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POTENTIAL OF BIOSALINE AGRICULTURE FOR CLIMATE CHANGE ADAPTATION AND POVERTY ALLEVIATION IN THE JORDAN VALLEY

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Abstract. *Jordan is a young, developing and aspiring nation but one of its main challenges is the scarcity of conventional resources of both water and energy. The water shortage in Jordan is attributed to its climate as part of the Middle East. Other factors adding to the problem are a high growth rate, expanding industries, urbanization, flood of refugees, climate change and inadequate integration of water, agriculture, energy, environmental and socio-economic policies. Marginal lands and high-salinity water are perceived as a strategy option for biosaline agriculture in the Jordan valley. Fresh Yarmouk river water, brackish ground water and treated wastewater are available resources in this semi-arid area of Jordan. Historically, water authorities adopted the blending of fresh and saline water for irrigation, but salts have been accumulating in the top soil due to limited precipitation and leaching. Bioslaine agriculture is proposed as part of a new paradigm to better manage water, agricultural, and socio-economic resources in this important and unique ecosystem. Considering the available brackish ground water resources, treated effluents and cultivable saline lands, biosaline agriculture can be introduced especially in land zones of high salinity. Cash crops such as palm trees which are salt tolerant yet of high economic value should be considered. Vegetables such as salicornia which is known to be very salt tolerant should replace sensitive crops to soil/water salinity. Three halophyte plants were demonstrated to be successful in bio-reclamation of a saline sodic soil in Ghor Al-Safi at the southern Jordan Valley about 10 km south of the Dead Sea (Al-Naser, 2009). The three halophytes are: Tamarix aphylla L , Atriplex numularia L., and Atriplex hallimus L. This paper provides an assessment and framework for biosaline agriculture as part of future strategy for water and land management in the Jordan Valley.*

1 INTRODUCTION

Jordan is classified as a semi-arid country. The highlands (width of around 30 km and a length of some 300 km), enjoy a Mediterranean climate; while temperatures in the Jordan Valley, Wadi Araba and Aqaba can rise in summer to 45°C with an annual average of 24°C.

The rainy season in Jordan extends from October to April, with the peak of precipitation during January and February. Snowfall occurs generally once or twice a year over the highlands, figure 1 shows location and long term average precipitation in Jordan [1].

Evaporation potential ranges from 1600 mm/year in the north western part of the country to more than 4000 mm/year in Aqaba and the eastern desert. In the Jordan Valley, evaporation rates range from 2000 mm/year in the north to 2500 mm/year in the Dead Sea. These evaporation rates are 5 to 80 times the average amounts of rainfall these areas receive [2] .

Irrigated agriculture is an important factor in the economy of Jordan and it takes up to 65 % of the country's water budget. The total water uses differ from year to year and depend on the available resources. In 1994, the total uses added up to about 910 MCM while in the year 2006, the country's water budget was around 1350 MCM [3]. In 2022, it is projected that the total water requirement is 1647 MCM (million m^3) with a deficit of 360 (MCM). 890 MCM of this total will go for agriculture. Projected amount of reclaimed wastewater is 232 MCM in 2022 with 137 MCM in the Jordan Valley alone [3].

The supply-demand equation has been chronically unbalanced in Jordan; therefore the government has focused on development of new water sources while trying to optimize demand management in all sectors. Alternative resources

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such as non-renewable groundwater and reclaimed wastewater have been used. Moreover, desalination of brackish water has been introduced and a major desalination project at the Red Sea (Aqaba) has been in feasibility studies phase and expected to operate in 2028.

Numerous efforts and projects by nationally and donor-supported initiatives have been implemented. Many studies on the agronomic, social and environmental aspects of reclaimed wastewater use have been underway. Policies and regulations have been updated frequently to cope up with the indispensable need for wastewater resource while mitigating health and environmental impacts therein. Currently, there are about 30 major wastewater treatment plants (WWTPs) serving all cities and towns in Jordan [3].

