

IRRIGATION WATER MANAGEMENT IN SEMI-ARID REGIONS- CASE STUDY JORDAN

MOHD. S. MAHAFDAH

Climate Change, Sustainable Agriculture and Food Security (CCSAFS), Faculty of Agriculture, Jerash University, Jerash, Jordan.

Abstract

Water resource management and planning is challenging in the last decade. However, reform in water management can make important contributions to minimize and reduce water scarcity. The agricultural sector uses a major share of the available water resources globally. Irrigation water management is an important mean for food security in semi-arid-arid region. This paper review the research work done concerning irrigation water management in Semi-arid region-Jordan. There is yet study to critically review the irrigation water management, in semi-arid-arid region. A wide range of the reviewed research works did not considered the geopolitical condition of Jordan as one of the main cause of water shortage problem. The current review study could pave the road for researchers to cover all the weakness point illustrated in this study. While more effort should be done to investigate and address the irrigation water management in Jordan.

Keyword: Water Management, Irrigation Water, Jordan, Semi-Arid.

INTRODUCTION

Water resource management and planning is challenging in the last decade ((Pluchinotta et al, 2018). Due to rapid population growth, urbanization, conflicting demand by various stakeholders and land degradation (Abu-Allaban et al., 2015).However, reform in water management can make important contributions to minimize and reduce water scarcity(Rao et al., 2020).Where, water supply increases due to climate variability(Gebretsadik and Romstad,2020).Hence climatic pattern is one of the core universal environmental challenges facing all sectors(Fahad et al., 2020)climate change is a major concern for semi-arid-arid region (MDJ, 2020).

Decline in water availability due to rising temperature and growing demand present significant environmental threat to agriculture(Gebretsadik and Romstad, 2020, Fahad et al., 2020, Bobojonov et al., 2016).Likewise, Management of limited and shared water resources is a complex challenge(Pluchinotta et al, 2018). The agricultural sector uses a major share of the available water resources globally. Hence, 67% of total groundwater is consumed by agriculture sector (Sutecdiffé et al., 2021). Moreover, the irrigation requirements reached about 67% of the total water consumption in 2018 (MWI, 2019). Reform in irrigation management can make important contributions to reduction in irrigation water scarcity (Rao et al., 2020).

Irrigation water management is an important mean for food security in semi-arid-arid region (Kidane et al., 2019). Jordan consider as one of the most water stressed region globally. Due to climate change, massive influx of refugees from neighboring countries, population's growth and limited water resources (MWI, 2020). Where, the average precipitation over 80% of the country is less than 100mm/year. The gap between supply and demand is increasingly lead to

more environmental challenges. The annual per capita available water is decline up to less than 90mm³ per year in 2020(MWI,2021). Water management in Jordan started as early as 1952. Water resources management has become an increasingly urgent issue (Fahad et al., 2020). Challenges facing water resources management and planning in Jordan with different managements options (Al-Rawashdeh and Shboul, 2016, Orude 2015, Al-Omari et al., 2014, Hadadine et al., 2010, Abu-Qadis and Batayneh, 2002, Jaber et al., 2001, Jaber et al 1977, Al—kloub et al., 1997). As it often introducing conflict among users and uses ((Pluchinotta et al, 2018).

The ways, to use the existing water resources, more efficiently rising awareness about the importance, of water conservations and promote the policies (Hadoush, 2020). Which lead to sustainable management in Jordan So as to increase productivity (Carr et al., 2014, Al-Zubi, 2007). Irrigation development started in Jordan as early as 1940. Where, hydraulic and control structure had been established along Jordan valley beds and major springs (Al-Zubi, 2007).The irrigated area in Jordan is about 40, 00 ha (MWA, 2019).

This paper review the research work done concerning irrigation water management in Semi-arid region. First, Irrigation water in Jordan, secondly, Climate change and irrigation water in Jordan. Thirdly, water scarcity and crises in Jordan. Fourthly, wastewaters, brackish water& grey water used for irrigation purposes. Fifthly, Water users Associations (WUAs). At the last Ground water and Irrigation, water pricing. Hence, there is yet study to critically review the irrigation water management, in semi-arid-arid region. Specially Jordan as a case study. Moreover, there are a little study reviewing the literature discussing the irrigation water management to pave the road for future research in semi-arid-arid region.

