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CASE STUDY

A statistical approach to the water scarcity implications on food security

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ABSTRACT

BACKGROUND AND OBJECTIVES: Jordan faces significant food security challenges due to population growth, climate change, and urbanization, straining limited water resources. Water supply expansion is constrained by economic and environmental factors, leading to a critical impact on agriculture, which stands as the largest consumer of water. The study emphasizes the crucial importance of regional water sources in ensuring food security, as the quantity and quality of irrigation water have a direct influence on crop yield and productivity. Managing irrigation is crucial for sustainability and livelihoods, given Jordan's reliance on food imports and climate change-induced production variability. This study delves into potato cultivation, examining the interconnections among irrigation water availability, crop yield, and self-reliance

METHODS: Irrigation with freshwater and blended treated wastewater in the middle and northern Jordan Valley is compared, using stepwise regression analysis and assuming other agricultural inputs to be optimal. Food security indicators, which include agricultural and socio-economic factors, along with water scarcity indicators, encompassing both water quantity and quality, were methodically chosen and examined.

FINDINGS: Regression analysis of potato production in Jordan revealed that increased blended water positively impacts yields, while higher water requirements and chloride levels negatively affect them. The negative implications of effective rainfall in combined water irrigation were evident, emphasizing the necessity for precise control over the levels of water quality and quantity. The study found that higher local potato production enhances self-sufficiency, crucial for food security. Enhanced water management techniques and advancements in agricultural practices have led to an increase in potato self-sufficiency, even in the face of dwindling water resources. Challenges from stable water requirements and decreasing rainfall can be addressed with advanced irrigation techniques and adaptive practices.

CONCLUSION: Improved water and crop management contribute to enhanced potato self-sufficiency in Jordan, despite varying water quality parameters. Furthermore, the results of research offer important information regarding the adjustment of potato cultivation to evolving climate patterns, including changes in precipitation temperature. These adaptation strategies can be shared and implemented in other countries facing similar climatic challenges.

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INTRODUCTION

Jordan is confronted with significant food security obstacles as a result of swift population expansion, climate variability, and restricted water supplies. Economic and environmental constraints impact agricultural productivity, as agriculture is the largest global water consumer. Between 2000 and 2018, the population of Jordan experienced a significant increase from 5 million to 10 million individuals, with the influx of Syrian refugees playing a contributing role in this demographic growth (UN, 2024; FAO, 2020; Christoforidou *et al.,* 2022). Jordan's food security strategies involve either importing food or boosting local production. The 2008 global food price crisis highlighted the risks of heavy reliance on imports, leading to a renewed focus on self-sufficiency despite challenges like climate change and limited agricultural expansion (Smith *et al.,* 2019; Mrdalj and El Bilali, 2021). It is crucial to comprehend water use management in order to effectively tackle water scarcity. Freshwater is crucial for agricultural irrigation in Jordan, but its scarcity poses challenges for food security (Abu-Awwad, 2021; Mallareddy *et al*., 2023; Abu-Afifeh *et al*., 2023). Water management plays a critical role in agriculture, where the implementation of precision irrigation methods enhances both water conservation and crop productivity (Jiries *et al.,* 2010). The practice of blended water irrigation, which involves the combination of treated wastewater and freshwater, serves as an effective solution to address freshwater scarcity and enhance agricultural sustainability (MWI, 2023). Potatoes are a key crop in Jordan, making up 8.4 percent (%) of total production and covering 4,350 hectares (ha), with an annual yield of 167,000 tons (DOS, 2024). Wheat and barley are also important staples, alongside other crops like tomatoes and zucchini. Food security and water scarcity are urgent global issues. Food security depends on factors like food quantity, quality, availability, access, and socio-economic stability, as defined by the Food and Agriculture Organization (FAO) (Clapp *et al.,* 2022). Water scarcity arises due to a combination of economic, social, and ecological factors, exacerbated by challenges related to water quality issues, climate change, and pollution (Esmaeilion *et al*., 2021). The likelihood of future food shortages can be attributed to water scarcity, emphasizing the necessity of predictive models. By 2050, about 2.3 billion people may face severe water scarcity due to population growth and urbanization (Zhang *et al*., 2020). Data and models are instrumental in comprehending the effects of water scarcity on food security, providing valuable insights for the development of regional strategies (Nkiaka *et al*., 2021). This study examines statistical methods for water scarcity data, using benchmarks from food security data. The discussion focuses on new models utilizing adaptive filtering techniques, which are connected to food security in terms of efficiency and stability (Herman *et al*., 2020). The assessment concludes with practical recommendations and future steps (Nicholson *et al*., 2021). Stepwise regression is a method that chooses variables one by one based on the adjusted R-square value in order to predict a dependent variable. It involves forward selection and backward elimination to optimize the model. This has been shown to significantly enhance empirical prediction models in the fields of economics and agricultural economics (Sinaga and Darnius, 2023). Xiao *et al*. (2019) conducted a study on the water usage in agriculture in the Heihe River region of Northwest China, finding that it makes up 90% of the total water consumption. The analysis of crop incomes and water demands in Zhangye City was conducted by utilizing meteorological data and farmer surveys. The Crop water assessment tool (CROPWAT) model calculated the water needs of different crops, showing that seed corn, the most lucrative crop, and field corn required the highest amounts of water. The study advocated for seed corn and potato cultivation to balance economic returns and water conservation. Gabr (2021) used FAO-CROPWAT 8.0 and Climate Water Assessment Tool (CLIMWAT)-2.0 models with historical weather data from 1975 to 2014 to estimate water requirements for eight major irrigated crops in two agroecological regions in Egypt. This study highlighted the vital importance of local water resources in influencing food security, especially in Jordan. The quantity and quality of irrigation system water have a substantial effect on crop yield and productivity. Amirouche *et al*. (2023) examined agricultural water management in Algeria, focusing on water-intensive crops like potatoes. They used FAO's CROPWAT and AquaCrop models to estimate water requirements over 31 years in the semi-arid Wilaya of Tiaret. The robust relationship between the models' predictions underscored their dependability. AquaCrop's incorporation of factors

such as fertilization and salinity control provided extra advantages, improving irrigation techniques and boosting water efficiency and crop output. Gaddikeri *et al*. (2024) used CLIMWAT 2.0 and CROPWAT 8.0 to estimate crop evapotranspiration and create irrigation strategies tailored to the climatic conditions of six districts in Madhya Pradesh, India. The calculations unveiled notable differences in the water needs of various crops and districts. Effective irrigation management is essential for the sustainability of agriculture and the livelihoods of communities. Food production and economic stability are closely intertwined. In Jordan, a nation heavily dependent on food imports, the implementation of self-sufficiency measures is of utmost importance. This need is heightened by limited agricultural expansion and a growing population. Additionally, climate change also results in fluctuations in food production, highlighting the importance of implementing effective irrigation techniques to maintain stable crop harvests. Conducting long-term studies on the effects of water quantity and quality on potato production is crucial to understand the cumulative impacts of irrigation practices and climatic variability on crop yield. The development of tactics to maximize the usage of both freshwater and blended water in potato cultivation can effectively harmonize water efficiency and crop yield. Evaluating the socio-economic impact of different types of irrigation water can help farmers and policymakers make informed decisions. Additionally, investigating the impact of effective rainfall on water availability and potato production, while leveraging local knowledge systems, can improve the adoption of sustainable practices. Comparing irrigation practices between different regions and countries with similar challenges can identify best practices and innovative solutions adaptable to local conditions. The current study aims to investigate the correlation between irrigation water and potato crop yield in the context of food security through the utilization of stepwise regression analysis. This study has been carried out on the Jordan Valley in Jordan for the period of 2008-2023.

