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Stakeholder perspectives on fostering the Water-Energy-Food Nexus in Jordan: Lessons beyond agricultural water management

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Abstract

The water–energy–food (WEF) nexus is an integrated conceptual tool for achieving sustainable development especially for countries facing limitations in one or more of its three pillars. The approach relies on bringing different stakeholders from the water, agriculture and energy sectors together to collaboratively plan and adopt a holistic approach to resources management. This enables them to address sector-specific issues and develop a comprehensive understanding of the connected sectors leading to better outcomes. However, WEF nexus implementation is currently in its infancy in many countries and stakeholders are in the process of learning how to effectively communicate and collaborate with each other. In this paper, we report the state of the WEF nexus in Jordan, a dry country grappling with water, energy and food production challenges in a changing climate. Stakeholders from line

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ministries, academics, private sector players and non-state actors were brought together to discuss the status of the WEF nexus and identify challenges that need to be overcome for full realization of the WEF nexus as an operational framework for integrated development at country level. Stakeholders identified 7 cardinal lessons in the process of WEF nexus implementation in Jordan. These are that (i) data/information sharing is vital (ii) WEF nexus requires funding, (iii) collaborations among actors is key, (iv) inclusivity in planning is necessary, (v) clear responsibilities and boundaries among stakeholders are needed, (vi) sustainability and cohesion are a must and (vii) building trust among and within organizations is a primary ingredient for success. A deeper understanding of the interrelated dynamics of these challenges is required to foster the WEF nexus in Jordan as the issues are grave but not insurmountable. It is therefore suggested that deliberate efforts are needed from a technical and policy angle to ensure full operationalization of the WEF nexus approach in Jordan and elsewhere.

Keywords: food-energy-water nexus, sustainability, stakeholders, perception, Earth observation

1. Introduction

The majority of the sustainable development goals are directly or indirectly linked to water, energy and food (Mugagga & Nabaasa, 2016; Wang et al., 2021). Therefore, the water–energy–food (WEF) nexus approach that delineates the intricate connections among these sectors, is recognized as an important cornerstone for achieving sustainable development (Biggs et al., 2015; Simpson & Jewitt, 2019). It has been recognized that insufficient comprehension of the WEF Nexus is a significant global economic challenge (Waughray, 2011), with the Bonn conference stressing that applying the Nexus approach is an essential paradigm shift for development (Hoff, 2011). The WEF Nexus approach arises from the grand challenges associated with ensuring universal access to water, energy, and food. The increasing global population, rapid economic growth, accelerated urbanization, and evolving lifestyles, have intensified the demand for these essential services in the face of multiple supply challenges.

The impacts of climate change and the degradation of natural resources are challenging the capacity to meet water, food and energy needs in many countries across the world and at various times. In response to this complex scenario, the WEF nexus approach has emerged as a novel management approach for integrated solutions to these challenges (Nhamo et al., 2018; Zhang et al., 2018). The goal of the nexus approach is to guarantee the sufficient and equitable provision of water, energy, and food to all while fostering the sustainable utilization of natural resources (D'Odorico et al., 2018).

The WEF nexus serves as a strategic framework to address the intricate interconnections among these vital sectors, ensuring resilience in the face of growing challenges and promoting a holistic and sustainable approach to resource management (Hoff, 2011). It recognizes that actions in one sector can have significant impacts on others and that integrated planning and management are therefore essential for sustainable development at various levels (Albrecht et al., 2018; Mishra et al., 2021).

The WEF nexus approach has now been regarded as the standard approach for a systematic and simultaneous dovetailing of governance approaches, technology and decarbonization across all related sectors (Lazaro et al., 2022; Pahl-Wostl et al., 2018). While this approach is promising, there are already many challenges in operationalization of the WEF nexus approach at local, regional and global levels (Dargin et al., 2019; Liu et al., 2017; Yillia, 2016). The scale and impacts of these challenges are different within and between countries; therefore, understanding each country's status quo is required to ensure that the WEF nexus approach can reach its maximum potential. To achieve this, it is essential to implement comprehensive assessments tailored to each country's specific needs and conditions. The levels of maturity of WEF nexus varies across regions and countries. For example, high maturity of WEF nexus is observed in Europe and Australia, with strong policy frameworks and integration across sectors. Medium maturity is seen in North America, Latin America, and parts of Asia, where sectoral approaches are being augmented with Nexus thinking. Low to medium maturity is evident in Sub-Saharan Africa and Central Asia, where resource management is crucial but institutional and technical capacity constraints are limiting Nexus integration (Apeh & Nwulu, 2024; Orimoloye, 2022; Purwanto et al., 2021). Jordan has recognized the importance of an integrated approach and has been working on policies and strategies considering the WEF Nexus (Al-Addous et al., 2023; Government of Jordan, 2022).

