (Lloyd, 1969). The renewable water resources and the reused treated waste waters in Jordan without the Yarmouk River water, amount to about 900 MCM/year (Salameh et al., 2018).

The surface and groundwater resources of the country have been developed to a great extent and from within the country no additional water can be developed. On the contrary, the groundwater resources are overexploited and require rehabilitation and some of them have been totally depleted and rehabilitation of some of these groundwater resources may have become technically impossible (MWI, 2017). **Figure 4** shows an example of the dropping groundwater levels


Well Name: WADI TABILAH (S43) ID: K 1000 Aquifer: RAM
E: 258300 N: 869100 Depth: 663m Basin: Qaa Disi
Depth to Water (m, bmp)
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94
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106
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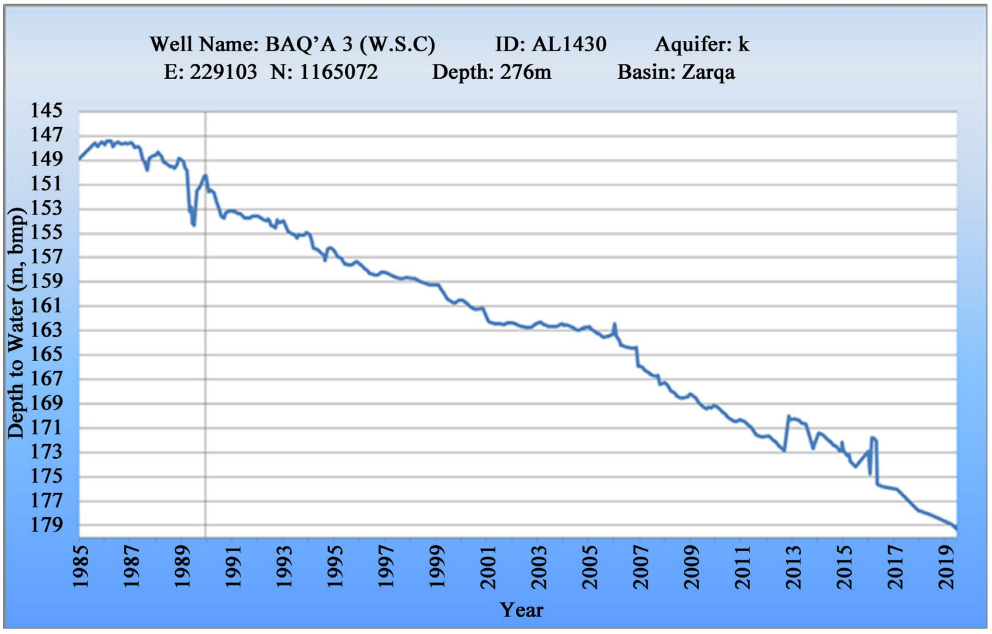
Well Name: BAQ'A 3 (W.S.C) ID: AL1430 Aquifer: k
E: 229103 N: 1165072 Depth: 276m Basin: Zarqa
Depth to Water (m, bmp)
145
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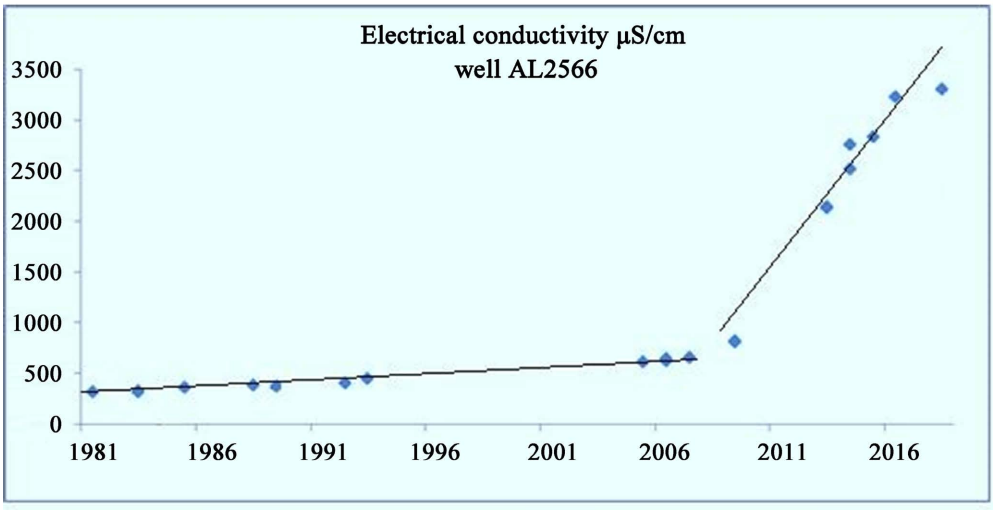
Electrical conductivity µS/cm
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0
1981
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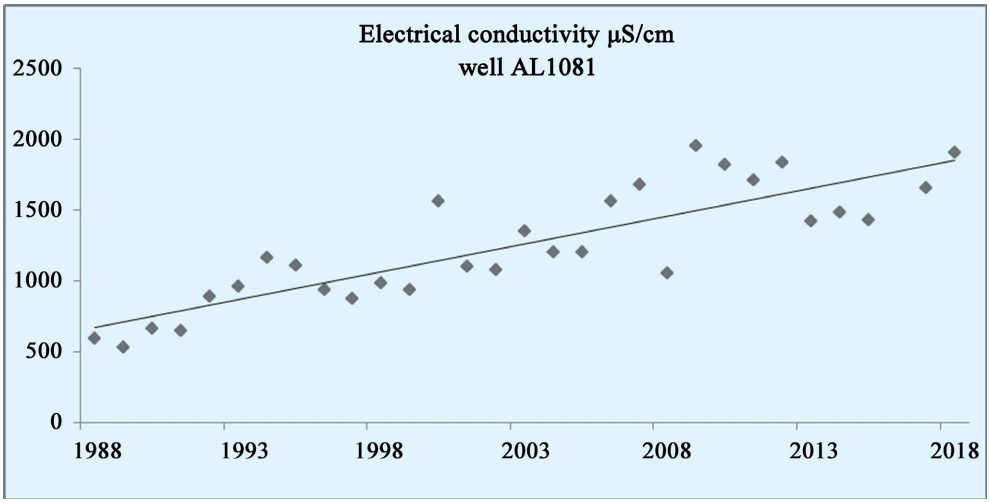