1. Irrigation Water In Jordan

Freihat et al., 2020, Al-Omari et al., 2015, Mustafa et al., 2015, Ammari et al., 2013, Abu-Awwad, 2001. Illustrated the farmer's, roles and their participations, in irrigation water management. They concluded that the irrigated agriculture in Jordan is potentially threatened by progressively increasing soil salinity. Where, some emerging technologies and methodologies need to be adopted to improve irrigation water management efforts. Nevertheless, the authors did not discuss the irrigation water in the southern part of Jordan. Moreover, the illustrated studies did not address the crucial role of farmers associations in improving water allocation in Jordan. The roles of water in increasing agricultural productivity were not well elaborated.

Al-Omari et al., 2015, investigated the irrigation water management in Jordan; the study illustrated the possible adaptation options for the deficit in the irrigation demand. They implemented the water evaluation and planning system. The study concluded that the Red-Dead Sea –Canal mega project would reduce the deficit in the irrigation water demand. Where, the limitations of the used model were not addressed. The geopolitical condition factor not well addressed as well.

The effect of irrigation water, in arid soil in Jordan, was addressed by Al-Zubi, 2007. The study investigated the effect of irrigation quality on soil profile. The author insisted that there is a crucial role of water to increase the agricultural productions in Jordan, however, the major challenges facing water sector were the over consumption of water for many purposes. The author discussed the detritions of irrigation water during the last decade. In contrary, the author did not investigate the southern part of Dead Sea area soil profile. Likewise, the effect of the soil salinity, in that important part in Jordan.

2. Climate Change And Irrigation Water In Jordan

Wang et al., 2016, Hammouri et al., 2015, Shamir et al., 2015 and Al-Bakri et al., 2010. Addressed the climatic variability and change impact on different environmental aspect specially water resources. Where, they used different hydrological models to evaluate different strategies and adaptation to climate change, they concluded that the water resources management become more complicated due to climate change. The researchers did not mentions in their study the limitation of the models they used in their studies. Though, the did not elaborate the different climatic scenarios in different parts in Jordan. Where, the climatic data used in their studies considered short term data. To addressed climate change impact in irrigation water in semi-arid regions.

Hammouri et al., 2015. They used statistical software (JMP) and quantitative ratio- level approach to analyze the available water resources. And existing demand to assess the current and future water demands, along with available adaptation options. They concluded that public awareness and training progress have a crucial role in water planning and management process. Never the less, the public awareness of climate change was not well addressed. Their study did not explore the significant role of water users, education level in irrigation water management process,

Bakri et al., 2010. The climate change impact in rain- fed agriculture in Jordan. They used crop simulation model (DSSAT). They concluded that under rain-fed condition water was the limiting growth factor. Likewise, soil water conservation is one of the important adaptation measure to climate variability and climate change. They used 27 year climatic data which according to many researchers not sufficient to addressed the climate change. Where, the model used limitations was not illustrated.

Orud, 2015, addressed the water budget of the Dead Sea region. The study concluded that the substantial sediment yield has a serious adverse consequence on the dams constructed over the area and the quality of water. Nevertheless, the study did not illustrate the trend analysis of side stream wadis flow. Although, the research study did not explore the hydrographs, of the eastern and western side of the Dead Sea areas. Where, the extreme, events in the study areas was not elaborated.

3. Conventional & Non-Conventional Water Resources Management In Jordan.

Al-Rawashdeh and Al-Shboual, 2016, examine the status of water resources volition from socio-economic and political perspectives. They concluded that the country in Middle East needs a regional program on water economic. Their study emphasized in the importance of improving the integration of socio-economic and political aspects of water efficiency and uses. Never the less, the information is addressed are deficit of updated information's with weak elaboration. Although, the research study did not considered the climate change issue while examine the water status. Moreover, the authors did not elaborate the cooperation between water users and governmental bodies.