This paper aims to provide a scoping overview of the status, potential, and difficulties in implementing the WEF nexus approach for dryland countries with a specific focus on agriculture, using Jordan as a case study. Specifically, the objectives are to (i) understand the physical and policy

landscape in Jordan regarding WEF nexus, (ii) draw experiences in WEF issues in a dryland country from various stakeholders, (iii) identify current and potential bottlenecks to achieving the full potential of WEF, (iv) and document lessons learned and share perspectives on moving forward in enhancing the WEF Nexus approach's contribution to sustainable development in the country. Jordan was selected as the focus of the study because of its limited natural resources and predominantly arid climate with minimal rainfall and high temperatures. Despite these challenges, it is a model peaceful country in the Middle East facing increasing pressures from changing climatic conditions, migration and conflicts in neighboring countries.

2. Methodological approach

Two approaches were used to characterize the status and stakeholder perspectives on WEF in Jordan (i) scoping the status of the water, energy, and food sectors from a narrative literature review and (ii) stakeholder perspective solicitation.

2.1 Scoping the status of WEF Nexus in Jordan

The first part of the study is based on a narrative literature review of available documents on the characteristics of the country and the local status quo of the WEF nexus. A narrative review, which identifies, describes, and discusses the state-of-the-art of a specific topic or theme from a more theoretical and contextual point of view was used in this analysis (Rother, 2007; Snyder, 2019). This approach enables the summarizing or synthesizing of what has been written on a particular topic to appreciate the value of existing information, condition, or status independently from comparative analysis (Mauer & Venecek, 2022; Sylvester et al., 2013).

A narrative approach was selected for this review for three reasons (i) the majority of relevant WEF documents are in official government, private sector and non-state actors documents that are not indexed in common scientific databases (ii) WEF is a relatively new concept for the country and the region, and therefore is not yet readily available in context-specific ways for Jordan in databases and (iii) it was anticipated that important information on WEF-nexus in Jordan is in multiple languages specifically English and Arabic. A narrative reviews is therefore suitable for this task because it identifies and reviews broad published literature on a topic to capture a wide range of related subjects and intricacies without focusing on quantitative metrics, excluding other materials and/or weighing them by prevalence (Haddaway et al., 2020; Paré & Kitsiou, 2017). All published literature on the characteristics of the country, the status quo of the WEF sectors, and current challenges were scoped and analyzed to identify status and trends.

2.2 Stakeholder perspectives on WEF in Jordan

2.2.1 Stakeholder identification

For this study, a stakeholder is defined as a person whose work has a direct or indirect impact or connection, now or in the future, on the water, energy, and/or food/agriculture sectors in Jordan (Daher et al., 2020; Rountree et al., 2021). The stakeholders were brought together as part of a Nuffic-Orange Knowledge Program (OKP) funded project on Earth Observation and Geoinformation Technologies to Foster Water-Energy-Food Nexus Interventions (NexusWatch). The stakeholders were selected by a theoretically based quota sample, with the intention of having a composition of people who could represent different key attributes and diversity. These include that they represented all three WEF sectors, had a balance in gender and age-groups, and had a good representation of the diverse roles and institutions in these sectors including state agencies, non-profit organizations, industry, the private sector, and academia (Supplementary materials 1). There was a balance in the distribution of the stakeholders across the water, energy and food sectors (Figure 1). The stakeholders were identified through peer and expert networks and were invited to participate collectively in a workshop identifying the challenges, opportunities, and sustainable pathways of WEF in the country to both identify individual and collective perspectives on WEF.