Figure 4. Drop in groundwater levels in two observation wells illustrating the strong declines in the groundwater levels in the different groundwater basins in Jordan and increasing salinity in two wells as a result of over extraction.

affecting all aquifers and groundwater basins in the country.

Many major projects have been implemented: Dams, weirs and ditches and excavations have been constructed to harvest water, irrigation canals were built, and domestic water supplies were extended to serve more than 95% of the inhabitants including the remote and sparsely populated areas and refugee camps (MWI, 2020) (**Figure 5**). Even in areas where the source of water lays tens of kilometers away from the settlement, water was brought to the inhabitants through pipe connections. Thirty two cities and towns accommodating the majority of Jordan's population are now served by sanitary sewage systems and waste water treatment facilities (around 68% of all households) (MWI, 2020) (**Figure 6**).

Industries are either supplied with water through the water supply networks, by allowing them to drill their own groundwater wells or by diverting water from existing dams.

In the Jordan Valley area, the King Abdullah Canal (KAC) was constructed along the eastern bank of the Jordan River. It extends for some 110 km and irrigates 170,000 dunums. Other irrigation projects were implemented in the southern area of the Dead Sea, putting around 46,000 dunums to use. In addition, the lands of the Jordan Valley lying above the reaches of the KAC were irrigated using the waters of the side wadis and some groundwater, bringing the total irrigated land in the Jordan Valley area to around 280,000 dunums (JVA, 2006).

Concerning domestic water supplies, expensive projects proved to be necessary in order to serve the population centers, which generally lay far away from potential water resources. For example, the capital city of Amman gets its domestic water from different sources extending 100 km to the east (Azraq), 55 km to the west (Jordan Valley area), 100 km to the southwest (Mujib Zarqa Ma'in), and 300 km to the south (Disi) with pumping heads of up to 1400 meters, that is