MATERIALS AND METHODS

The primary objective of this study is to examine the volume and standard of irrigation water utilized in the Jordan Valley (JV) for potato cultivation, a key crop in the region. More specifically, the condition of irrigation using BW in the middle part of the JV is considered, in comparison with irrigation using FW in the northern part of JV, assuming other agricultural production inputs and parameters to be optimal. Thus, the core focal points were quality of irrigation water from various sources, along with the water needs and productivity of potatoes in relation to food security in Jordan.

Study area description

The north and middle JV (Fig. 1), situated along the western border of Jordan, is a region characterized by its strategic location, distinct topography, varied climate, diverse crops, and critical water resources.

The JV stretches from the Sea of Galilee in the north to the dead sea in the south. The Northern JV is situated close to the Syrian borders, whereas the Central JV stretches southwards towards the heart of Jordan (Al-Husban and Ayen, 2020). This region forms part of the larger Jordan Rift Valley, which is a significant geographical feature in the Middle East. The JV is part of the Great Rift Valley system, renowned for its impressive and diverse topography. It features a mix of fertile plains, rolling hills, and steep escarpments. The valley is situated at a considerable distance below sea level, with heights dropping to as low as 400 meters (m) below sea level in the vicinity of the Dead Sea. This topography contributes to its unique microclimate and agricultural potential (Alhejoj and Salameh, 2023). The weather in the northern and central JV regions is mainly Mediterranean, with hot and dry summers, as well as mild and wet winters. The region experiences substantial variations in temperature and precipitation. Summers can see temperatures soaring above 40 degrees Celsius (°C), while winter temperatures are more moderate, typically ranging between 10 °C and 20 °C. The amount of rainfall experienced annually fluctuates across the region, with higher levels of precipitation observed in the northern territories in contrast to the southern regions. Typically, the annual rainfall falls within the range of 200 to 500 millimeters (mm). (Rodrigo-Comino, 2021). Its fertile soils and favorable climate conditions make the JV a prime agricultural zone. The region supports a wide variety of crops, including vegetables, citrus fruits, bananas, and dates. In the North JV, is known for cultivating common crops such as tomatoes, cucumbers, and peppers, while grapes and melons are also

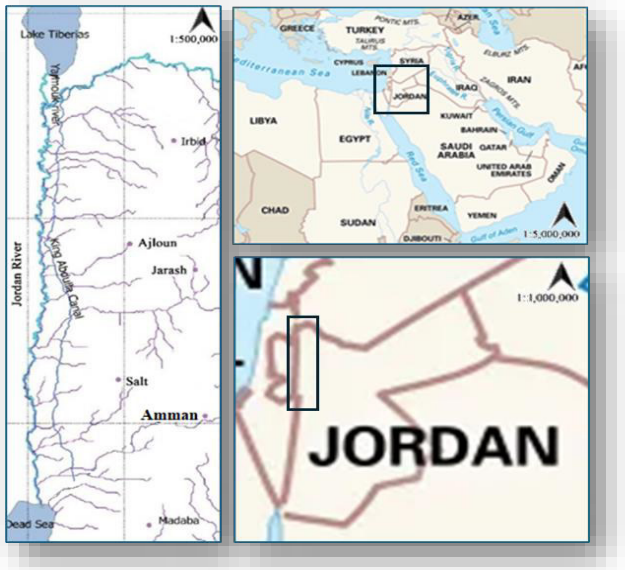

Fig. 1: Geographic location of the study area in the Jordan Valley of Jordan (Salameh and Abdallat, 2020)

substantially cultivated in the Middle JV. These crops benefit from the valley's extended growing season and relatively stable climatic conditions (Ananda *et al*., 2020; Anbar *et al*., 2020). The agricultural productivity of the JV is heavily reliant on its water resources.. The region relies heavily on the Jordan River, which flows through the valley from the Sea of Galilee to the Dead Sea. Additionally, a multitude of springs and groundwater reservoirs play a crucial role in meeting the irrigation requirements of the valley. However, water scarcity remains a critical concern as a result of increased agricultural needs, agreements on water distribution among regions, and the effects of climate change. To mitigate these challenges, the use of treated wastewater for irrigation has become increasingly important, especially in the Middle JV, helping to sustain agricultural activities amidst limited fresh water irrigation (FW) availability (Almanaseer *et al*., 2020; Tawfik *et al*., 2023).

Stepwise regression analysis

Stepwise regression involves fitting regression models by automatically selecting predictive variables through a systematic procedure (Harrell, 2015). The objective was to pinpoint a subset of variables that held the most significance in forecasting the dependent variable. A correlation analysis was conducted to check for multicollinearity among the variables. The results revealed no significant multicollinearity concerns, as all correlation coefficients were well under the commonly accepted thresholds. Therefore, the econometric estimation had been proceeded with confidence in the independence of the variables. The general form of the multiple regression equation is shown in Eq. 1 (Harrell, 2015):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \qquad (1)$$

Where, Y is the dependent variable; β_0 is the variable intercept (e.g., crop yield); $\beta_1, \beta_2, \ldots, \beta_k$ are the coefficients of the independent variables; $X_1, X_2, \ldots, X_k$ are the independent variables (e.g., soil quality, rainfall, irrigation); and ε is the error term. In stepwise regression, involves the incremental inclusion or exclusion of variables from the model according to predetermined criteria, such as p-values derived from statistical tests (Harrell, 2015). The present study utilized forward selection as the stepwise regression technique to ascertain significant predictors. The initial model contained only the intercept. At each step, the predictor variable that resulted in the greatest increase in R-square value was added to the model. The selection process involved iterative evaluation of the R-square for all potential predictors at each stage, with the inclusion of the variable that contributed the most significant

enhancement to the model's fit. This forward selection continued until no remaining variables could significantly increase the R-square, ensuring that the final model included only those predictors that significantly contributed to explaining the variance in the dependent variable. The Augmented Dickey–Fuller (ADF) test serves the purpose of ascertaining the stationarity of a time-series, indicating the constancy of its statistical characteristics such as mean, variance, and autocorrelation over time. The ADF test is an extension of the Dickey-Fuller test and is used to test for a unit root in a time series sample. Stepwise regression, while useful for variable selection, has notable limitations. It can lead to overfitting, especially with small samples or many predictors, resulting in models that may not generalize well to new data. Additionally, the approach may generate unreliable models that are susceptible to slight data alterations and frequently fail to account for significant relationships between variables. Moreover, it neglects the integration of theoretical insights or previous studies, potentially resulting in the omission of crucial variables that align with established theories. These limitations indicate that while stepwise regression is valuable for exploratory analyses, it should be complemented with alternative techniques or theoretical perspectives for more robust Modeling (Sinaga and Darnius, 2023).