2.2.2 Soliciting stakeholder perspectives on WEF

Stakeholder perspectives were solicited from the stakeholders in a facilitated dialogue meeting conducted in Amman, Jordan in October 2023. The facilitator guided the discussion around the challenges and lessons learned in WEF implementation in the country and practical experiences and preferences were presented and noted. A facilitated discussion approach was decided because it did not constrain the responses and ensured a safe and open discussion. Stakeholders listed WEF challenges, ranked them using consensus and then described them in detail during the moderated discussion. The facilitator also sought as much as possible to generate a consensus on an issue and in cases where this was not possible, the majority opinion was used. The results of the analysis are structured around the Jordanian context, a scoping of the water, energy and food sectors, and key lessons learned in fostering WEF in the country.

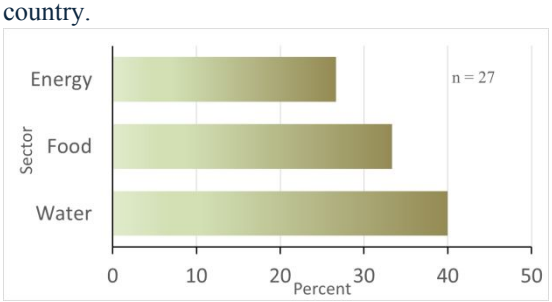

Figure 1: Distribution of stakeholders across the sectors.

3. Jordan country context

Jordan is located in the Middle East, bordered by Israel and the West Bank to the west, Syria to the north, Iraq to the northeast, and Saudi Arabia to the south and southeast. It also has a short coastline along the Red Sea to the south (Figure 2). The capital city is Amman, and other major cities include Aqaba, Irbid, and Zarqa. Jordan has a diverse population, including a significant number from Syria, Palestine, Iraq, and Yemen (UNHCR, 2024). The population is predominantly Arab, and the official language is Arabic. Jordan has a developing economy, with industries such as phosphate mining, agriculture, and services playing crucial roles, with the country being highly dependent on external aid (World Bank, 2022).

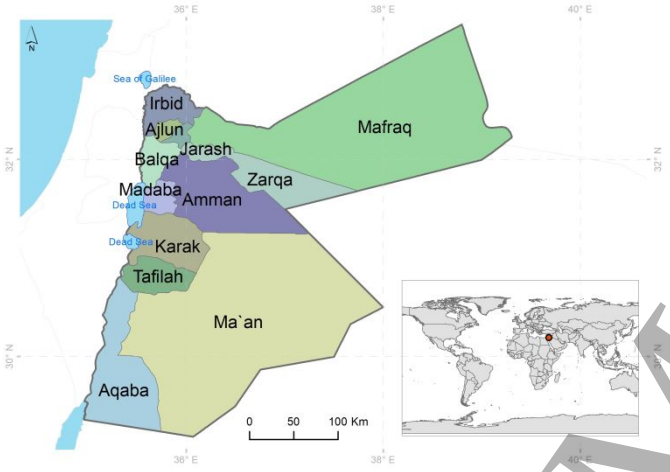

Figure 2: Map showing the distribution of the administrative regions of Jordan. The insert shows the location of Jordan in the middle east.

Jordan is classified as an upper middle-income country with a Gross National Income (GNI) per capita of $4,256 in 2021 for its 11 million population (Government of Jordan, 2022). The population includes a significant number from conflict-affected areas in Syria, Palestine and Yemen, placing additional strain on the country's resources and infrastructure. The country has an area of 89,213 km^2. The climate of Jordan ranges between desert and arid to Mediterranean climate with hot and dry summers and wet and cool winters. Land terrain has a great influence on the climatic regions of Jordan. The climate variation across the country is influenced by topography. The rainy season extends from around October to May with high amounts of seasonal rainfall occurring through the months of December to March (Al Qudah et al., 2021).

Climate change is threatening to further exacerbate water scarcity issues in the country with cascading impacts on other sectors. Climate change impacts, including changes in water availability and extreme weather events, are considered within the WEF nexus framework. For example, many parts of the country are experiencing a negative trend in already low rainfall, increases in mean temperatures and number of hot days for a region that already has high temperatures (Figure 3). Climate change adaptation and resilience strategies are integrated into overall planning (IPCC, 2021).