The gaps between the demand and supply in Jordan in relation to the impact of the proposed Red-Sea- Dead Sea Canal project were addressed by Al- Omari et al., 2014. The study used the water evaluation and planning model. They concluded that the gap between demand and supply would increase in the coming year without implementing the RDC mega project. They do not illustrate the limitation of the model and the impact of aquifer recharge in the canal. Although, the negative impact of the mega project were not mentions.

The efficiency of water harvesting technique efficiencies in Jordan were examine by Abu-Zreig et al., 2011. A field experiment for evaluation was conducted. They concluded that there is a crucial role of ditch technique in reducing runoff and segment loss. Where, the infiltration and soil moisture increased, Never the less, the climatic data used for evaluation was for 10 years which considered short data. (Sixt et al., 2018). Moreover, the socioeconomic aspect regarding water harvesting was not addressed. The different water harvesting technique efficiencies were not well elaborated.

The desalination project and its impact on the environment were illustrated by Abu-Qdais, 2008. The author addressed the negative and positive impact of implementation of the Red – Dead Sea Canal (RDC). The concluded that the brine rejection well be the main adverse environmental problem, the study did not address the environmental impact related to the construction and operation of such mega project. Where, the socioeconomic impacts were not elaborated.

The gaps between the supply and demand in Jordan were examined by Abu-Qdais and Batayneh, 2015; the researchers explore the detritions options. Where, population growth and water demand scenarios were the base of evaluation. The study concluded that desalination option is visible option in Jordan. Hence it can bridge the gap between demand and supply. The study did not consider the quality of surface water abstraction and the brackish water treatment were not addressed. Likewise, the stress in water resources, caused by the influx of refugees, from neighboring country were not addressed. The link between climate change and water demand and supply were not elaborated.

Jaber et al., 2001, describe the development of a decision support system for non-conventional water resources in Jordan. The study used the Hierarchy process in their study. The research work concluded that the water desalination option were the best options, for the water management. However, the authors did not agree with many researchers who believe in the

invisibility of the desalination options except near to the Red Sea.-Jordan. The socioeconomic aspect of the desalination option was not addressed.

4. Water Scarcity and Crises in Jordan

The water scarcity makes the management effort very complex from environmental, socio-economic and political perspective. Aquifer and basin are the primary source of water. Lack of natural water resources are the main reason behind the severe water crisis and shortage in Jordan. (Hussein, 2018, Koch et al., 2018 Luck et al., 2019).

Jaber et al., 1997, addressed the water scarcity issue in Jordan. The study discussed the issue related to the gap between the demand and supply. The study concluded that the water scarcity is fundamental constraints for future growth and development in Jordan. They recommended a long-term plan to minimize the water crisis. The study failed to elaborate the role of water governance issue considering the geopolitical condition in Jordan. Likewise, the study did not considered the over pumping of water as a major issue causing a future water crisis.

Al-Omari et al., 2007. In their research work insisted that water scarcity in Jordan is due to climate change and variability. The study illustrated the role of water management and it's significant, to the sustainability of all sectors. specially the socio-economic development in Jordan. The study investigated the impact of climate change, in water demand. Due to the rapid increase in evapotranspiration. That could have severe consequence on the socio economic development. The study did not elaborate the different climatic scenarios. In which the impact of climate change could be reduced or minimize. The study failed to elaborate the role of stakeholders, in Jordan in water management practices.

Hadadin et al., 2009. Investigated the long-term, water crisis faced by Jordan. Due to limiting water resources and climate change, caused by natural and human factor. The study addressed the water crisis problem and solutions. The study concluded that the expansion of population and the economic growth affected both the quality and quantity of water resources. The study did not address the climatic and socioeconomic factor as the main cause of the crisis. The study failed to elaborate the crucial role of economic development in increasing the water demand in Jordan.

The primary evolution of water shortage problem, were illustrated by Hadadin et al., 2010.the study discussed the essential elements of sustainable water solutions. The study presented specific recommendations, addressing water resources shortage in Jordan. Never the less, solutions related to the socioeconomic factor did not elaborate. The geopolitical conditions of Jordan did not addressed as one of the main cause of water shortage problem.