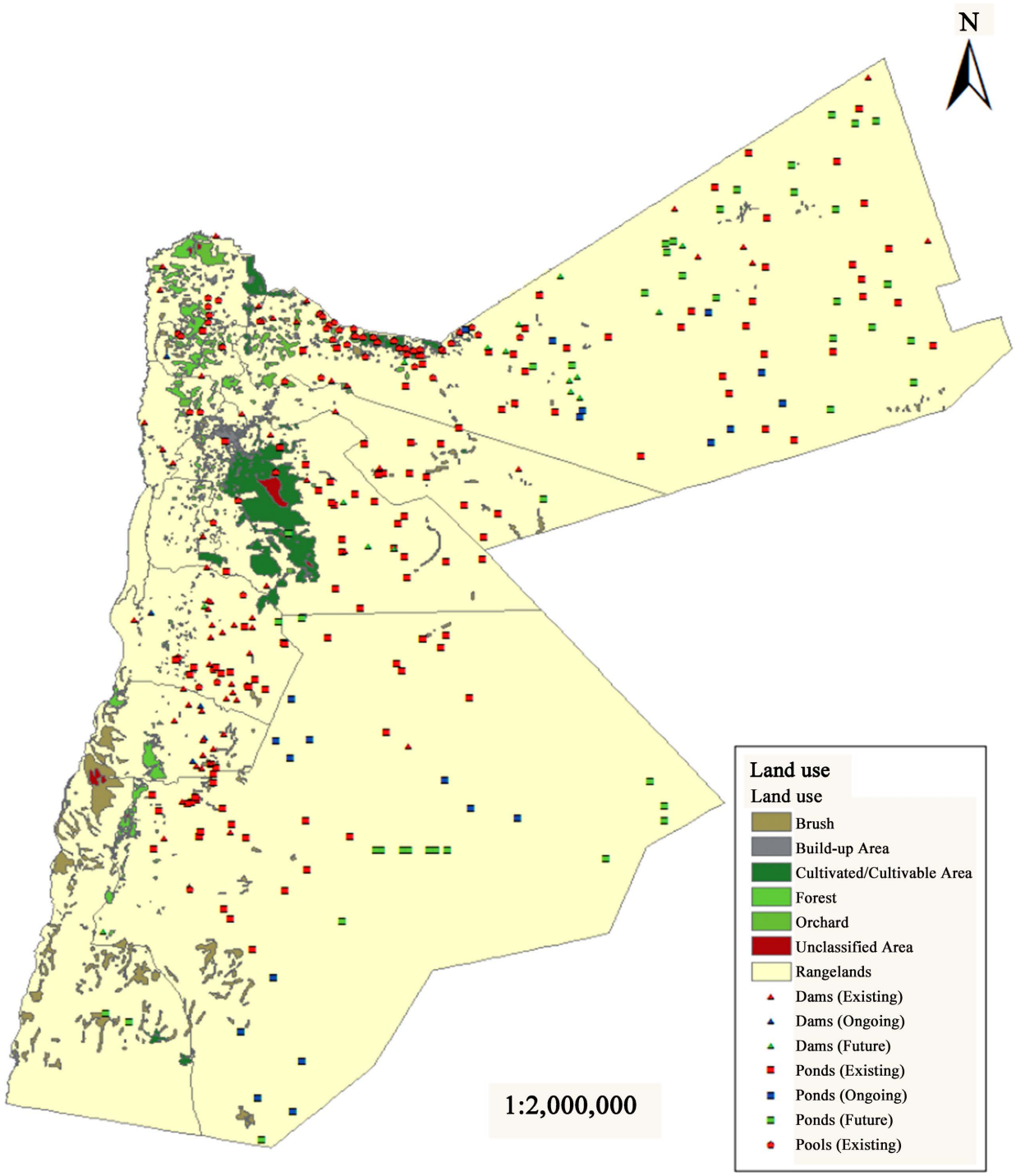

Figure 5. Water harvesting projects of dams, weirs, ponds, and pits with land use in Jordan (MWI, open files).

in addition to frictional losses. This is in fact for a non-oil-producing country a very expensive undertaking.

Water Security issues in Jordan were discussed in two papers published by the UNESCO (Salameh & Shteiwi, 2019; Abdallat & Za'arer, 2019). These two studies illustrate the achievements of Jordan to reach at a water secure sector and indicate the water security issues which still have to be addressed.

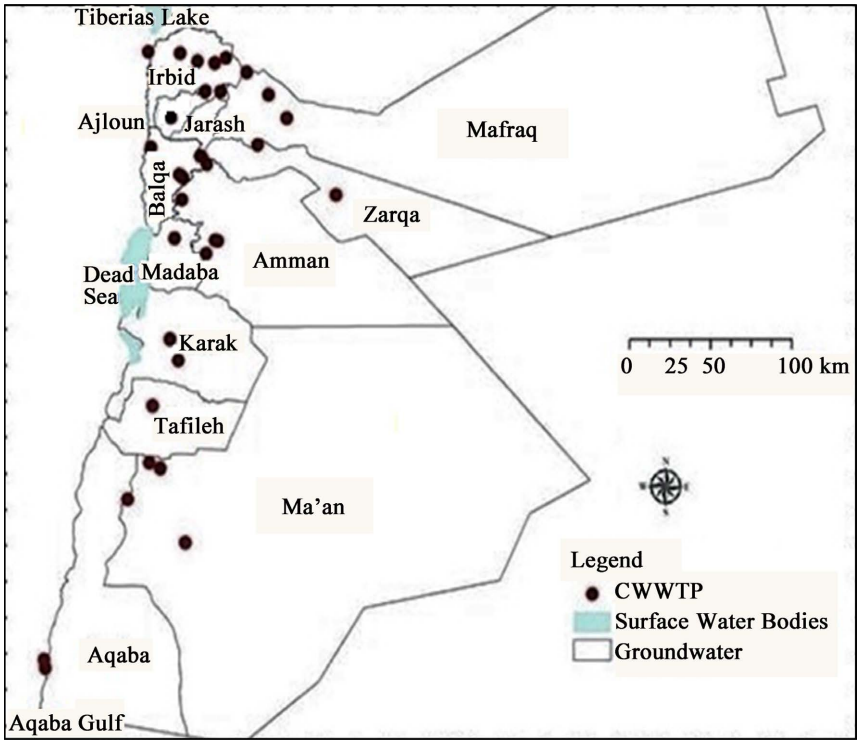

Figure 6. Distribution of the centralized wastewater treatment plants in Jordan (MWI, open files).

Considering the water sector situation in the country utmost care must be given to manage the sector in a satisfactory way and to program strategic projects in order to serve the society, the economics, and the political comfort.

Climate change is gradually affecting the country, especially in what concerns the quantity of precipitation over the country, which has been declining since decades. **Figure 7** shows the yearly precipitation amounts falling over Jordan, their long-term averages, and their 5-years moving average indicating around 12% decline in the average precipitation over the last 70 years.

In this article, the shortcomings in the water sector management are addressed and the way forward is delineated to reach a more robust and resilient water sector with all its positive impacts on the social, health, economic and political life in the country.