Water scarcity and food security indicators

Food security indicators, which include agricultural and socio-economic factors, and water scarcity indicators, which encompass both water quantity and quality, were methodically selected and analyzed. This comprehensive analysis aimed to understand the interplay between agricultural productivity, socio-economic conditions, and water availability and quality. The data spanning from 2008 to 2023 were gathered from various sources including the Department of Statistics (DOS), Ministry of Agriculture (MOA), Ministry of Water and Irrigation (MWI), and Jordan Valley Authority (JVA). Seasonal Decomposition using Time Series Analysis was employed to break down the observed time series into its trend, seasonal, and residual components. This technique enabled the detection of inherent patterns, seasonal fluctuations, and unpredictable variations in the dataset, leading to a holistic comprehension of the temporal dynamics. The area of land cultivated with potato and irrigated with FW in the JV (APFWJV) measures the extent of land relying on scarce FW resources for potato cultivation, which is crucial for understanding the strain on these resources. The area of land cultivated with potato and irrigated with BW in the JV (Fresh water irrigation) indicates a shift towards using BW for irrigation, reflecting adaptive strategies to cope with water scarcity. The cultivated potato land area in Jordan (CPJOR) serves as a fundamental metric for evaluating various irrigation methods. Additionally, potato production from FW-irrigated land in the JV (PPFWJV) assesses the productivity and efficiency of using FW, while potato production from blended water-irrigated land in the JV (PPBWJV) allows for evaluation of the effectiveness of BW irrigation on crop yield (Martínez-Valderrama *et al.*, 2023). The population growth in Jordan (POPJOR) plays a crucial role as a socio-economic indicator, influencing the demand for food and exerting further pressure on water resources. The potato production rate from FW-irrigated land in the JV (PPRFWJV) measures the efficiency of FW usage in terms of production per area. Similarly, the potato production rate from blended water-irrigated land in the JV (PPRBWJV) demonstrates the productivity comparison associated with the use of BW. The overall potato production rate in Jordan (PPRJOR) provides a productivity metric across different irrigation methods, helping to gauge the broader implications of irrigation practices on food security (Al-Kharabsheh and Ta'any, 2005). Quantities of water supplied to lands cultivated with potato and irrigated with FW in the JV (QWSPFWJV) reflect the volume of FW dedicated to potato farming. In contrast, the quantities of water supplied to lands cultivated with potato and irrigated with BW in the JV (QWSPBWJV) measure the volume of BW used, which is important for resource allocation (Alkhaza'leh *et al.*, 2023). Crop water requirements for potato in FW-irrigated land in the JV (CWRPFWJV) are essential for planning and ensuring an adequate water supply for optimal growth. Similarly, crop water requirements for potato in blended water-irrigated land in the JV (CWRPBWJV) provide insights into the water needs of crops under BW irrigation. Crop water requirements were estimated using the CROPWAT 8.0 and CLIMWAT models (free tools for calculating crop water and irrigation requirements provided by the FAO). All calculation procedures

Table 1: Water scarcity and food security indicators

Pilar	Description of the indicator	Unit	Code	Source
Agricultural	Area of land cultivated with potato and irrigated with FW in the JV	du	APFWJV	MOA, JVA
	Area of land cultivated with potato and irrigated with BW in the JV	du	APBWJV	MOA, JVA
	Area of land cultivated with potato in Jordan	du	APJOR	MOA, JVA
	Potato production from FW-irrigated land in the JV	ton	PPFWJV	MOA, JVA
	Potato production from BW-irrigated land in the JV	ton	PPBWJV	MOA, JVA
Socioeconomic	Population growth in Jordan	cap	POPJOR	DOS
	Potato production rate from FW-irrigated land in the JV	ton/du	PPRFWJV	MOA, JVA
	Potato production rate from BW-irrigated land in the JV	ton/du	PPRBWJV	MOA, JVA
	Potato production rate in Jordan	ton/du	PPRJOR	MOA, JVA
	Area of land cultivated with potato and irrigated with FW in the JV	du	APFWJV	MOA, JVA
	Area of land cultivated with potato and irrigated with BW in the JV	du	APBWJV	MOA, JVA
Water quantity	Quantities of water supplied to lands cultivated with potato and irrigated with FW in the JV	m3/du	QWSPFWJV	MWI, JVA
	Quantities of water supplied to lands cultivated with potato and irrigated with BW in the JV	m3/du	QWSPBWJV	MWI, JVA
	Crop water requirements for potato in FW-irrigated land in the JV	mm	CWRPFWJV	MWI, JVA
	Crop water requirements for potato in BW-irrigated land in the JV	mm	CWRPBWJV	MWI, JVA
	Effective rainfall in FW-irrigated land in the JV	mm	ERFWJV	MWI, JVA
	Effective rainfall in BW-irrigated land in the JV	mm	ERBWJV	MWI, JVA
Water quality	Salinity of water supplied to FW-irrigated land in the JV, measured by electrical conductivity	dS/m	ECFWJV	MWI, JVA
	Boron concentration in water supplied to FW-irrigated land in the JV	ppm	BOFWJV	MWI, JVA
	Chloride concentration in water supplied to FW-irrigated land in the JV	ppm	CLFWJV	MWI, JVA
	Salinity of water supplied to BW-irrigated land in the JV, measured by electrical conductivity	dS/m	ECBWJV	MWI, JVA
	Boron concentration in water supplied to BW-irrigated land in the JV	ppm	BOBWJV	MWI, JVA
	Chlorine concentration in water supplied to BW-irrigated land in the JV	ppm	CLBWJV	MWI, JVA

used in CROPWAT 8.0 were based on the two FAO publications of the Irrigation and drainage series, namely, No. 56 “Crop Evapotranspiration - Guidelines for computing crop water requirements” (Allen *et al*., 1998) and No. 33 titled “Yield response to water” (Doorenbos *et al*., 1980). The dates for the potato crop development stage required to run CROPWAT were set at 30 days. The way these dates changed over the period 2008-2023 involved cumulative data collection over the years; data were accumulated for each year incrementally (e.g., until 2008, then until 2009, and so on). For the FW irrigated lands, a rainfall and climate station was selected, whereas a different station was designated for the BW irrigated lands in the study. Effective rainfall in FW-irrigated land in the JV (ERFWJV) and in blended water-irrigated land (ERBWJV) indicate the natural water contribution, reducing the need for additional irrigation. Salinity of water supplied to FW-irrigated land in the JV, measured by electrical conductivity (ECFWJV), is a key water quality indicator, as high salinity can affect crop yield and soil health. Boron concentration in water supplied to FW-irrigated land (BOFWJV) must be managed to prevent toxicity in crops, whereas the concentration of chloride (CLFWJV) has a direct impact on plant growth and the usability of water. For blended water-irrigated land, salinity levels (ECBWJV), boron concentration (BOBWJV), and chlorine concentration (CLBWJV) are similarly critical for evaluating the suitability of BW for irrigation and its effects on crops (Abuzaid and Jahin, 2021; Alrbaihat and Abu-Afifeh, 2023). The combination of these indicators offers a thorough analysis of the relationship between food security and water scarcity (Table 1). Agricultural parameters emphasize the reliance on freshwater and the adjustment to using brackish water. Socio-economic metrics demonstrate the impact of population growth and productivity levels. Indicators related to water quantity and quality evaluate the effectiveness of water usage practices in terms of sustainability. These indicators signify the need for improved water management to maintain potato production in Jordan (PPJOR) and its self-sufficiency percentage (SSPJOR). The combination of these two components enables a comprehensive examination of agricultural sustainability and resource allocation,