Abu-Allaban et al., 2015, conducted a research work to assess the water scarcity impact of climate change in Jordan. To assess the possible impacts of climate change, in water basins in Jordan. Incremental scenarios of climate change had been deployed. The study concluded that there will be a reduction in annual precipitation and surface runoff. Nevertheless, only dry and wet scenarios were used. The limitations of the study were not elaborated.

5. Wastewater, Brackish Water & Grey Water

The reuse of wastewater in Jordan was addressed by Ammary, 2005. Where, the application and issue related to wastewater reuse were discussed. The study concluded that new reuse application could be explore by good quality effluent. However, the impact of introducing pollutant into groundwater basins which can be altered the soil and groundwater properties not well addressed. The perception of water users was not elaborate. Likewise, the study did not discussed the wastewater reuse regulation in Jordan Carr et al., 2011 explore and investigated the farmers' perception of water reuse for irrigation in Jordan. The study concluded that the importance of the water reuse. Farmers' actual and perceived capacity to control water quality and ability to manage the negative aspect are influence the farmers' perceptions. Nevertheless, the research work did not explore the significant of education level and training program. To influence, the farmers perceptions regarding wastewater reuses. (Al Nakshabandi et al., 1997, Shahn, 2004, Al-Omari et al., 2009, Al-Omari et al., 2013, , Al-Omari et al., 2019, Shigei et al., 2020). Investigate some environmental problems, that link with treated water. That used for irrigation purposes in Jordan. The studies concluded that a risk of organic substances .contamination of edible plant. Organic substances may affect the quality of resources, the use of wastewater in agriculture in Jordan. The wastewater reuse could be a significant solution to reduce irrigation water demand in Jordan. Nevertheless, the studies did not elaborate the irrigation water user's perception on wastewater reuse. Several brackish water resources were identified in various part of Jordan by A l-Haddi,1999, Al-Hamaiedeh and Bino, 2010, Assyed et al., 2015, Al-Naber and Molle, 2017. The studies concluded that the lack of guideline standard and guideline regarding the possible uses and method of using brackish water. Grey water reuse reduces demand up to 30%, in irrigation water up to 50%. Irrigated with grey water did not show an adverse effect in plant productions. Nevertheless, the brackish and grey water reuse regulations in Jordan were not illustrated. The infrastructure and technologies implemented were not discussed. The perceptions of water users regarding brackish and grey water were not well elaborated.

Shatanawi and Fayyad, 1996, Halalsheh et al., 2008, Hillel et al., 2015, Saiden, 2020. Investigate the water reclamations and reuses in Jordan. The studies concluded that Monitoring of water reuse is required for understand the water quality status. Majority of industrial wastewater came from chemical, agricultural and food industries. Priority was given to the use of reclaimed water in agriculture sector. The concentrations of traced element were to be low in the reclaimed water and within guideline for irrigation water. However, the perception of water users regarding reclaimed water not well addressed. The socioeconomic factors impact regarding reclaimed water not illustrated. Control and management of reclaimed water was not elaborated.

6. Water Users Association (Wuas) In Jordan

The role of WUAs in Jordan addressed by Omid et al., 2012, Mustafa et al., 2015. The studies demonstrate the political imperatives of water resources management in Jordan. illustrated the significant factors influencing the success of WUAs in Jordan .The research works concluded

that the WUAs is going to be constructed by the state. The WUAs have a crucial role in gaining access to patronage and water that the farmer's prefer. The human factors are the important factors influencing WUAs problem. Longer training has a casual effect on increasing participation in WUAs. Nevertheless, the studies did not elaborate the biasness rate while conducting the survey. The researchers did not discussed the whether the WUAs formation were location sensitive or not. The studies did not illustrate the stakeholder's perception on WUAs formations.