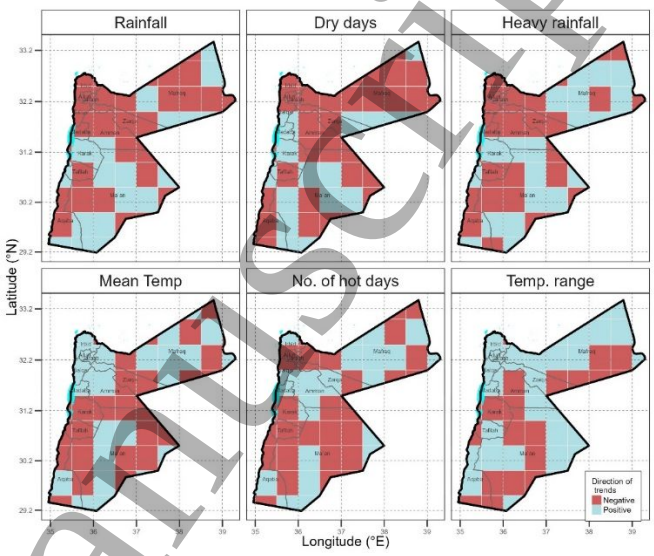

Figure 3: Annual trends in climate indices for Jordan between 1981 and 2019. The Mann-Kendall test was used to determine the direction of the trend in each grid cell. Data from W5E5.

Given Jordan's geographical location and shared environmental challenges with neighboring countries, international cooperation is essential in addressing the WEF nexus. This includes collaborative efforts on water management, environmental conservation, and food security (World Bank, 2022). Key points related to the WEF Nexus in Jordan include water management, agriculture, and environmental sustainability. Jordan faces water scarcity issues, and more effective water management is crucial as almost three-quarters of the country is classified as deserts (Ministry of Water and Irrigation, 2019; Qtaishat, 2020). In few of the WEF-nexus assessments for Jordan, the focus has been on water poverty (Jemmali & Abu-Ghunmi, 2016), the water-energy nexus (Al-Masri et al., 2019), or the water-agriculture nexus (Talozi et al., 2017) with limited studies on the interconnectedness of all the three pillars of the WEF nexus.

4. WEF sector status in Jordan

4.1 Water

Jordan is the second most water scarce country worldwide, with an annual per capita water availability of about 60 m^3, which is well below the global average (5500 m^3) and for Middle Eastern countries (480 m^3) (Al-Ansari et al., 2014; Hussein, 2018; Ministry of Water and Irrigation, 2023b). The country's renewable water supply currently only meets about two-thirds of the population's overall water needs, with the rest compensated by groundwater, which is being abstracted faster than it is being recharged (Al-Addous et al., 2023). Agriculture is by far the largest user of both surface and groundwater, consuming 62% of surface water and 47% of groundwater in the country (Table 1). Jordan's total water usage in 2022 was 1.1 billion m^3, of this, 519 million m3 was allocated for domestic consumption, 537 million m3 for agricultural use, and 35.2 million m^3 for industrial activities (Ministry of Water and Irrigation, 2023a). The country's major surface water resources, the Jordan River and the Yarmouk River, are shared with Israel and Syria which leaves only a small amount for Jordan (Daoud et al., 2022).

The Disi Water Conveyance Project from the non-renewable Disi aquifer to the capital Amman, opened in July 2013, increases available resources by about 12% (Qtaishat, 2020; Radaideh, 2022). It is planned to bridge the remaining gap between demand and supply through increased use of reclaimed water and desalinated seawater (Daoud et al., 2022; Zawahri, 2023). Water scarcity impacts every aspect of Jordanian life, and it is one of the greatest challenges to economic growth and development. Water scarcity is even projected to increase due to the effects of climate change, which will result in lower and more erratic rainfall patterns and high temperatures, resulting in increased water scarcity impacts on crops and livestock (Al-Bakri et al., 2013; Al Qatarneh et al., 2018; Hussein, 2018). The combined effects of climate change and population growth (including migration) is anticipated to put more pressure on limited land and water resources and to increase the challenge of sustainable development in Jordan.

Jordan's water sector is dealing with challenging matters that are closely related to aridness, the fast-growing population, and the geopolitical circumstances of the country. Al-Muqdadi et al. (2021) describe the water situation in the country as dire and confounded by climate change and the conflicts in the region, which, apart from other things, increase pressure on infrastructure and the water supply system. In addition , water use is not efficient, and the high loss of water is also one of the other problems (Zawahri, 2023). The water distribution network is deteriorating due to poor maintenance, leading to leakages and wastage (Government of Jordan, 2022; Tawfik et al., 2023; Zawahri, 2023).