2. Methodology

In the current work and depending on the results of three previous studies: (Salameh & Shteiwi, 2019; Abdallat & Zaarir, 2019; Salameh & Raggad, 2021) the inadequately or the not addressed water security issues in Jordan are formulated and their governing actual situations are analyzed based on the available information in the publications, reports, and studies of the Ministry of Water and Irrigation and in articles published in scientific journals. After analyzing the current situation of the water sector, scientific suggestions are presented to deal with the outstanding water security issues in order to reach a

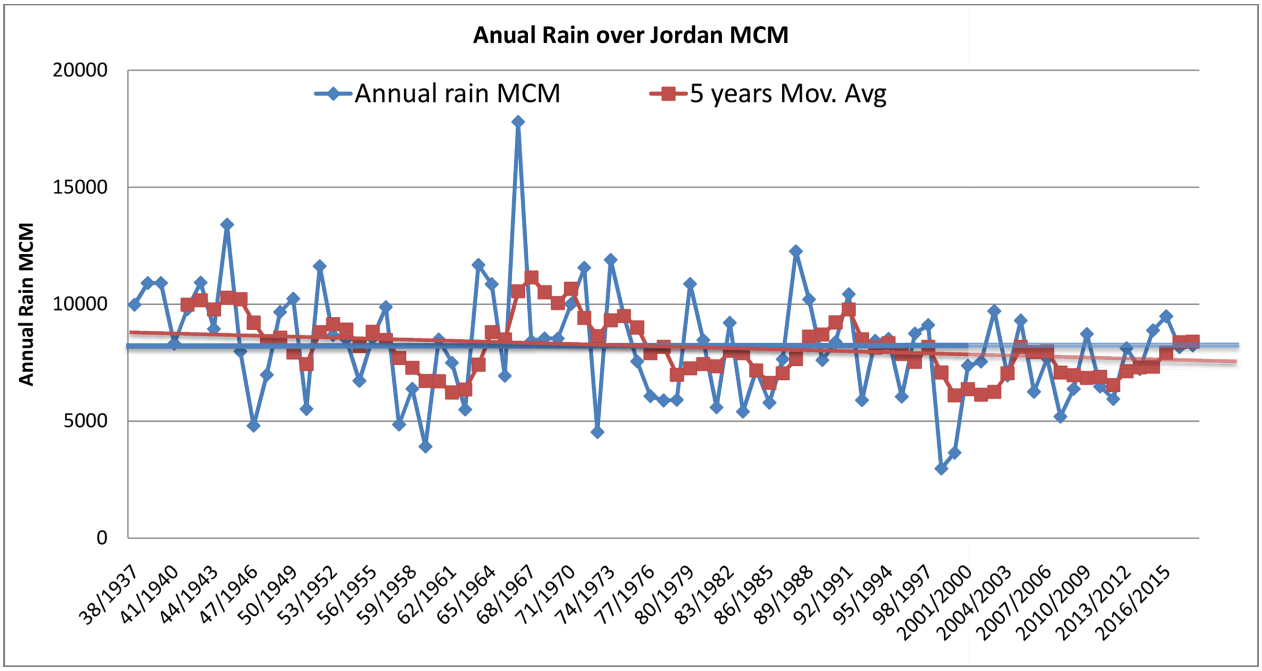

Figure 7. Annual precipitation amounts falling over Jordan, their long-term averages, and their 5-years moving average.

more robust and sustainable water sector.

3. Water Issues to Be Dealt with in an Adequate Way

1) Interrupted water pumping for household uses

Inhabitants of Jordan used, until the early 1980s to obtain household water by continuous pumping for 24 hours a day 365 days a year. Due to water shortages or better said to delays in new supply projects and hence the inability to keep the entire water supply network under pressure a new policy war introduced by the water agencies at that time and that is pumping water through the different network sections for a few days a week. Upon that inhabitants started to construct household water storage facilities in the form of house cistern or roof tanks to collect the pumped water for use when pumping is interrupted and until it is resumed. Water pumping durations to the different use areas was reduced gradually to reach, at present, 36 hours a week, and even 24 hours a week in some areas (MWI, 2017, open files) forcing herewith the inhabitants to increase their water storage capacities at homes to cover at least one week's water consumption needs.

The interrupted water pumping resulted in negative technical, planning administrative, social, economic and psychological impacts such as:

- Reluctance of the responsible water authorities to develop and allocate new water resources for household uses to return to continuous pumping.
- Gradual reduction of the weekly pumping hours to 36, which represents an indication on the failing of the water management in Jordan to develop new resources in time. That reflects also the failure of the local and foreign consultants in managing the water sector.

- Interrupted pumping has during the last four decades led to increasing damages in pipelines, pumps, water meters, etc.
- The pumped water leaking from the water supply networks estimated at about 15% of the pumped water (MWI, open files, 2017) becomes partly re-sucked into the network through the same leaking sites, when pumping stops and negative pressure develops in the network. The re-sucked water may carry with it pollutants from outside the network into it.
- Most Jordanians suffer psychologically from the consequences of interrupted pumping, especially when their stored water starts to empty and when waiting for new water pumping to resume. Also they stay worried about the sufficiency of the pumped water to fill their storage facilities for use in the coming week. In addition, Jordanians are alert not to leave or forget a water tap running by a mistake or to have in-house water leakage leading to emptying their storage facilities and leave them without water until pumping resumes or being forced to truck expensive water to their houses, which sometimes takes days without water.
- Water storage facilities at homes, whether roof tanks or cisterns are exposed to pollution which can affect human healthy negatively.
- Repair maintenance and renewal of water storage facilities are borne by the owner of these facilities.
- Water losses from house storage facilities are high due to corrosion, failing water floats and untighten fixings and that applies in more severe way to low altitude houses where water pressure in the supply network is highest.
- Interrupter water pumping and storage at homes is a very expensive undertaking borne by the population. The cost of a storage tank of 1 m^3 (the average water use in a weeks' time) is around 100 JD. In addition, for each employee, worker, student, people, soldier etc. institutions store an average of 0.5 m^3 of water in their facilities. Roof tanks and cisterns need pumps, fittings, installation, repair, maintenance and renewal every 10 years. The sums up to a minimal total cost per person every 10 years to 200 JDs and for all 11 million inhabitants in Jordan more than 2200 million JD equivalent to about $US 3.15 billion, to be renewed every 10 years (The average lifetime of storage facilities, devices, fittings maintenance and repair).