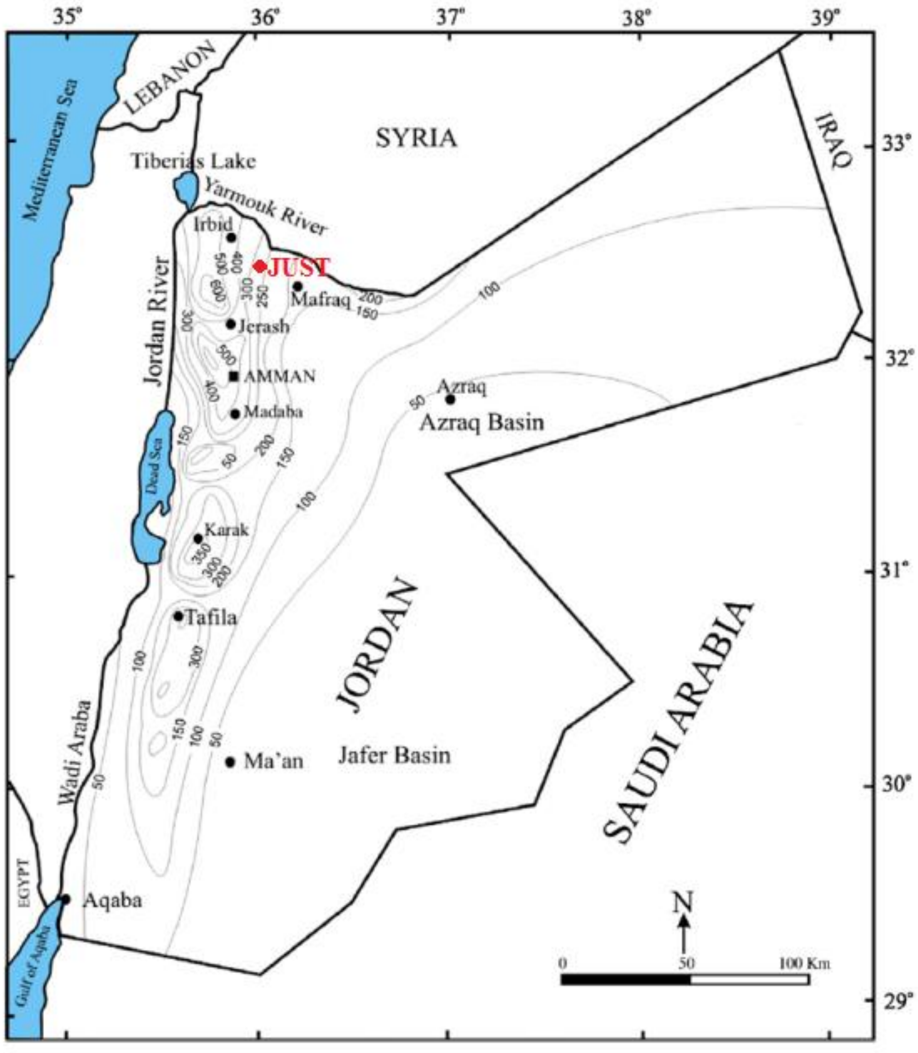

Figure 1. Average distribution of long-term (1938–2005) rainfall in Jordan [1]

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2 METHODS

This paper reports an assessment of biosaline agriculture potential in the Jordan Valley. Salinity maps were developed by JVA, sources of salinity flows into the Zarqa river ecosystem were identified through desk top study, site visits and interviews. Major salinity sources are domestic wastewater, brine, and Olive Mills and other industrial discharges. Mass balance calculation was used to estimate the amount of salts entering the river ecosystem from identified sources.

3 ANALYSIS AND RESULTS

3.1 Reclaimed wastewater reuse in irrigation and the flux of salts

Water reuse in arid and semi-arid areas like Jordan is indispensable. Fresh water resources are limited and vulnerable to increasing pressures by population growth as well as climate change related droughts. While water reuse in agriculture has been a common practice in Jordan, the high levels of salt in streams of treated effluents are still a challenge for reuse. Accumulation of this salinity may cause irreversible deterioration of the fertility and quality of the receiving soils.

Jordan Ministry of Water and Irrigation (MWI) records show that precipitation has decreased over the last decades. Accordingly, the water used for agriculture was reduced from 80% of the fresh water in the seventies of the last century to around 60% in recent years. This is because of the diversion of most water resources into municipal usage. Agriculture received attention in the water strategy by considering blending treated wastewater effluent with fresh water as a water resource in accordance with national, WHO and FAO standards for reuse in irrigation [1]. Traditional water usage from available resources including treated water resources are shown in Table 1.