Table 1: Annual volume and percentage of water use by sector and source in Jordan for 2021 (Source: Ministry of Water and Irrigation (2023a)). Water from desalination is insignificant at national level.

Use	Surface water		Groundwater		Treated waste water		Total volume	
	Million m^3	%	Million m^3	%	Million m3	%	Million m^3	%
Domestic	141	46.07	378	61.16	0	0	519	47.57
Irrigation	161	52.61	212	34.3	164	98	537	49.2
Industry	4	1.3	28	4.53	3.2	2	35.2	3.2
Total	306	100	618	100	167.2		1091.2	100

The water sector governance in Jordan is mainly organized across the different departments, and it is poor in collaborating well with other sectors and different stakeholders. Al-Masri et al. (2019) highlighted the deficits in integrating WEF related policies and the importance of coherent and detailed policies which take into account the interconnections among the WEF sectors in Jordan. This split-up obstructs the achievement of sustainable water management practices. Financial constraints also prevent the enlargement of modern infrastructure and the further implementation of water-saving technology (Al-Masri et al., 2019; Al-Muqdadi et al., 2021).

4.2 Energy

The energy security is an important pillar for the sustainable development of Jordan. The primary energy sources for Jordan are imported oil (54%), natural gas (35%), and renewable energy (wind and solar, 7%) with the remainder coming from coal (2%) and coke (1%) (Ministry of Energy and Mineral Resources, 2022). Of these sources, less than 10% is locally produced, mainly in terms of renewable energy, meaning that Jordan is reliant on imported energy (Jordan Strategy Forum, 2023). Currently, the country still consumes about 9.6 million cubic meters of natural gas annually in generating electricity, an amount that is still supplemented further through a partnership and connection with the regional grids (Ministry of Energy and Mineral Resources, 2022).

Jordan is also a node in the electrical connections of neighboring countries. Jordan's power demand is growing from two perspectives: economic growth in several sectors and population growth, both natural and through immigration

from neighboring countries caused by regional instability (Abu-Rumman et al., 2020). Jordan is on the path towards a clean-energy future through the promotion and adoption of renewable energy and green technologies across all sectors. Jordan's target is to have a 31% renewable energy share in its local electricity generation by 2030, with trends in the recent past showing growth in renewable energy supply in the country (Figure 4). Much of the expected additional capacity will be solar PV. If the same capacity factor is maintained, an additional capacity of 3.35 GW must be installed on top of the current 2.58 GW. Jordan's electrified future is already visible if the sheer number of fully electric vehicles (EV) flooding into the country is considered.

There is a nationwide rush to meet the growing number of EVs by matching the infrastructure to the demand, both special electricity tariffs and countless charging points are either deployed or under development. Another tangible change is the number of technology deployment initiatives that distribute and install green and energy saving technologies across the country, such as renewably sourced rural electrification expansion, solar PV installations for town buildings, solar water heaters for residential areas, and a push to phase out costly inefficient technology in areas such as lighting.

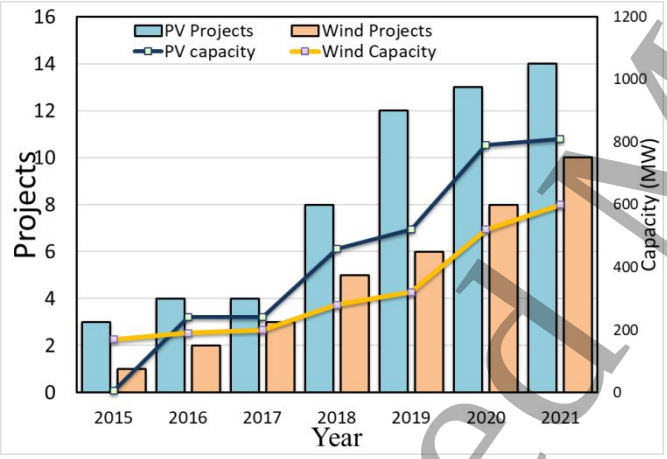

Figure 4: Jordan's renewable energy capacity growth (2015-2021) Data source: (Ministry of Energy and Mineral Resources, 2022).