To sum up a Jordanians spend around US$ 30 each every year just to keep water running in their facilities, because of the adapted policy of the water authorities to resort to interrupted water pumping.

2) Over-exploitation of groundwater resources

Population growth and improving living standards, water demand in Jordan has substantially exceeded renewable resources. In addition, irrigation by groundwater extractions has intensified during the last few decades. This has led to over exploitation of the groundwater resulting in declines in the water levels of more than 1 m/yr in the major aquifers and to water quality degradations (MWI & BGR, 2019; MWI, 2016; Salameh, 2008). **Figure 4** illustrate the drop in

groundwater levels in observation wells in the majority of groundwater basins in Jordan.

Groundwater wells were drilled all over the country for drinking, irrigational and industrial uses and extractions gradually tapped the non-renewable groundwater found in surficial unconfined aquifers and the desert aquifer containing non-renewable groundwater which resulted in severe drops in their groundwater levels (Salameh et al., 2018).

In addition to depleting groundwater resources and degrading groundwater qualities over-exploitation has resulted in gradual decreases of important springs and ceasing of spring and seepage discharges in wadis and desert oasis (Azraq and Taba). Not to ignore here are the negative impacts on biodiversity and aquatic species (Alhejoj et al., 2014, 2017). According to Taimeh (2015), irrigated agriculture depending on the extraction of non-renewable groundwater in Jordan is of low-value and it can in no way cover the cost of replacing the extracted groundwater, which, in the case of Jordan, is only possible by sea water desalination at Aqaba and transferring it to the areas of groundwater depletion.

The easy policy followed by the water authorities to satisfy the increasing water demand by increasing pumping of non-renewable groundwater has its limits which are depletion and quality deterioration as can be illustrated on the examples of Jafr, Dhuleil, Azraq and other groundwater basins and is threatening all groundwater basins in the country.

The Ministry of Water and irrigation has applied some policies and programs to conserve the groundwater stocks from depletion and deterioration (Salameh et al., 2018), but that has not been applied to the Ministry's increasing extractions from the depleting aquifers and therefore, overexploitation rates increased with the result that by now all groundwater aquifers and basins are by now threatened by the ultimate fate of depletion and salinization.

Immediate implementation of rescue programs is now required and that can only be done by developing ultimate sources (Only possible by desalination of sea water) in order to relieve the overexploited groundwater resources.

3) Water use efficiency in agriculture

Agriculture water use efficiency is a major rewarding field for research, development and implementation, because it saves water, improve production quantitatively and qualitatively and offers more job opportunities for trained people.

At present, the planning and development of agricultural projects suffer of leaky water conveyance systems and outdated irrigation practices (Taimeh, 2015; Cherfane & Kim, 2012).

Advancement in the irrigation water use sector is positively changing the lifestyles of people and societies and adding security to the social, economic and political comfort of countries, especially in the arid and semi-arid areas of the Globe (Salameh & Al-Ansari, 2021; Al-Ansari, 1998).

In some areas in Jordan outdated tradition farming systems are still in use consuming high amounts of water for modest agricultural production in quan-

tity and quality. In some other areas more advanced agricultural practices are in use and in other areas advanced techniques are applied but the latter is found in limited agricultural areas.

The use of pressurized water conduits, drip and other more efficient irrigation systems and advanced agricultural practices results in saving appreciable amounts of most needed water (FAO, 2018; WB, 2017). Governmental advanced farming management is highly required to advocate the use of smooth metering, regular irrigation, control systems, soil moisture devices, cameras, tele-measurements, leakage detection and monitoring. That is expected to result in more efficient water use, saving water, increasing agricultural productivity of a water unit, improving product quality, bringing higher returns to farmers and improve export potentials, improve food security, guarantee more secure jobs, and higher personal qualifications' requirements to operate advanced systems (WB, 2017; FAO, 2018).

The Middle East area is gradually facing droughts, soil physical deterioration and salinization, groundwater depletion and quality degradation in addition to shortages in water supplies (FAO, 2018; WB, 2017). This is not expected to leave the inefficient water use practices to survive for long. Optimization of water use by raising its use efficiency requires changing the way water is delivered to farms and the way it is applied in irrigation. The faster the introduction of advanced devices, practices, and management in the irrigation sector, the more the farming sector will be secure, jobs guaranteed, food production continues, lower unemployment rates leading to social and economic comfort and to political stability.

Not developing the practices and management of the irrigated sector in a proper and fast way to save water and increase agricultural production jeopardize the rights of other people willing to make use of the saved water.

Advanced water use and management in irrigation can save 30% - 50% of the presently used quantities of water and it will lead to quantitatively and qualitatively improved agricultural production.