Table 2. Statistics of variables used in the analysis over 2008-2023

Indicator	Unit	Statistics					Augmented Dickey-Fuller Test	
		Maximum	Minimum	Mean	Standard deviation	Coefficient of variation	Dickey-Fuller	p-value
APFWJV	du	10616	5510	7701	1438	19%	-2.4514	0.04004
APBWJV	du	19421	7706	12147	2833	23%	-2.7132	0.03022
APJOR	du	72558	34029	50646	12398	24%	-2.7092	0.03071
PPFWJV	ton	36829	17460	24967	5383	22%	-2.88654	0.02317
PPBWJV	ton	55516	24918	38737	9711	25%	-2.8982	0.02112
POPJOR	cap	11500000	6293000	9109813	1790401	20%	-2.488	0.03954
PPRFWJV	ton/du	4.3	2.2	3.4	0.70	21%	-2.6965	0.03193
PPRBWJV	ton/du	4.3	2.2	3.3	0.71	22%	-2.92442	0.01622
PPRJOR	ton/du	4.0	2.3	3.3	0.58	18%	-2.6644	0.03841
QWSPFWJV	m3/du	721	363	574	103	18%	-2.3976	0.04019
QWSPBWJV	m3/du	320	107	200	66	33%	-2.8035	0.02678
CWRPFWJV	mm	331	329	330	0.90	0%	-2.3345	0.04773
CWRPBWJV	mm	327	324	325	0.88	0%	-2.7996	0.0276
ERFWJV	mm	27.7	23.2	24.6	1.13	5%	-2.7781	0.02857
ERBWJV	mm	24.4	21.6	23.1	0.93	4%	-2.5219	0.03865
ECFWJV	dS/m	2.46	1.64	1.98	0.25	12%	-2.965	0.01495
BOFWJV	ppm	0.94	0.24	0.54	0.20	38%	-2.987	0.01259
CLFWJV	ppm	416	261	327	45	14%	-2.9692	0.01373
ECBWJV	dS/m	1.27	0.75	1.10	0.12	11%	-2.7642	0.03007
BOBWJV	ppm	0.30	0.02	0.17	0.08	44%	-2.8657	0.02339
CLBWJV	ppm	245	102	174	36	20%	-2.677	0.03736
PPJOR	ton	273906	103224	169637	40029	24%	-2.8386	0.02426
SSPJOR	%	98.6	62.1	86.0	9.1	11%	-2.4514	0.04004

providing direction for tactics aimed at harmonizing food output with limitations in water availability.

RESULTS AND DISCUSSION

Statistical analysis of water scarcity and food security indicators

The provided data are presented in Table 2, offering a comprehensive overview of key indicators relevant to potato cultivation in Jordan. The indicators are classified into different pillars including agriculture, socio-economic factors, water quantity, and water quality in the table, offering a comprehensive analysis that illuminates different facets of potato cultivation in the area. In the agricultural pillar, the data include crucial metrics such as the area of land cultivated with potatoes and corresponding production, for the period from 2008 to 2023. The JV showed a range of 5510 to 10,616 du for FW irrigation in the years 2022 and 2015, respectively, and 7706 to 19,421 du for BW irrigation in the years 2011 and 2014, respectively. Across Jordan overall, the cultivated land spans from 34,029 (2013) to 72,558 (2015) du. Potato production varies significantly, with FW irrigation in the JV yielding between 17,460 (2011) and 36,829 (2019) tons, and BW irrigation producing from 24,918 (2017) to 55,516 (2014) tons. The production rates in the JV exhibit a range of 2.2 to 4.3 tons per du, indicating disparities in irrigation techniques and farming methods. In the socio-economic pillar, the table highlights population growth in Jordan, ranging from approximately 6,293,000 (2008) to 11,500,000 (2023) caps, providing context for demographic trends that have impacted agricultural demands and resource management over a period of 16 years. The Water Quantity section provides a breakdown of the amount of water distributed per unit of cultivated land, specifically measured in dunums. In the JV, FW irrigation provides 363 (2022) to 721 (2011) cubic meter per dunum (m^3/du), while BW irrigation supplies 107 (2023) to 320 (2014) m^3/du. The data highlights the fluctuation in water accessibility and its essential impact on agricultural output. Water quality indicators such as electrical conductivity (EC), boron concentration, and chloride concentration are also presented, showing variability based on the type of irrigation used. This information is vital in evaluating the possible effects on the health and productivity of crops. The standard deviation (SD) and coefficient of variation (CV) are also essential statistical measures that offer deeper insights into the variability and relative variability of

key indicators related to potato cultivation in Jordan. The SD quantifies the spread of data points relative to the mean, illustrating the extent to which variables like potato yield and water volume deviate from their average levels. For instance, in potato production, SD values such as 5383 tons for FW-irrigated areas and 9711 tons for BW-irrigated areas indicate considerable variability in production levels, influenced by factors such as water availability and agricultural practices. Similarly, SD values for water quantities supplied to potato fields, such as 103 m^3/du for FW irrigation and 66 m^3/du for blended water irrigation, indicate how consistent the water supply is across different irrigation methods. Lower SD values indicate a water supply that is more stable and predictable, essential for ensuring crop yields. On the other hand, the CV provides a standardized measure of dispersion comparison to the mean. Comparing the variability across different datasets, while also taking into consideration their respective means, can be advantageous. For example, CV values of 21% for potato production rates in FW-irrigated areas and 22% in blended water-irrigated areas indicate their similar relative variability, despite slightly different mean production rates. Understanding the stability and potential risks linked to agricultural outputs under various irrigation conditions is crucial for gaining valuable insights. In terms of water quality, lower CV values for parameters such as electrical conductivity (EC) and boron concentration in both irrigation types (FW and BW) suggest more consistent water quality, which is critical for crop health and productivity. Regarding PPJOR, the data indicate significant fluctuations in potato production, from a minimum of 103,224 tons in 2013 to a maximum of 273,906 tons in 2016, with an average production of 169,637 tons. The substantial standard deviation of 40,029 tons suggests a significant degree of fluctuation in production quantities, potentially attributable to variables such as weather patterns, water accessibility, farming techniques, and market requirements. The CV (24%) reflects a moderate level of relative variability in potato production. Jordan's self-sufficiency percentage reflects the degree to which the country is able to fulfill its potato requirements through internal agricultural output. The self-sufficiency percentage ranges from a low of 62.1% in 2013 to a high of 98.6% in 2023, with an average of 86.0%. The 9.1% standard deviation implies a moderate level of variability, pointing towards the fact that Jordan is able to consistently fulfill a substantial part of its potato requirements through local farming practices. The CV (11%) confirms this low relative variability, signifying a stable level of self-sufficiency over time. The null hypothesis (H_0) of the ADF test posits that the time-series has a unit root, meaning that it is non-stationary (Harris, 1992). Conversely, the alternative hypothesis (H_1) posits that the time-series lacks a unit root and is thus considered stationary. A p-value less than 0.05 typically indicates that the null hypothesis can be rejected, suggesting that the time-series is stationary. Each of the indicators in the table supplied exhibits p-values below 0.05, enabling the rejection of the null hypothesis of a unit root for every series. Consequently, based on the outcomes of the ADF test, it can be concluded that each of these time-series exhibits stationarity. The statistical characteristics of these series, including measures like mean and variance, are shown to be consistent over time, allowing for the application of time-series analysis and modeling without the need for extra adjustments to ensure stationarity. Moreover, a significance level of $\alpha = 0.05$ was chosen for all statistical tests. It was found that all p-values obtained from the ADF test were significant.

These metrics are essential for policymakers and agricultural stakeholders in Jordan. The modest fluctuation in potato yield highlights the necessity for implementing measures to ensure stable production levels, such as enhancing agricultural techniques, optimizing water resources, and adjusting to changes in climate patterns (Jiries *et al.*, 2010; MWI, 2023). On the other hand, the relatively stable self-sufficiency percentage suggests that, despite fluctuations in production, Jordan can consistently meet a substantial portion of its potato demand through local cultivation, which is a positive indicator of food security.