7. Ground Water and Irrigation Water Pricing in Jordan

The irrigation water and ability of users, to pay for water in Jordan was illustrated by Tableh et al., 2015. The study examines the water user's capacity to cope with the water tariff increasing. The study used Residual imputation method (AIM). Incorporate with quantitative method .To estimate water value for the irrigation scheme. The study concluded that there is a significant relationship between efficient irrigation use and increasing in irrigation water prices, which only will occur in water allocated and bill by volume rather than by area. However, the irrigation water quality was not will addressed to examine how it could influence the result. Likewise, result was location sensitive which may not applicable in some part of Jordan.

Irrigation water pricing mechanism and policy in Jordan were investigated by Molle et al., 2008. The study discusses the alternative and policies related to water prices. The study concluded that farmers would reconsider benefit risk with higher water prices. The study did not explore the farmer's perception in increasing irrigation water prices. The water prices strategies and its impact on the allocation of irrigation water in Jordan were investigated by Doppler et al., 2002, Venot and Molle, 2008. The studies concluded that the farmers tend to focus more on risk than on average result. Likewise, a mixture effect could result from rising water prices. Reducing groundwater abstraction to sustainable level through the bylaw not be met. Increasing in irrigation water prices or quotas lowering could exacted to raise over all economic efficiency. However, the economic and social consequences related to over abstraction of ground water have to be carefully considered. However, the studies did not elaborate the stakeholder's perception regarding irrigation water prices. The studies did not address the future pricing mechanism when the irrigation water demand will increase. Ground water statues and over consumption were estimated by Salameh et al., 2014, Al-naber and Molle, 2017.the studies indicated that Jordan relies to 70% of water supply on groundwater extractions. The surface water exploitation has reached or met exceed its limits. The studies concluded that Irrigation in some area have reached its limits and results in aquifer depletion and Stalinization of land used mainly for agriculture. Groundwaters have a vital role in ensuring domestic and irrigation water supply. A wide range of regulations and policies to control groundwater abstraction were issued .Nevertheless, geopolitical condition regarding ground water did not illustrate. The simulations of ground water future scenarios were not done.

CONCLUSION

Water resource management and planning is challenging in the last decade. However, reform in water management can make important contributions to minimize and reduce water scarcity. The agricultural sector uses a major share of the available water resources globally. The reviewed literature regarding irrigation water management in Jordan had some weakness point. The reviewed literature did not elaborate the role of the socioeconomic condition regarding irrigation water. Where, the southern part of Jordan did not address. While in the context of climate change impact in irrigation water the reviewed literature had a shortage and lack of long term climatic data which could affect the results of the studies. Where, different climatic scenarios were not illustrated. In reviewed literature regarding conventional and non-conventional water management the research work did not elaborate the socioeconomic aspect. While discuss the water management options. However, the environmental impact related to mega project construction and operations were not well addressed. Likewise, the reviewed literature did not considered over pumping as one of most important cause of water crisis. Where, the roles of stakeholders in water management were not illustrated. The literature reviewed failed to explore the crucial role of economic developments in increasing water demand in Jordan. wide range of reviewed research works did not considered the geopolitical condition of Jordan as one of the main cause of water shortage problem. In the context of water reuse most of the reviewed literature did not discussed the guideline and the regulations regarding water reuse for many purposes. Where, the water users perception regarding water reuse not will addressed. Moreover, the reviewed literature did not elaborate the distrust issue between WUAs and the governmental bodies, however, the perception of stakeholders regarding WUAs were not addressed. The current review study could pave the road for researchers to cover all the weakness point illustrated in this study. While more effort should be done to investigate and address the irrigation water management in Jordan.