Year	**Surface water**	**Ground water**	**Treated water**	**Total** (MCM)
2006	280	480	80	840
2007	260	505	91	856
2008	252	499	101	852
2009	276	494	101	871
2010	280	511	103	894
2011	272	517	103	892
2012	231	509	102	842
2013	245	540	109	894
2014	259	588	125	972
2015	274	602	133	1009

Table 1. Water usage from different resources (2006-2015)

As seen in Figure 2, most sewage treatment plants in Jordan delivers effluent to Zarqa river that feeds the lake of KTR (King Talal Reservoir) which in turn is a major irrigation water source for the Jordan valley. KAC (King Abdalla Canal) carries Jordan's share of Yarmouk river fresh water through the Jordan valley. With elevated salinity level in Zarqa river and KTR, authorities adopted blending of this saline water with fresh Yarmouk river water in certain parts of the Jordan valley.

Zarqa river basin and the Jordan valley ecosystem is receiving huge amounts of salts from domestic wastewater effluents, industrial effluents, brine reject, Olive mills among other sources [4]. Continuing the existing management scenario will result in the salinization of more areas of fertile land in the Jordan valley. Instead, a new policy should consider a shift of model such that in lieu of keep accumulating salts in the low-precipitation middle Jordan Valley, a

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new model that uses local reuse strategies as well as the adoption of biosaline agriculture should be considered. Three species of halophytes were identified and planting these on marginal land in the Jordan valley using high salinity water can prove economic and environmentally sustainable.

The main reason for the salinity problem in Zarqa river is indeed the domestic wastewater effluents and industrial enterprises within the Amman-Zarqa basin. Most of these industries tap ground water reserves that are more and more depleted and their level of TDS is rising. A sizable number of these industries rely on small desalination plants to produce the good quality water needed for their products. The brine is disposed of either to Zarqa river directly or is used with other industrial effluents for local farming; thus polluting both the surface as well as the subsurface water in the basin. With such practices going on the salinity problem in the whole basin is expected only to get worse.

In this study, calculations were made to estimate the yearly tonnage of salts that enters Zarqa river and are available to either further pollute the ground water reserves and/or reach the best agricultural land in the middle JV.

Another source identified as a source of salinity in Zarqa river water is the illegal and legal dumping of Olive Mills Wastewater (OMW). This takes place during the season of olive harvesting and processing as olive oil between the months of October and January each year. OMW is heavily polluted with many parameters of concern like COD, Phenols and TDS. The typical range of TDS level in OMW is 42000 to 60000 mg/L as noted earlier.

While removing salts at the treatment plant level might turn out to be cost prohibited, other management scenarios are considered. These include the feasibility of using this high salt water in biosaline agriculture, adoption of better irrigation management at the farm level, cutting the industrial inflow of salinity into Zarqa River, and blending marginal quality water with a better quality streams wherever is feasible.