Potato production dependency on water scarcity and food security indicators

Stepwise regression is a method for fitting regression models in which the choice of predictive variables is carried out through an automatic procedure. The evaluation of the relationship between potato production and water scarcity, as well as food security indicators, required a step-by-step process of including or excluding potential explanatory variables. This process was iteratively based on the coefficient of determination (R-square), adjusted R-squared, and p-value thresholds (Harrell, 2015). The dependent

Table 3. Analysis of variance for potato production (PPJOR)

Variable	Parameter Estimate	Standard Error	Type II SS	F-value	p-value
Intercept	148359206	32394209	6288850315	20.97	0.0018
PPRJOR	65859	9703	13812845968	46.07	0.0001
QWSPFWJV	142.6	74.9	1087645895	3.63	0.0933
QWSPBWJV	748.3	171.1	5737030102	19.13	0.0024
CWRPFWJV	-421408	91815	6316224497	21.07	0.0018
ERBWJV	-415788	92011	6122755598	20.42	0.002
CLBWJV	-661.8	146.8	6089846282	20.31	0.002
ECFWJV	165466	50268	3248631323	10.83	0.011

variable (Y) was Potato Production (PPJOR), while the independent variables (X) were the agricultural, socio-economic, and water quality and quantity indicators, as detailed in Eq. 2 (Harrell, 2015):

(2)

$$PPJOR = \beta_0 + \beta_1\ APFWJV + \beta_2\ APBWJV + \beta_3\ APJOR + \beta_4\ PPFWJV + \beta_5\ PPBWJV + \beta_6\ POPJOR + \beta_7\ PPRFWJV + \beta_8\ PPRBWJV + \beta_9\ PPRJOR + \beta_{10}\ QWSPFWJV + \beta_{11}\ QWSPBWJV + \beta_{12}\ CWRPFWJV + \beta_{13}\ CWRPBWJV + \beta_{14}\ ERFWJV + \beta_{15}\ ERBWJV + \beta_{16}\ ECFWJV + \beta_{17}\ BOFWJV + \beta_{18}\ CLFWJV + \beta_{19}\ ECBWJV + \beta_{20}\ BOBWJV + \beta_{21}\ CLBWJV$$

The provided Eq. 3 (Harrell, 2015) and Table 3 have been utilized to consolidate the findings of the stepwise regression analysis, specifically examining the correlation between PPJOR and different factors associated with water scarcity and food security. Each row presents a variable's parameter estimate, standard error, Type II sum of squares (SS), F-value, and p-value (Pr > F). None of the other variables reached the 0.1500 significance threshold for inclusion in the model. The model is outlined in the following section, along with a comprehensive analysis of the findings.

$$PPJOR = 148359206 + 65859\ PPRJOR + 142.6\ QWSPFWJV + 748.3\ QWSPBWJV - 421408\ CWRPFWJV - 415788\ ERBWJV - 661.8\ CLBWJV + 165466\ ECFWJV \quad (3)$$

The cultivation of potatoes in Jordan is significantly impacted by a range of factors, as emphasized through the statistical analyses. The potato production rate per dunum (PPRJOR) presented a robust impact on production quantities, with a parameter estimate of 65,859 and a highly significant F-value of 46.07 ($p < 0.0001$). It is evident that comprehending the fluctuations in potato yield per unit of land is essential in evaluating the level of potato self-sufficiency within the country. Factors such as soil fertility and agricultural practices influence this parameter. However, challenges associated with water supply management arise. While the quantity of water supplied through blended water irrigation (QWSPBWJV) was positively correlated with potato production, with an estimate of 748.3 and an F-value of 19.13 ($p = 0.0024$), freshwater irrigation (QWSPFWJV) showed less statistical significance (F-value of 3.63, $p = 0.0933$), suggesting a complex impact on overall water resource management. The combination of water irrigation is expected to improve potato yields as a result of its well-rounded nutrient composition and the potential for reduced salinity levels when compared to using solely freshwater irrigation. Water quantity plays a pivotal role in potato cultivation, yet it also poses challenges. Crop water requirements for freshwater-irrigated land (CWRPFWJV) and effective rainfall in blended water regions (ERBWJV) were both found to negatively impact potato production. CWRPFWJV, with a parameter estimate of −421,408 and an F-value of 21.07 ($p = 0.0018$), underscoring that higher water demands decrease production efficiency. Increased water demands for freshwater-irrigated areas may result in inefficiencies stemming from possible water scarcity and ineffective water management techniques, which can have a negative impact on the growth and productivity of crops. Similarly, ERBWJV, showing a parameter estimate of −415,788 and an F-value of 20.42 ($p = 0.002$), suggests that effective rainfall in blended water areas correlates with reduced potato yields. The efficient distribution of rainfall in blended water areas could potentially lead to improved soil moisture preservation and well-timed precipitation, ultimately enhancing the growth of crops. However, excessive rainfall can also lead to waterlogging and nutrient leaching, negatively impacting yields. Furthermore, various elements including inadequate irrigation timing resulting in either water scarcity or surplus, heightened soil salinity and contamination from processed wastewater, insufficient soil vaeration, and the existence of disease-causing agents or hazardous

substances in processed wastewater contribute to the issue. These factors collectively could stress the crops and reduce yields, thus justifying the research findings (Battikhi and Hill, 1986). The potato production landscape is additionally complicated by water quality parameters. Chloride concentration in blended water (CLBWJV) exhibited a significant negative relationship with potato yields, indicated by a parameter estimate of −661.8 and an F-value of 20.31 ($p = 0.002$). This statement highlights the adverse influence of increased chloride levels on the productivity of crops. Elevated chloride levels in blended water can increase soil salinity, leading to osmotic stress in plants, reduced nutrient uptake and, ultimately, lower yields. Conversely, the salinity of freshwater (ECFWJV), with a parameter estimate of 165,466 and an F-value of 10.83 ($p = 0.011$), unexpectedly showed a positive effect. The presence of elevated salinity levels in freshwater environments may imply the presence of naturally-occurring minerals that could potentially have a positive impact on the growth of potato plants. This could be attributed to an increase in nutrient availability or a decrease in competition from weeds and pests that are not well-adapted to saline conditions. In summary, Jordan's potato production is closely connected to the availability and quality of water resources within the region. While certain factors such as blended water irrigation show potential benefits, other factors such as high water demands and adverse water quality parameters present significant challenges. The optimization of management strategies is crucial in achieving a sustainable increase in potato production, all the while ensuring the preservation of water resources for upcoming agricultural demands. These findings aligned with Devaux (2014) who stated that the potato is vital to global food security and its importance is expected to grow. From 2020 to 2030, the potato's contribution to global food production is projected to rise from 3.74% to 6.42%, marking an increase of 2.68 percentage points. Potatoes play a crucial role as a staple crop due to their nutritional value and ability to thrive in various environmental conditions and soil types. Several factors threaten global food security. Population growth is anticipated to increase by 50% by 2050, leading to greater food demand. The planting regions conducive for agriculture are being altered by the increasing temperatures associated with climate change, consequently impacting the productivity of crops. Trade uncertainty, including restrictions and conflicts, poses risks to food security. Additionally, the COVID-19 pandemic has disrupted global food supply chains and driven up food prices.

Self-sufficiency percentage of potato dependency on water scarcity and food security indicators

The data presented in (Fig. 2) illustrates a clear upward trend in potato production in Jordan between 2008 and 2023, particularly highlighting notable spikes in 2011, 2014, and 2016. During these years, production levels reached as high as 216,483 tons in 2011, 204,084 tons in 2014, 273,906 tons in 2016, and 188,631 tons in 2023. Correspondingly, the self-reliance ratio of potatoes exhibited a consistent increase over the years, reaching a remarkable 98.6% in 2023. This overall increase suggests a positive correlation between time and potato production efficiency, likely due to improvements in agricultural practices, resource management, and possibly technological advancements in potato farming. Increased potato production is often associated with higher levels of self-sufficiency in many instances. In 2016, a total of 273,906 tons were produced, resulting in a self-sufficiency rate of 86.1%. Conversely, by 2023, the production quantity had decreased to 188,631 tons, yet achieving a record high self-sufficiency rate of 98.6%. This trend indicates that, as Jordan increases its potato production, it becomes more self-sufficient, reducing the need for imports and enhancing food security. On the other hand, during years characterized by decreased potato production, the corresponding self-sufficiency rates tend to decrease as well. To illustrate, in 2013, when the production hit a record low of 103,224 tons, the self-sufficiency percentage plummeted to 62.1%. This suggests that reduced production capacity directly impacts Jordan's ability to meet its potato consumption needs domestically, thereby lowering self-sufficiency. The prevailing tendency indicates that increased production typically results in greater self-reliance; however, certain years may diverge from this norm. In 2011, despite a high production of 216,483 tons, the self-sufficiency percentage was slightly lower, at 82.3%, compared to other high production years. Additionally, in 2017 and 2018, with moderate production levels (155,639 tons and 153,199 tons, respectively), the self-sufficiency percentages were quite high (at 93.1% and 91.4%, respectively). The irregularities indicate that self-sufficiency is influenced not only by production volumes, but also by factors like distribution efficiency, storage