References

1. Ammary, B. Y. (2007). Wastewater reuse in Jordan: Present status and future plans. *Desalination*, 211(1-3), 164-176.
2. Freihat, N. M., Shannag, H. K., & Alkelani, M. A. (2021). Effects of supplementary irrigation on performance of 'Nabali' and 'Grossa de Spain' olives under semi-arid conditions in Jordan. *Scientia Horticulturae*, 275, 109696.
3. Abu-Allaban, M., El-Naqa, A., Jaber, M., & Hammouri, N. (2015). Water scarcity impact of climate change in semi-arid regions: a case study in Mujib basin, Jordan. *Arabian Journal of Geosciences*, 8(2), 951-959.
4. Abu-Awwad, A. M. (2001). Influence of different water quantities and qualities on lemon trees and soil salt distribution at the Jordan Valley. *Agricultural Water Management*, 52(1), 53-71.
5. Abu-Zreig, M. M., Tamimi, A., & Alazba, A. A. (2011). Soil erosion control and moisture conservation of arid lands with stone cover. *Arid Land Research and Management*, 25(3), 294-307.A
6. Al Naber, M., & Molle, F. (2017). Water and sand: is groundwater-based farming in Jordan's desert sustainable?. *Groundwater for Sustainable Development*, 5, 28-37.
7. Al-Hadidi, M. S. (1999). Brackish water management and use in Jordan. *Desalination*, 126(1-3), 41-44..

8. Al-Hamaiedeh, H., & Bino, M. (2010). Effect of treated grey water reuse in irrigation on soil and plants. *Desalination*, 256(1-3), 115-119.
9. Al-Kloub, B., Al-Shemmeri, T., & Pearman, A. (1997). The role of weights in multi-criteria decision aid, and the ranking of water projects in Jordan. *European Journal of operational research*, 99(2), 278-288.
10. Al-Nakshabandi, G. A., Saqqar, M. M., Shatanawi, M. R., Fayyad, M., & Al-Horani, H. (1997). Some environmental problems associated with the use of treated wastewater for irrigation in Jordan. *Agricultural Water Management*, 34(1), 81-94.
11. Al-Omari, A. S., Al-Karablieh, E. K., Al-Houri, Z. M., Salman, A. Z., & Al-Weshah, R. A. (2015). Irrigation water management in the Jordan Valley under water scarcity. *Fresenius Environ Bull*, 24, 1176-1188.
12. Al-Omari, A., Al-Houri, Z., & Al-Weshah, R. (2013). Impact of the As Samra wastewater treatment plant upgrade on the water quality (COD, electrical conductivity, TP, TN) of the Zarqa River. *Water science and technology*, 67(7), 1455-1464.
13. Al-Omari, A., Al-Quraan, S., Al-Salihi, A., & Abdulla, F. (2009). A water management support system for Amman Zarqa Basin in Jordan. *Water resources management*, 23(15), 3165-3189.
14. Al-Omari, A., Al-Quraan, S., Al-Salihi, A., & Abdulla, F. (2009). A water management support system for Amman Zarqa Basin in Jordan. *Water resources management*, 23(15), 3165-3189.
15. Al-Rawashdeh, M. S., & Al-Shboul, H. A. The Effects of Water Deficiencies in Middle East.
16. Al-Zu'bi, Y. (2007). Effect of irrigation water on agricultural soil in Jordan valley: An example from arid area conditions. *Journal of Arid Environments*, 70(1), 63-79.
17. Ammari, T. G., Al-Hiary, S. I., & Al-Dabbas, M. (2013). Reclamation of saline calcareous soils using vegetative bioremediation as a potential approach. *Archives of Agronomy and Soil Science*, 59(3), 367-375.
18. Assayed, A., Chenoweth, J., & Pedley, S. (2015). Assessing the efficiency of an innovative method for onsite greywater treatment: Drawer compacted sand filter—A case study in Jordan. *Ecological Engineering*, 81, 525-533.
19. Assayed, A., Chenoweth, J., & Pedley, S. (2015). Assessing the efficiency of an innovative method for onsite greywater treatment: Drawer compacted sand filter—A case study in Jordan. *Ecological Engineering*, 81, 525-533.
20. Bobojonov, I., Berg, E., Franz-Vasdeki, J., Martius, C., & Lamers, J. P. (2016). Income and irrigation water use efficiency under climate change: An application of spatial stochastic crop and water allocation model to Western Uzbekistan. *Climate Risk Management*, 13, 19-30.
21. Carr, G., Potter, R. B., & Nortcliff, S. (2011). Water reuse for irrigation in Jordan: Perceptions of water quality among farmers. *Agricultural Water Management*, 98(5), 847-854.
22. Doppler, W., Salman, A. Z., Al-Karablieh, E. K., & Wolff, H.-P. (2002). The impact of water price strategies on the allocation of irrigation water: the case of the Jordan Valley. *Agricultural Water Management*, 55(3), 171-182
23. Fahad, S., Inayat, T., Wang, J., Dong, L., Hu, G., Khan, S., & Khan, A. (2020). Farmers' awareness level and their perceptions of climate change: A case of Khyber Pakhtunkhwa province, Pakistan. *Land use policy*, 96, 104669.
24. Freihat, N. M., Shannag, H. K., & Alkelani, M. A. (2021). Effects of supplementary irrigation on performance of 'Nabali'and 'Grossa de Spain'olives under semi-arid conditions in Jordan. *Scientia Horticulturae*, 275, 109696.