4.3 Agriculture

Jordan has a land area of around 8.9 million ha with three distinct and diverse agricultural climatic zones; the Jordan Valley, the Highlands, and the Eastern Desert. According to Jordan's Fourth National Communication on Climate Change, 2023, the agricultural area in Jordan is about 400 000 ha (4.5% of Jordan's land area). The irrigated area is very limited (96 000 ha), and the majority of arable land is rainfed, but the average rainfall is below 200 mm per year in 90% of Jordan's areas, which makes it one of the world's most water-deficient countries (Anbar et al., 2020; Noria Research, 2022; Tawfik et al., 2023). Agricultural exports account for 25% of all Jordan's exports. Although agriculture encompasses food, industrial and non-food cash crops, for this discussion, the term agriculture is limited to food production.

A considerable quantity of the Jordanian production of fruits and vegetables is exported to high-end markets such as Western and Eastern Europe, as Jordan has a competitive advantage as a supplier of fresh fruits and vegetables (El-Zubi & Shuaibi, 2021; MoEnv, 2020) . Tomatoes are the most important crop in terms of production quantity, followed by cucumber and gherkins, potatoes, olives and watermelons, completing the top five mostly produced crops (Figure 5).

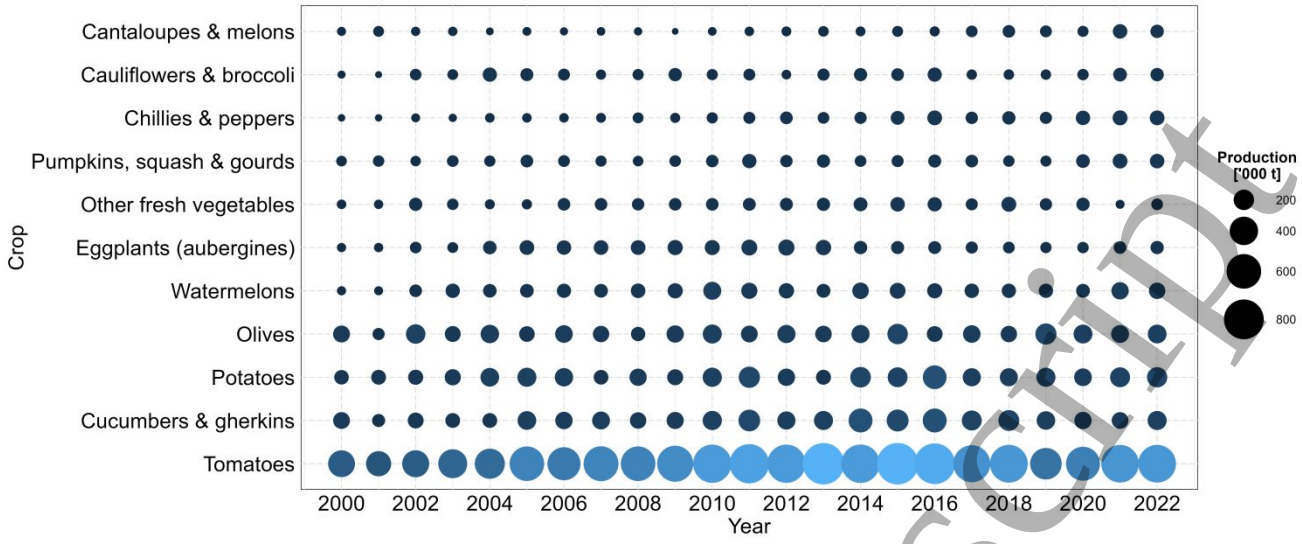

Figure 5: Trends and amounts of agricultural crops for the most important crops in Jordan between 2000 and 2022 (Data from FAOSTAT).The circle diameters and the color both represent production levels.

From farmers to agri-food processors, retailers, and consumers, Jordan's rich and diverse agricultural system plays a critical role in the economy. It accounts for 5.6% of the gross domestic product (GDP), contributes to national food security (Ministry of Water and Irrigation, 2019). Beyond the economy, however, the agriculture sector is a critical enabler of employment, rural development, and food security, as well as being a focus for addressing many of the environmental and climate change-related challenges facing the country. The government aims to improve the exportability of agricultural goods while at the same time coping with climate change and achieving sustainable development goals.

The agriculture sector has been growing and increasing its share with a variety of lucrative investment opportunities present in Jordan's agriculture sector (Al-Addous et al., 2023). However, Jordan is still a substantial net importer of food, a situation that is unlikely to change any time soon because of a myriad of factors. Boosting farmers' productivity can help them leverage the food system, earn more money from what they grow, and meet the demand coming from cities for higher-value crops.