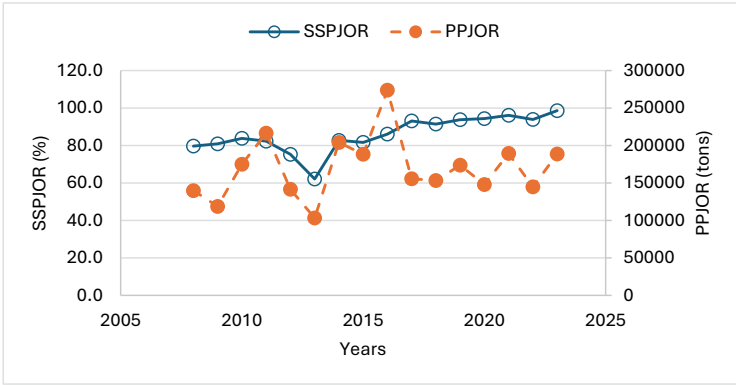

Fig. 2: Potato production in Jordan (PPJOR; tons) towards self-sufficiency percentage of potato in Jordan (SSPJOR; %)

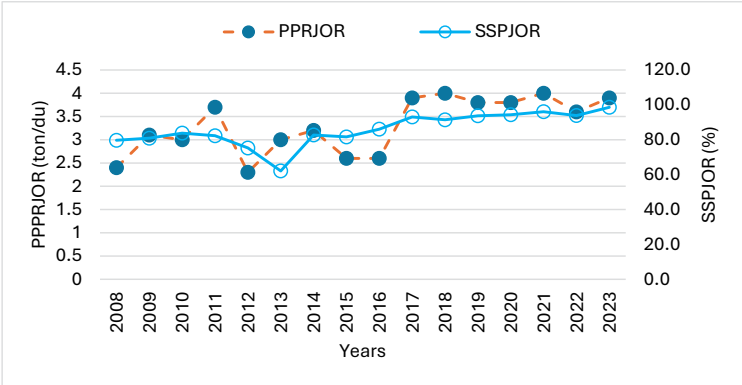

Fig. 3: Potato production rate in Jordan (PPRJOR; ton/du) towards self-sufficiency percentage of potato in Jordan (SSPJOR; %)

capabilities, and potential fluctuations in consumption patterns.

Fig. 3 illustrates the variations in the potato production rate (PPRJOR) throughout the years, displaying a clear upward trajectory in more recent years. For instance, production rates peaked in 2017 and 2018 at 3.9 and 4.0 tons per dunum, respectively, and maintained relatively high levels through to 2023. Correspondingly, the self-sufficiency percentage also presented a significant upward trend, peaking at 98.6% in 2023. The implication here is that increased production rates correlate with higher levels of self-sufficiency, underscoring the significance of enhancing productivity to attain food security. Higher potato production rates generally correlate with higher self-sufficiency percentages. In 2018, the self-sufficiency percentage reached 91.4% with a production rate of 4.0 tons per dunum. Similarly, in 2023, a production rate of 3.9 tons per dunum corresponded to the highest self-sufficiency percentage of 98.6%. Increasing the productivity per unit of land has the potential to greatly enhance Jordan's ability to meet its own potato production needs. In contras, years characterized by reduced production levels frequently exhibit diminished self-sufficiency percentages. In 2012, the production rate was at its lowest at 2.3 tons/du, resulting in a self-sufficiency percentage of 75.3%. The significance of production efficiency in fulfilling domestic demand and decreasing reliance on imports is highlighted by this trend. There are some deviations from this trend. For instance, in 2011, despite a high production rate of 3.7 tons/du, the self-sufficiency percentage was slightly lower (at 82.3%), compared to other high-production rate years. Similarly, in 2016, with a production rate of 2.6 tons/du, the self-sufficiency percentage was relatively high (at 86.1%). The irregularities indicate that self-sufficiency levels are influenced by factors beyond production rates, including domestic consumption

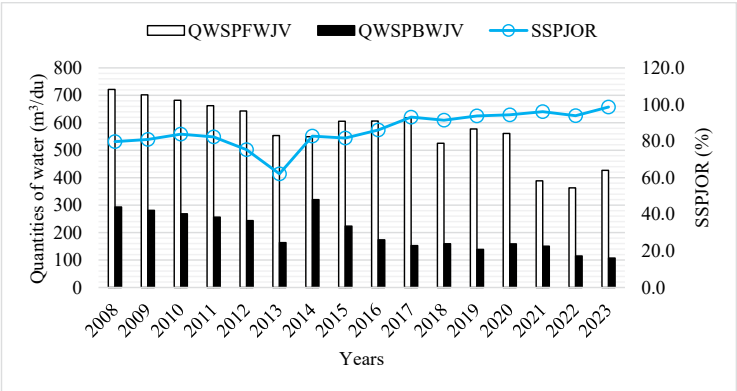

Fig. 4: Quantities of water supplied to freshwater irrigated lands (QWSPFWJV) and blended water irrigated lands (QWSPBWJV) in the Jordan Valley (m^3/du) towards self-sufficiency percentage of potato in Jordan (SSPJOR; %).

patterns, import-export dynamics, and potentially storage and distribution efficiencies.

Fig. 4 demonstrates a downward trend in the volume of water allocated for potato cultivation in the JV area between 2008 and 2023. Both FW irrigation (QWSPFWJV) and BW irrigation (QWSPBWJV) experienced a decrease over this timeframe. from 2008 to 2023, the quantities of water supplied for potato cultivation in the JV—both for FW irrigation (QWSPFWJV) and BW irrigation (QWSPBWJV)—generally decreased. FW irrigation levels fell from 721 m^3/du (in 2008) to 427 m^3/du (in 2023), while BW irrigation levels dropped from 293 m^3/du to 107 m^3/du over the same period. The self-sufficiency percentage displayed fluctuations despite the reductions, yet it demonstrated an increasing pattern, climbing from 79.7% in 2008 to a peak of 98.6% in 2023. The relationship between water supply and self-sufficiency reveals interesting insights. Despite the general reduction in FW supply, self-sufficiency has increased, suggesting that factors such as improved agricultural practices, better water management, and more efficient use of water resources might have played significant roles. In 2023, the minimum FW supply of 427 m3/du aligned with the maximum self-sufficiency percentage of 98.6%, suggesting a potential improvement in FW usage efficiency. Correspondingly, the reduction in BW availability was linked to a rise in self-reliance, indicating enhanced efficiency in utilizing BW for the growth of potatoes. High self-sufficiency percentages in 2021 and 2022, despite low BW supplies, further support this observation. Specific years provide a deeper understanding of these trends. In 2013, significant reductions in both FW (554 m^3/du) and BW (163 m^3/du) supplies were associated with the lowest self-sufficiency percentage of 62.1%, the lowest recorded at that time. t is clear from this that significant cuts in water resources can have a detrimental effect on self-sustainability, particularly in the absence of effective water conservation practices. Conversely, in 2021 and 2022, despite low water supplies (389 and 363 m^3/du for FW; 150 and 115 m^3/du for BW), self-sufficiency percentages were high (96.1% and 93.9%), suggesting that improved water management and agricultural practices have mitigated the negative impacts of reduced water supply. Jordan›s advancement in effectively utilizing scarce water resources to enhance self-reliance in potato production underscores the significance of of sustainable water management in agricultural productivity.