25. Gebretsadik, K. A., & Romstad, E. (2020). Climate and farmers' willingness to pay for improved irrigation water supply. *World Development Perspectives*, 20, 100233.
26. Hadadin, N., Qaqish, M., Akawwi, E., & Bdour, A. (2010). Water shortage in Jordan—Sustainable solutions. *Desalination*, 250(1), 197-202.
27. Halalshah, M., Dalahmeh, S., Sayed, M., Suleiman, W., Shareef, M., Mansour, M., & Safi, M. (2008). Grey water characteristics and treatment options for rural areas in Jordan. *Bioresource technology*, 99(14), 6635-6641.
28. Hammouri, N., Al-Qinna, M., Salahat, M., Adamowski, J., & Prasher, S. O. (2015). Community based adaptation options for climate change impacts on water resources: The case of Jordan. *Journal of Water and Land Development*.
29. Hdoush, A. A. A. (2021). Water requirements for irrigated crops in semi-arid region in Jordan using sentinel satellite images. *Physics and Chemistry of the Earth, Parts A/B/C*, 122, 102949.
30. Hillel, N., Geyer, S., Licha, T., Khayat, S., Laronne, J. B., & Siebert, C. (2015). Water quality and discharge of the Lower Jordan River. *Journal of Hydrology*, 527, 1096-1105.
31. Hussein, H. (2018). Lifting the veil: Unpacking the discourse of water scarcity in Jordan. *Environmental Science & Policy*, 89, 385-392.
32. Jaber, J. O., & Mohsen, M. S. (2001). Evaluation of non-conventional water resources supply in Jordan. *Desalination*, 136(1-3), 83-92.
33. Jaber, J. O., Probert, S. D., & Badr, O. (1997). Water scarcity: a fundamental crisis for Jordan. *Applied Energy*, 57(2-3), 103-127.
34. Kidane, T. T., Wei, S., & Sibhatu, K. T. (2019). Smallholder farmers' willingness to pay for irrigation water: Insights from Eritrea. *Agricultural Water Management*, 222, 30-37.
35. Koch, J., Wimmer, F., & Schaldach, R. (2018). Analyzing the relationship between urbanization, food supply and demand, and irrigation requirements in Jordan. *Science of the Total Environment*, 636, 1500-1509.
36. Lucke, B., al-Karaimh, S., & Schörner, G. (2019). Channels, terraces, pottery, and sediments—A comparison of past irrigation systems along a climatic transect in northern Jordan. *Journal of Arid Environments*, 160, 56-73.
37. Metrology Department of Jordan, Open Files, 2020.
38. Molle, F., Venot, J. P., & Hassan, Y. (2008). Irrigation in the Jordan Valley: Are water pricing policies overly optimistic?. *agricultural water management*, 95(4), 427-438.
39. Mustafa, D., Altz-Stamm, A., & Scott, L. M. (2016). Water user associations and the politics of water in Jordan. *World Development*, 79, 164-176.
40. Mustafa, D., Altz-Stamm, A., & Scott, L. M. (2016). Water user associations and the politics of water in Jordan. *World Development*, 79, 164-176.
41. MWI, (2019). Open file. Ministry of Water and Irrigation. Jordan.
42. MWI, (2020). Open file. Ministry of Water and Irrigation. Jordan.
43. MWI, (2021). Open file. Ministry of Water and Irrigation. Jordan.
44. Omid, M. H., et al. "Factors influencing the success of water user associations in Iran: a case of Moqan, Tajan, and Varamin." *Journal of Agricultural Science and Technology* 14.1 (2012): 27-36.
45. Oroud, I. (2015). Water Budget Assessment for a Typical Watershed in the Karak Plateau, Jordan. *Jordan Journal of Earth and Environmental Sciences*, 7(2).