4) Illegal water uses

According to the Ministry of Water and Irrigation reports, water losses from the supply networks make around 47% of the pumped water. Of that around 15% are considered physical losses and the rest of around 31% are illegally used or stolen water from the supply networks (MWI, open files, 2017).

The illegally tapped water is used in farming or sold for household and industrial uses. In addition, many illegal wells have been drilled in Jordan for their water use in irrigation or to be sold for household or industrial uses.

But being illegally obtained free (at no cost), the water use in farming is unnecessary luxurious.

Controlling all illegally used water will not increase the available amounts of water in any major way because that water, although illegally tapped, is being used.

But that does not mean to let water illegal tapping continue because of two negative consequences:

- This is none revenue water for the Ministry of Water and Irrigation, because its extraction, chlorination or purification and pumping costs are borne by the Ministry without any returns. Stopping illegal tapping of water will improve the financial situation of the Ministry of Water and Irrigation, which will allow it to develop new resources and improve its services.
- The illegally tapped water used in irrigation is of drinking water quality and is allocated for that purpose. Irrigated agriculture can also survive by using lower water qualities. Therefore, saving the illegally tapped drinking water means allocating better quality water for drinking and saving the purification cost of water of impaired quality to become suitable for drinking purposes.

Therefore, very strict measures and punishments must be applied to put an end to all illegal water tapping, irrespective of whom is tapping that water.

5) Per capita water use

The per capita household water use averaged around 80 l/c/d until before the start of the refuge wave coming from Syria to Jordan. Since then, and although major water supply projects were implemented such as Disi to north Jordan (100 MCM/yr), the per capita water use has gradually declined to reach around 73 l/c/d mostly as result of the modest water uses of the refugees (ESC, 2020).

Considering the living standard in Jordan where each household has one or more toilets, a kitchen, dish washers, washing machine, daily showering, car washing, and small garden in most houses, even 80 l/c.d. can be considered not sufficient for a hygiene life. It is estimated that around 100 l/c.d. are needed at present for a hygiene life, taking into consideration the improved living standards and the semi-arid nature of the country. In the neighboring countries such as Syria, Iraq and Egypt for example household water uses amount to 120 - 140 l/c.d.

Therefore, water planning has to aim at increasing the net per capita household water supply to 100 l/c.d. Without that, the hygiene situation of the inhabitants is expected to deteriorate.

6) Water Desalination

Recent breakthroughs in sea water desalination by developing membrane technology have since the beginning of the current Century reduced desalination cost to less than $US 0.60/cubic meter of desalinated water (Haaretz, 2014; Black & Veatch Ltd., 2010; Water Technology, 2011) making desalination affordable for a wide spectrum of societies and uses and solved the problem of its affordability only by rich societies.

Desalination of adequate amounts of sea water is the only way to solve Jordan's water scarcity and avoid water supply crises. The low cost of desalination will lead to a more secure water supply situation. Desalination, in addition, is the way to reduced groundwater extraction and toavoid exhaustion and depletion of aquifers in the country. Other benefits of desalination are: Alleviation of potential conflicts over water resources with Jordan's neighboring countries sharing

the same water resource, which are prone to develop to armed conflict when triggered by an issue, social comfort resulting from more secure water supply, additional food production by using the resulting waste water in irrigation after proper treatment, increasing employment and alleviation of disputes among the different sectors of water users.

7) Water management

Water and sanitation are regulated by the Ministry of Water and Irrigation By-Law No. 14 of 2014 (MWI, 2014), the Water Authority of Jordan Law No. 18 of 1988 (MWI, 1988), and its amendments and the Jordan Valley Authority By-Law No. 30 of 2001 (MWI, 2001). Other relevant laws include the Public Health Law No. 47 of 2008 (MoH, 2008), the Environmental Protection Law No. 85 of 2006 (MoE, 2006), and the Groundwater By-law No. 85 of 2002 (MWI, 2002) and its amendments.

Article 25 of the "Water Authority Law of 1988 No.13" states: All water resources available within the boundaries of the Kingdom, whether they are surface or ground waters, regional waters, rivers or internal seas are considered State owned property and shall not be used or transferred except in compliance with this Law.

This article establishes the sovereignty of the state over all the resources in the country and emphasizes that no party is allowed to use them without the official agreement of the ministry. This can be interpreted as a water security issue, granting the ministry the right to dynamically manage the resources according to social economic and political developments.

The laws and by-laws transfer the full authority of the country's water resources to the Ministry of Water and Irrigation and give the mandate to this ministry to set up the water policy for the country; a mandate which guarantees the solemn right of the ministry to allocating the country's water resources.

The water management in Jordan is a progressive management using advanced technologies in resources development, water supply for household, industrial, and agricultural uses, quality control and all other related issues.

But, during the last decades this management has shown some weaknesses in the structure of the Ministry of Water and Irrigation which are leading to conflicts of interest concerning the overexploitation of the groundwater resources and the almost absolute control over product quality and quantity by independent authorities.