As shown in Figs. 5 and 6, the crop water requirements for potatoes in FW-irrigated land (CWRPFWJV) remained relatively stable from 2008 to 2023, fluctuating slightly between 329 mm and 331 mm. In contrast, effective rainfall on BW-irrigated land (ERBWJV) exhibited a downward trend, decreasing from 24.4 mm in 2008 to 21.6 mm in 2023. The self-reliance rate of potato production in Jordan experienced an overall growth, climbing from 79.7% in 2008 to 98.6% in 2023, despite fluctuations. The stability in crop water requirements (CWRPFWJV) suggests that this factor remained a consistent element in potato production. The self-sufficiency percentage did not experience any

significant adverse effects despite the minor rise from 329 mm to 331 mm. This implies that other factors, such as improved irrigation techniques and better crop management, may have played crucial roles in enhancing self-sufficiency. Conversely, the decrease in effective rainfall (ERBWJV) from 24.4 mm to 21.6 mm suggests a diminished supply of natural water for the cultivation of potatoes in BW-irrigated areas. However, the increase in self-sufficiency percentage during this period suggests that advances in water management practices and irrigation efficiency effectively mitigated the impact of reduced rainfall, demonstrating successful adaptation to changing water availability conditions. During certain years, significant fluctuations offer more comprehensive understanding. For instance, in 2013, the recorded precipitation was 23.1 mm and the crop water needs were 330 mm, aligning with the lowest self-sufficiency rate of 62.1%. This suggests that even slight increases in water requirements coupled with reduced rainfall can significantly affect production efficiency if not properly managed. Conversely, from 2017 onwards, the self-sufficiency percentage saw substantial growth, reaching 98.6% in 2023. During these years, crop water requirements were at their highest (331 mm), while effective rainfall was at its lowest (21.6 mm in 2023). During this era, the importance of enhanced water management and irrigation techniques in attaining a high level of self-sufficiency is emphasized, even in the presence of less than ideal natural water conditions. The information gathered during these years highlights the significance of employing adaptive agricultural techniques and optimizing water usage to support and improve potato cultivation in Jordan. As stated by Devaux (2014) water scarcity is a pressing issue, particularly in about 22 countries in North Africa and West Asia, with 15 of these already consuming more than their

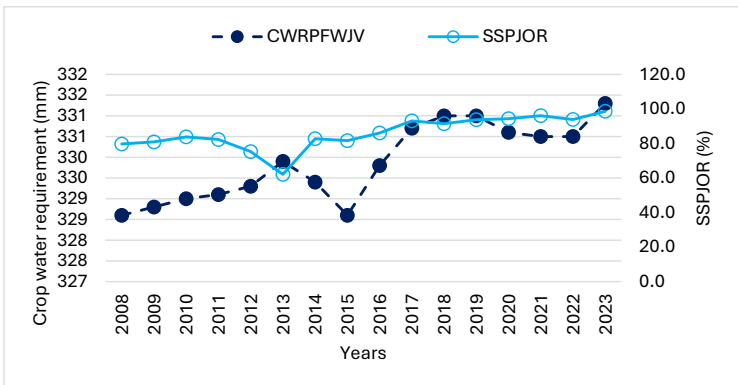

Fig. 5: Crop water requirement in freshwater irrigated lands in the Jordan Valley (CWRPFWJV; mm) towards self-sufficiency percentage of potato in Jordan (SSPJOR; %)

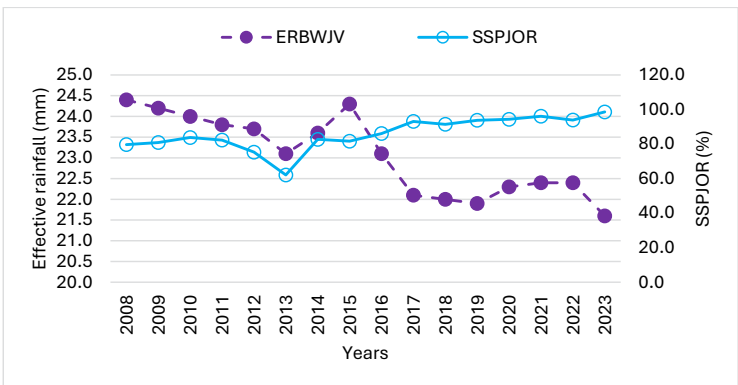

Fig. 6: Effective rainfall at the blended water irrigated lands in the Jordan Valley (ERBWJV; mm) towards self-sufficiency percentage of potato in Jordan (SSPJOR; %)

total renewable freshwater resources. Agricultural water efficiency in Africa is significantly lacking, as evidenced by a mere 3% utilization rate. This scarcity impacts potato production and other agricultural activities. Essential markers of food security encompass the frequency of malnourishment and the degrees of moderate or severe food insufficiency. These indicators have been updated through 2022 based on the latest data from the FAO.

As shown in Figs. 7 and 8, from 2008 to 2023, the electrical conductivity of FW (ECFWJV) used for irrigating potato crops in the JV fluctuated between 1.64 decisiemens per metre (dS/m) and 2.46 dS/m. The chloride levels in BW (CLBWJV) exhibited a notable degree of variation, with values ranging from 102 parts per million (ppm) to 245 ppm.. Over the same period, the self-sufficiency percentage of potato production in Jordan generally increased, starting at 79.7% in 2008 and reaching a peak of 98.6% in 2023.

The data indicates that there was no discernible pattern in the fluctuation of electrical conductivity in FW, while the self-sufficiency percentage of potato production exhibited a consistent increase over the years. Higher values of ECFWJV were observed in some years (e.g., 2.46 dS/m in 2008 and 2.42 dS/m in 2011) when the self-sufficiency percentage was lower, suggesting that higher salinity might negatively impact potato production. The chloride levels in BW (CLBWJV) exhibited a notable degree of variation, with values ranging. The variability of chloride concentration was

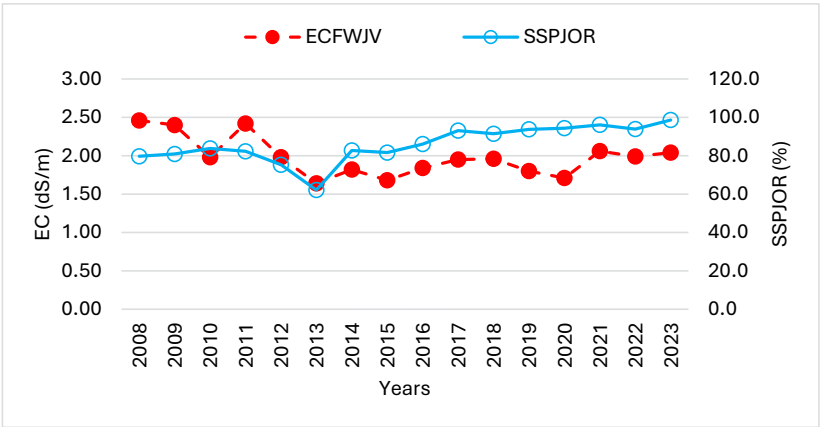

Fig. 7: Electrical conductivity of freshwater supplied for irrigation in the Jordan Valley (ECFWJV; dS/m) towards self-sufficiency percentage of potato in Jordan (SSPJOR; %).