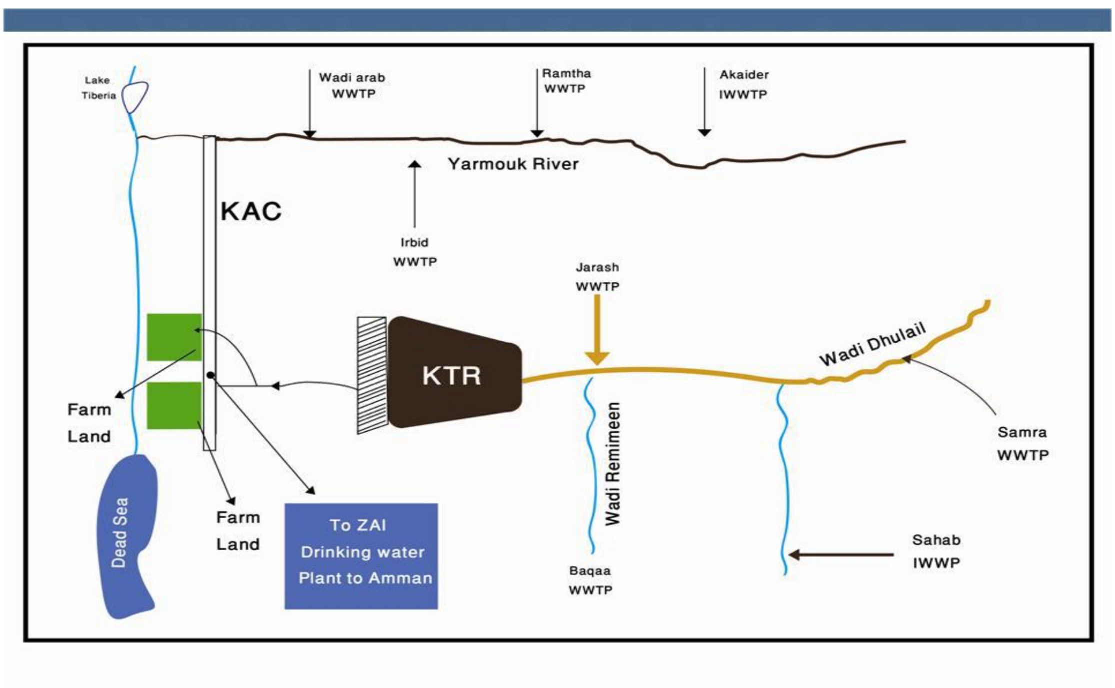

Figure 2. Schematic of irrigation schemes in the Zarqa river basin and the Jordan valley

3.2 Will biosaline agriculture be a solution?

Jordan valley is the premier agricultural land where irrigated agriculture consumes about 65 percent of the available fresh water resources in the country. The area is characterized with higher levels of poverty and unemployment compared to other parts of Jordan.

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Jordan strives for more efficient use of water and land resources, both in urban and rural environments. The increase in water demand, in addition to water shortage has led to a growing competition among various water use sectors and wastewater reuse in irrigation has been introduced as an indispensible strategy option. While the wastewater treatment has been modernized, salinity remains a challenging factor in effluent quality especially that low precipitation characterizes the Jordan valley.

Figure 3 shows classification of soil salinity in the Jordan valley where soils have been salinized by practices of wastewater reuse [5].

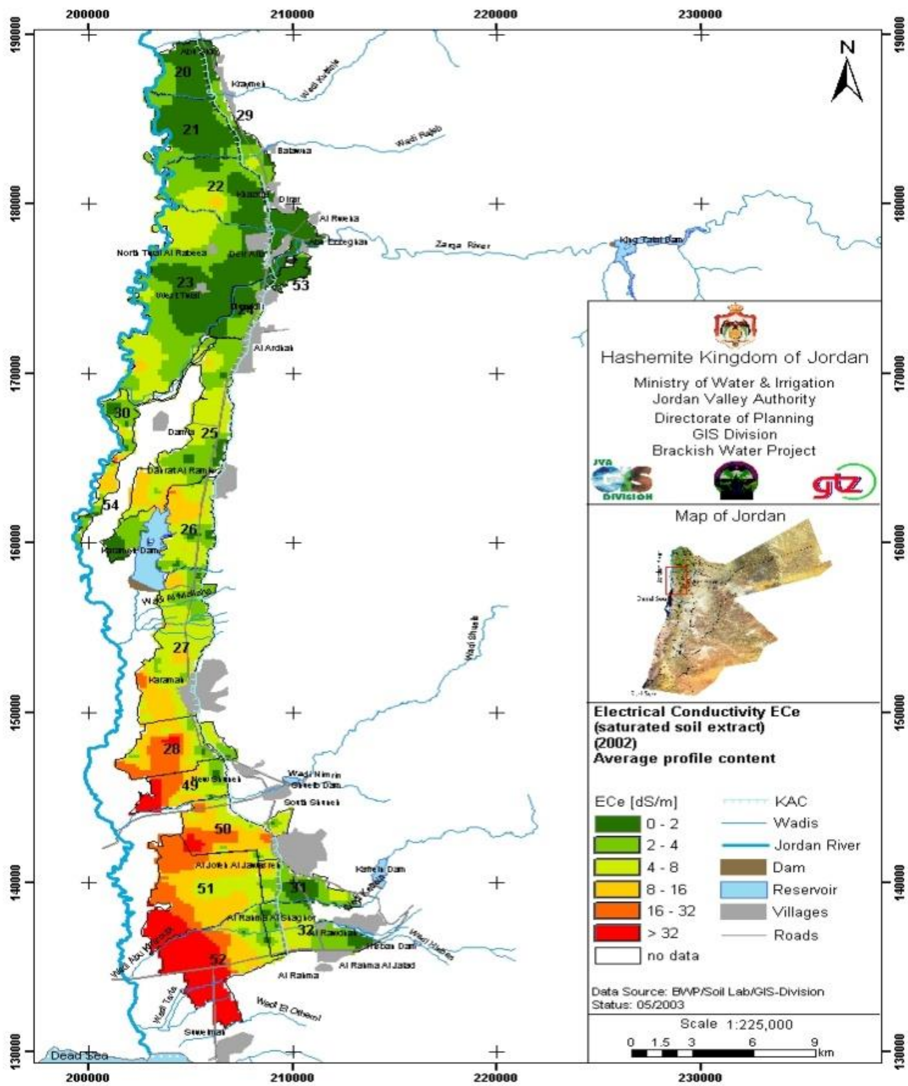

Figure 3. Soil salinity classification in the Jordan Valley (JVA, 2017)