Conflict of interest in developing the water resources

The increasing demand on water for all use sectors has led the Ministry of Water and Irrigation, in the last 3 decades to develop all water resources of the country. But, due to deficient planning to develop new sustainable resources, the ministry resorted to exploiting the unsustainable none-renewable groundwater resources, which has led to exhaustion of some groundwater bodies such as Jafr and Dhuleil and is, at present, threatening almost all other groundwater bodies and basins in the country. The conflict of interest here is that the ministry has the mandate to develop all water resources of the country, irrespective of the

impacts of that development on the continuity of these resources' yields and future generations' rights in them (MWI, 2016, 2002, 1988). There is a conflict between state ownership of the water resources and the damaging impacts of their exploitation with lacking control and without proper consideration to the damaging percussions on the countries natural resources.

This leads to the conclusion that the control over the ownership of water resources and their wise management for sustainability purposes should not be in the hands of the same organization that has to satisfy the demand by easily depleting the country's resources.

The right place for such mandate was the Natural Resources Authority, which has before a few years become part of the Ministry of Energy and Natural Resources, and as a part of the government not independent enough to be commissioned with the task of controlling, sustaining, and conserving the water resources of the country.

Control over product quality and quantity

The Ministry of Water and Irrigation has during the last decades established highly sophisticated laboratories for water and waste water physical, chemical and biological analyses. The ministry has also set and is rigorously implementing quality control programs for all water sources, for water and waste water treatment and suitability for the intended use purpose, and carrying out quality control programs for all water storage reservoirs and distribution systems under the ownership of the ministry. These programs are rigorous and satisfactory as self-control on the ministry's products.

The problem here is that no other independent sophisticated laboratories in the country are there with the mandate to control the water produced and distributed by the same ministry. The Ministries of Health and Environment have mandates to control the health and environmental situation in the country (MoE, 2006, 2008), but: 1) They are part of the government and not independent of it; 2) Their laboratories are not that sophisticated. Therefore, an, from the government independent agency has to be created in Jordan to control the products not only of the Ministry of Water and Irrigation, but also of other ministries to resemble the Environmental Protection Agency EPA of the United States.

4. Summary of Discussed Issues

The above discussed issues illustrate that Jordan has not yet reached a secure state in what concerns its water sector and that there are still very essential water security issues which have not yet been addressed or adequately addressed. The reluctance in dealing with these still outstanding, very critical security issues, such as the very low per capita household water use (73 l/c.d), the interrupted household water pumping (36 hrs/week)are expected to reflect negatively on the population with all these issues health and living standard implications. They will also have their negative impacts on the agricultural and industrial sectors with all possible percussions reflected in declining food production, increasing

unemployment, and poverty. Such negative impacts on the society and its economic base can be damaging for a developing country with a weak economy. Improving water use efficiency in the agricultural sector, increasing the availability of water only possible by desalinating sea water and changing the way the water sector is managed are key issues in reaching a more secure water sector.

5. Conclusion

Although Jordan has, during the last few decades, managed its scarce water resources to a satisfactory degree considering the crises type of management the country has been obliged to follow during the last 7 decades as a result of regional conflicts and refugee waves, some water security issues have not been satisfactorily addressed. This crisis management has reflected badly on the water sector; especially in the issue of developing appreciable quantities of additional water to satisfy the needs of the country. In addition, the lack of deep future insight of some water policy-makers has led to deteriorations in the water resources quantities and qualities, which have, during the last two decades led to social and economic discomfort of the population.

The major issues to reach a more secure water sector, such as: Interrupted water pumping for household uses, over-exploitation of groundwater resources, water use efficiency in agriculture, per capita water use, conflict of interest within the one water institution in developing the water resources, and the other conflict of interest in controlling products' quality and quantity have been discussed in this article and the way forward indicated. The major conclusion is that Jordan has to immediately start desalinating adequate amounts of seawater in Aqaba that will solve water shortages, alleviate overexploitation of aquifers, and increase per capita use to suit the living standards in Jordan. Some legal issues have also to be addressed to end the conflicts of interest prevailing in the sector expressed in the exclusive authority of the Ministry of Water and Irrigation to develop, treat, distribute, control the quality, and collect the fees of the water. This exclusive authority has to be redistributed and attached to different entities to solve that conflict of interest.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Abdallat, G., & Za'arir, R. (2019). *Security of Water Infrastructures against Sabotage and Damage in Jordan*. Water Security and the Sustainable Development Goals Publisher: UNESCO.

Al-Ansari, N. (1998). Water Resources in the Arab Countries: Problems and Possible Solutions. In *UNESCO International Conference on World Water Resources at the Beginning of the 21st Century* (pp. 3-6). UNESCO Publications.

Alhejoj, I., Bandel, K., & Salameh, E. (2014). *Macro-Faunal and Floral Species in Jordan*

and Their Use as Environmental Bio-Indicators (p. 259). University of Jordan Press.

Alhejoj, I., Bandel, K., & Salameh, E. (2017). Aquatic Mollusks: Occurrences, Identification and Their Use as Bioindicators of Environmental Conditions (Salinity, Trace Elements and Pollution Parameters) in Jordan. In O. Abdalla et al. (Eds.), *Water Resources in Arid Areas: The Way Forward* (pp. 295-318). Springer. https://doi.org/10.1007/978-3-319-51856-5_17

Black & Veatch Ltd. (2010). *The Wayback Machine (Press Release)*. Via edie.net.