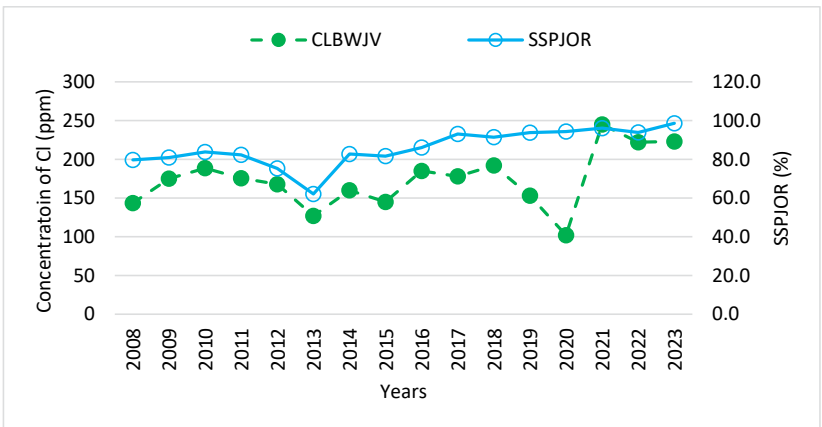

Fig. 8: Chloride concentration of the blended water supplied for irrigation in the Jordan Valley (CLBWJV; ppm) towards self-sufficiency percentage of potato in Jordan (SSPJOR; %)

more pronounced, as evidenced by significant spikes (for example, reaching 245 ppm in the year 2021). Despite these fluctuations, the self-sufficiency percentage rose significantly, indicating that potato production systems adapted to varying water quality levels. In years with lower chlorine concentrations (e.g., 127 ppm in 2013 and 102 ppm in 2020), the self-sufficiency percentage was either low or high, suggesting that other factors also play crucial roles in determining self-sufficiency beyond the chloride concentration alone. In 2013, the minimum electrical conductivity of FW was recorded at 1.64 dS/m, along with a relatively low chloride concentration of 127 ppm, which corresponded to the lowest self-sufficiency percentage of 62.1%. This suggests that, even with relatively good water quality, other factors significantly impacted self-sufficiency in that year. From 2017 onwards, the self-sufficiency percentage saw substantial growth—with peaks such as 98.6% in 2023—despite variations in both electrical conductivity and chloride concentration. In 2021, the self-sufficiency percentage was recorded at 96.1%, even with a high chloride concentration of 245 ppm. This indicates the effectiveness of improved agricultural practices, water management techniques and, perhaps, crop varieties more tolerant to salinity and chloride, which collectively enhanced self-sufficiency.

CONCLUSION

The regression analysis of potato production in Jordan identified several key factors influencing yields. The enhanced provision of mixed water had a beneficial influence on crop yields, while heightened crop water demands and increased chloride concentrations had an adverse impact. Additionally, effective rainfall in the context of blended water irrigation had a detrimental effect, highlighting the need to manage both water quality and quantity for optimal potato yieldsThe study revealed a direct relationship between increased domestic potato cultivation and the ability to meet one's own food needs, highlighting the importance of self-reliance in ensuring food security. However, factors such as import dynamics and consumption patterns also affect self-sufficiency, suggesting that productivity alone is not sufficient. Despite a decreasing water supply, improvements in water use and agricultural practices have enhanced potato self-sufficiency in Jordan. The stable water needs of crops and the decreasing amount of effective rainfall pose difficulties that may be mitigated by utilizing sophisticated irrigation methods and flexible strategies. Effective water and crop management have contributed to increased potato self-sufficiency, demonstrating the potential for better water use to improve food security. The research offers insights that could benefit other regions facing similar challenges, suggesting that optimized water management and agricultural practices can enhance potato yields and contribute to global food security. The results also offer significant information for adjusting potato cultivation to evolving climate circumstances and may direct global strategies and funding in the agricultural sector. Comparative studies with other regions could offer broader insights into potato production factors and foster international collaboration and knowledge exchange. However, this study focused on specific variables, including water quality parameters, potentially overlooking other factors like soil characteristics, pest management, and socio-economic variables. Moreover, depending on aggregated data could potentially lead to biases, making it challenging to generalize the findings to various crops or regions that have distinct agricultural methods and climate conditions. Additionally, the study underscores the significance of consistently monitoring and adapting agricultural practices in light of environmental shifts. Implementing advanced irrigation technologies and developing drought-resistant potato varieties could further bolster yield resilience. Cooperation with agricultural research institutions on a global scale has the potential to enhance the sharing of best practices and innovative ideas, thereby advancing sustainable potato farming practices worldwide.

AUTHOR CONTRIBUTIONS

A. Abu-Awwad, the corresponding author, has contributed in supervising the authors in analysing data, interpreting the results, and preparing the manuscript. J. Al-Btoosh prepared all the tables and figures and interpretation of the results. N. Obeidat participated in the interpretation of the results and manuscript preparation.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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ABBREVIATIONS

%	percent
^{o}C	Degree Celsius
b_0	Variable intercept
ADF	Augmented Dickey–Fuller
AER	Agro-ecological regions
APBWJV	Area of land cultivated with potato and irrigated with BW in the JV
APFWJV	Area of land cultivated with potato and irrigated with FW in the JV
APJOR	Area of land cultivated with potato in Jordan
BOBWJV	Boron concentration in blended water-irrigated land
BOFWJV	Boron concentration in water supplied to FW-irrigated land
BW	Blended water irrigation
cap	Capita
CLBWJV	Chloride concentration in blended water
CLBWJV	Chlorine concentration in blended water-irrigated land
CLFWJV	Chloride concentration in water supplied to FW-irrigated land
CLIMWAT	Climate Water Assessment Tool
CROPWAT	Crop water assessment tool
CV	Coefficient of variation
CWR	Crop water requirements
CWRPBWJV	Crop water requirements for potato in blended water-irrigated land in the JV
CWRPFWJV	Crop water requirements for potato in FW-irrigated land in the JV
CWRPFWJV	Crop water requirements for FW-irrigated land
DOS	Department of Statistics
dS/m	Decisiemens per metre
du	Dunum
EC	Electrical conductivity
ECBWJV	Salinity levels in blended water-irrigated land
ECFWJV	Salinity of water supplied to FW-irrigated land in the JV
ECFWJV	Salinity of freshwater
Eq.	Equation
ERBWJV	Effective rainfall in blended water-irrigated land in JV
ERFWJV	Effective rainfall in fresh water-irrigated land in the JV
FAO	Food and Agriculture Organization
FW	Fresh water irrigation
ha	Hectare
H0	Null hypothesis
H1	Alternative hypothesis
IWR	Irrigation water requirements
JV	Jordan Valley

JVA	Jordan Valley Authority
m^3/du	Cubic meter per dunum
MENA	Middle East and North Africa
mm	Millimetre
MOA	Ministry of Agriculture
MWI	Ministry of Water and Irrigation
ppm	Part per million
POPJOR	Population growth in Jordan
PPBWJV	Potato production from BW-irrigated land in the JV
PPFWJV	Potato production from FW-irrigated land in the JV
PPJOR	Potato production in Jordan
ppm	Parts per million
PPRBWJV	Potato production rate from BW-irrigated land in the JV
PPRFWJV	Potato production rate from FW-irrigated land in the JV
PPRJOR	Potato production rate per dunum
QWSPBWJV	Quantities of water supplied to lands cultivated with potato and irrigated with BW in the JV
QWSPFWJV	Quantities of water supplied to lands cultivated with potato and irrigated with FW in the JV
SD	Standard deviation
SS	Sum of squares
SSPJOR	Self-sufficiency percentage of potato in Jordan
ton	Ton
ton/du	Ton per dunum
X	Independent variables
Y	Dependent variable

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