It is seen from JVA's (Jordan valley Authority) average-salinity maps and the classification shown in table 2, below that the Valley has vast areas that are salt lands in the range of high, severe and even extreme salinity. Most of these are in the southern part of the Valley north of Dead Sea. However; there exist sizable areas of moderate salinity range where high salinity water can be used in biosaline agriculture. This will form a win-win situation whereby these marginal quality waters can be used to produce income generating crops and in the same time reducing salinity level in these areas and recovering the high-value land.

Land salinity class	ECe range, dS/m
Non-saline	0-2
Low salinity	2-4
Moderate salinity	4-8
High salinity	8-16
Severe salinity	16-32
Extreme salinity	Greater than 32

Table 2: Salinity classes for salt land suggested by Barrett-Lennard et al. (2008b)

A plan can and should be enacted to know the carrying capacity of each land zone as far as higher salinity water is concerned. For example, based on available rainfall (i.e salt leachability) in each land zone, and the level of salinity in available water, the plan should predict how many years in the future the current/proposed irrigation practice can be sustained without irreversible impact on soil fertility and productivity.

For land zones where soil salinity is high or very high, bio-reclamation with certain types of halophyte species should be considered. For example, the salt accumulator halophyte species, *Atriplexhallimus L., Atriplexnumularia L. and Tamarixaphylla L.* were respectively found to lower the salinity as EC from 84 to 5.46, 5.04 and 6.3 mS/cm at the top layer (0-30 cm) and from 49.6 to 5.46, 13.45 and 7.14 mS/cm in the lower soil (30-60cm) in the salty soils of Ghor Safi at the southern tip of the Dead Sea [6].

4 CONCLUSIONS

Management of the salinity problem associated with agricultural reuse of wastewater should simultaneously focus on two main approaches:

1. To mitigate the level of salts that escape to sewage networks and to cut on industrial brine that illegally ends up in Zarqa River.
2. The second approach is to adopt a strategy that takes in consideration water quality of KTR, soil salinity classification in the Jordan Valley and introducing biosaline agriculture in an integrated framework for agricultural activity in the Valley.

Biosaline agriculture should be introduced and encouraged especially in those land zones of high salinity. Cash crop trees such as palm trees which are salt tolerant yet of high economic value should be considered. Vegetables such as Salicornia which is known to be very salt tolerant should replace sensitive crops to soil/water salinity.

The challenge of water scarcity in Jordan is expected to increase with the impact of climate change. One of the most widely accepted ways of adaptation to climate change is the reuse of treated wastewater. Therefore; the question of salinity in this non-conventional water resource will need to be addressed more thoroughly than before. The management options outlined in this article would form helpful insights for the water policy community in the kingdom of Jordan.

Clean Development Mechanism (CDM) may provide an option for Jordan. Attention should be directed to the available brackish water resources and to the cultivable saline lands in the Jordan Valley, and a pilot project can be implemented whereby different varieties of salt-tolerant trees are planted on saline lands using reclaimed water and/or brackish ground water. This will form an income generating enterprise making use of the marginal quality water in a sustainable manner. To continue to use KTR water for the highly fertile soil in the middle Jordan Valley will only lead to loosing these lands to salinization unless mitigation measures are adopted such as alternating irrigation, i.e. one season with KTR water and the next with fresh KAC water which does not take place currently.

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REFERENCES

[1] Al-Ghazawi Ziad, Qasaimeh Ahmad and Beni-Melhem Khalid, Ablution gray water qualitative assessment and treatment by submerged membrane bioreactor: a case study in Jordan, Desalination and Water Treatment, July 2018 (1-9)
[2] USAID, Review of water policies in Jordan and recommendations for strategic priorities, Final Report, April 2012
[3] Water Authority of Jordan (WAJ), annual report, 2019
[4] Kunz et al, Salinity risk assessment in Wadi Dhuleil, GTZ No. 06.2017-9-002-00, 2007
[5] Jordan Valley Authority (JVA) annual report, 2017
[6] Al-Naser, Using three varieties of Halophytes in reclamation of high salinity soil in southern Jordan valley, 2009