46. Pluchinotta, I., Pagano, A., Giordano, R., & Tsoukiàs, A. (2018). A system dynamics model for supporting decision-makers in irrigation water management. *Journal of environmental management*, 223, 815-824.
47. Qdais, H. A. (2008). Environmental impacts of the mega desalination project: the Red–Dead Sea conveyor. *Desalination*, 220(1-3), 16-23.
48. Qdais, H. A., & Batayneh, F. (2002). The role of desalination in bridging the water gap in Jordan. *Desalination*, 150(1), 99-106.
49. Qdais, H. A., & Batayneh, F. (2002). The role of desalination in bridging the water gap in Jordan. *Desalination*, 150(1), 99-106.
50. Rao, F., Abudukeranmu, A., Shi, X., Heerink, N., & Ma, X. (2021). Impact of participatory irrigation management on mulched drip irrigation technology adoption in rural Xinjiang, China. *Water Resources and Economics*, 33, 100170
51. Saidan, M. N. (2020). Estimation of industrial water demand and reclamation in Jordan: a cross-sectional analysis. *Water resources and industry*, 23, 100129.
52. Salameh, E., Alraggad, M., & Tarawneh, A. (2014). Natural salinity sources in the groundwaters of Jordan—importance of sustainable aquifer management. *Geochemistry*, 74(4), 735-747.
53. Salman, A. Z., & Al-Karablieh, E. (2004). Measuring the willingness of farmers to pay for groundwater in the highland areas of Jordan. *Agricultural Water Management*, 68(1), 61-76.
54. Shamir, E., Megdal, S. B., Carrillo, C., Castro, C. L., Chang, H. I., Chief, K., ... & Prietto, J. (2015). Climate change and water resources management in the Upper Santa Cruz River, Arizona. *Journal of Hydrology*, 521, 18-33.
55. Shatanawi, M., & Fayyad, M. (1996). Effect of Khirbet As-Samra treated effluent on the quality of irrigation water in the Central Jordan Valley. *Water Research*, 30(12), 2915-2920.
56. Shigei, M., Ahrens, L., Hazaymeh, A., & Dalahmeh, S. S. (2020). Per- and polyfluoroalkyl substances in water and soil in wastewater-irrigated farmland in Jordan. *Science of The Total Environment*, 716, 137057.
57. Sixt, G. N., Klerkx, L., & Griffin, T. S. (2018). Transitions in water harvesting practices in Jordan's rainfed agricultural systems: Systemic problems and blocking mechanisms in an emerging technological innovation system. *Environmental Science & Policy*, 84, 235-249.
58. Sutcliffe, C., Knox, J., & Hess, T. (2021). Managing irrigation under pressure: how supply chain demands and environmental objectives drive imbalance in agricultural resilience to water shortages. *Agricultural Water Management*, 243, 106484.
59. Tabieh, M., Al-Karablieh, E., Salman, A., Al-Qudah, H., Al-Rimawi, A., & Qtaishat, T. (2015). Farmers' ability to pay for irrigation water in the Jordan Valley. *Journal of Water Resource and Protection*, 7(15), 1157.
60. Venot, J. P., & Molle, F. (2008). Groundwater depletion in the Jordan Highlands: can pricing policies regulate irrigation water use?. *Water resources management*, 22(12), 1925-1941.
61. Wang, Xiao-jun, Jian-yun Zhang, Shamsuddin Shahid, En-hong Guan, Yong-xiang Wu, Juan Gao, and Rui-min He. "Adaptation to climate change impacts on water demand." *Mitigation and Adaptation Strategies for Global Change* 21, no. 1 (2016): 81-99.