Cherfane, C. C., & Kim, S. E. (2012). Chap. 33. Arab Region and Western Asia, UNESCWA. In *Managing Water under Uncertainty and Risk: UN World Water Development Report 4* (pp. 705-742). UNESCO.

DoM: Department of Meteorology. Weather Data, Open Files. https://www.meteoblue.com/en/weather/archive/export/amman_jordan_250441

ESC: Economic and Social Council of Jordan (2020). *Jordan Country Report, Water Sector*. http://www.esc.jo/documents/report-2020/5.pdf

FAO (2018). *Iraq, Restoration of Agriculture and Water Systems Sub-Programme 2018-2020* (110 p.). http://www.fao.org

Haaretz (2014, January 24). *Over and Drought: Why the End of Israel's Water Shortage Is a Secret*?

JVA: Jordan Valley Authority (2006). *(Yousef HasanAyadi) Policy and Adaptation in the Jordan Valley*. https://lib.icimod.org/record/12348/files/559.pdf

Lloyd, J. W. (1969). *The Hydrogeology of the Southern Desert of Jordan* (120 p.). UNDP/FAO Publ. Tech. Rep. 1. Spec. Fund 212. https://www.academia.edu/21194192/The_hydrogeology_and_groundwater_resources_development_of_the_Cambro

MoE: Ministry of Environment (2006). *The Environmental Protection Law No. 85*. https://www.google.com/search?q=MoE+(2006).Ministry+of+Environment.+Jordan+The+Environmental+Protection+Law+No.+85.&oq=MoE+(2006).Ministry+of+Environment.+Jordan+The+Environmental+Protection+Law+No.+85.&aqs=chrome..69i57.22928j0j4&sourceid=chrome&ie=UTF-8

MoH: Ministry of Health (2008). *Public Health, Law No. 47*. http://www.ilo.org/dyn/natlex/natlex4.detail?p_lang=en&p_isn=108106&p_country=JOR&p_classification=15

MWI & BGR: Ministry of Water and Irrigation & Federal Institute for Geosciences and Natural Resources, Amman (2019). *Groundwater Resource Assessment of Jordan 2017*. https://www.bgr.bund.de/EN/Themen/Wasser/Produkte/produkte_node_en.html

MWI: Ministry of Water and Irrigation & Jordan Valley Authority (2001). *By-Law No. 30 of 2001*.

MWI: Ministry of Water and Irrigation & Water Authority of Jordan (1988). *Law No. 18 of 1988 and Its Amendments*. http://gis.nacse.org/rewab/taggedDocs/Water_Authority_Law_18_of_1988_T.pdf

MWI: Ministry of Water and Irrigation (2002). *Groundwater By-Law No. 85 of 2002 and Its Amendments*. http://gis.nacse.org/rewab/docs/Underground_Water_Control_By-Law_85_of_2002.pdf

MWI: Ministry of Water and Irrigation (2014). *By-Law No. 14*. http://extwprlegs1.fao.org/docs/pdf/jor159136.pdf

MWI: Ministry of Water and Irrigation (2016). *Groundwater Sustainability Policy*. http://extwprlegs1.fao.org/docs/pdf/jor159136.pdf

MWI: Ministry of Water and Irrigation (2017). *Jordan Water Sector Facts and Figures*

2017. https://jordankmportal.com/resources/jordan-water-sector-facts-and-figures-1

MWI: Ministry of Water and Irrigation (2020). *Vulnerable Water Resources in Jordan, Hot Spots*.

MWI: Ministry of Water and Irrigation, Jordan, Open Files. http://waterjo.mwi.gov.jo/En/Pages/Home.aspx

NWMP (1977 and Updates). *National Water Master Plan (2005) Volume 5: Groundwater Resources*. Ministry of Water and Irrigation, MWI & Gesellschaft für Technische Zusammenarbeit GmbH, GIZ.

Salameh, E. (2008). Over-Exploitation of Groundwater Resources and Their Environmental and Socio-Economic Implications: The Case of Jordan. *Water International, 33,* 55-68. https://doi.org/10.1080/02508060801927663

Salameh, E. M., & Shteiwi, M. (2019). Water Security in Jordan. In *Water Security and the Sustainable Development Goals* (pp. 19-31). UNESCO.

Salameh, E., & Al-Ansari, N. (2021). Deficient Developmental Planning Leading to Water Conflicts across Political Borders: The Way Forward. *Engineering, 13,* 158-172. https://doi.org/10.4236/eng.2021.133012

Salameh, E., & Raggad, M. (2021). What Ought to Be Done to Increase the Future Water Security as a Fundamental Base for Social, Economic and Political Stability—The Case of Jordan. *Journal of Water Resources and Protection*. (in press) https://www.scirp.org/journal/jwarp

Salameh, E., Shteiwi, M., & Al-Raggad, M. (2018). *Water Resources of Jordan—Political, Social and Economic Implications of Scarce Water Resources (World Water Resources Book 1)*. Springer Publishing Co. https://doi.org/10.1007/978-3-319-77748-1

Taimeh, A. Y. (2015). *Food Security in Jordan*. The University of Jordan Press.

Water Technology (2011). *Perth Seawater Desalination Plant, Seawater Reverse Osmosis (SWRO), Kwinana*.

WB: World Bank (2017). *Iraq Country Water Resource Assistance Strategy, Addressing Major Threats to People's Livelihoods*. World Bank, No. 36297.