5. Interconnectedness of WEF sectors in Jordan

The water, energy and food sectors in Jordan are strongly interconnected and interdependent. In the water sector, Jordan faces severe water scarcity. The country traditionally relied heavily on the Jordan River, but its flow has significantly decreased over the years (Abdulla et al., 2018; Givati et al., 2019; Hammouri et al., 2017). Jordan is highly dependent on energy imports, as it lacks significant domestic energy resources (Juaidi et al., 2022). The country has been working on diversifying its energy mix, including investments in renewable energy sources like solar and wind power.

Finally, for food, Jordan faces challenges in food security due to limited arable land, water scarcity, and the need to import a substantial portion of its food (Shevah, 2015). Agriculture is a significant consumer of water resources, and the country is exploring more water-efficient and sustainable agricultural practices. It was established that renewable energy appears to be an essential solution to enhance all the sectors combined. For example, it is imperative for Jordan to produce the quantities of energy needed to desalinate sea water and irrigate crops to ensure an adequate food supply for its population (Albatayneh et al., 2022). For this reason, there are currently more than 50 brackish water desalination plants using reverse osmosis installed by farmers in the Jordan Valley for irrigation purposes with capacities of up to 2 400 m3/d (Qtaishat et al., 2017).

The interconnections between the water, energy, and food sectors can affect each other in many ways. Water is crucial for agriculture, which is the largest consumer of water in the country (Purwanto et al., 2021; Rasul & Sharma, 2016). At the same time, energy is required to pump, desalinate, and treat water, making the water sector highly dependent on energy. In turn, food production, particularly in the country, depends on water availability and affordable energy for irrigation and processing.

The energy sector relies on water for cooling and hydropower generation. For example, in Jordan, there is a hydropower plant at the King Talal dam on the Az Zarqa River and has a capacity of 5 MW. In addition, the head of the cooling water at the Aqaba thermal power station is also used to generate hydroelectric power. These two stations together generate over 60 GWh of electricity (0.4% of the electricity generated in the country) (Shatnawi et al., 2021; Siam et al., 2022). Biomass is another source of energy

although it is not well developed (contributing 0.1% of the total energy). The country generates nearly 3 million tons of municipal solid waste annually, and this can be potentially used for energy production (Myyas et al., 2023). Climate change affects all three sectors, with potential impacts on water availability, energy production, and agricultural productivity. The policy and management of the WEF in Jordan have different aspects.

Jordan has recognized the importance of an integrated approach and has been working on policies and strategies that consider the WEF nexus (Government of Jordan, 2022). Examples of these policies include the Jordan National Water Strategy 2016-2025, Red Sea-Dead Sea Water Conveyance Project (Red-Dead Project), Sustainable Energy for Water Desalination, Jordan Renewable Energy and Energy Efficiency Fund (JREEEF) for Agriculture, Scaling Solar-Powered Irrigation, Rehabilitation of Jordan's Agricultural Water Sector and the Disi Water Conveyance Project among others.

Efforts include promoting water and energy efficiency, sustainable agricultural practices, and renewable energy development. For example, there are designs for energy savings in water and wastewater treatment facilities (Alrbai et al., 2024; Salameh et al., 2009). There are many challenges that face WEF in Jordan. Balancing the competing demands of water, energy, and food while ensuring sustainability is complex. In addition, political and economic factors, as well as regional conflicts, can affect resource availability and management. In summary, the WEF Nexus approach in Jordan involves addressing the interconnected challenges of water scarcity, energy dependence, and food security. Considering the interdependencies among these vital sectors, integrated and sustainable solutions are crucial for the country's development.

6. Key lessons learned in fostering WEF nexus in Jordan

Form the stakeholders, seven key overarching lessons have been learned in fostering WEF nexus in Jordan. These are that (i) data/information sharing is vital, (ii) WEF nexus requires funding, (iii) collaborations among actors are key, (iv) inclusivity is necessary from design, (v) clear responsibilities and boundaries among stakeholders are needed, (vi) sustainability and cohesion are a must and (vii) building trust among and within organizations is a primary ingredient for a successful WEF nexus approach (Figure 6). Each of these are described in more detail in the sections below.

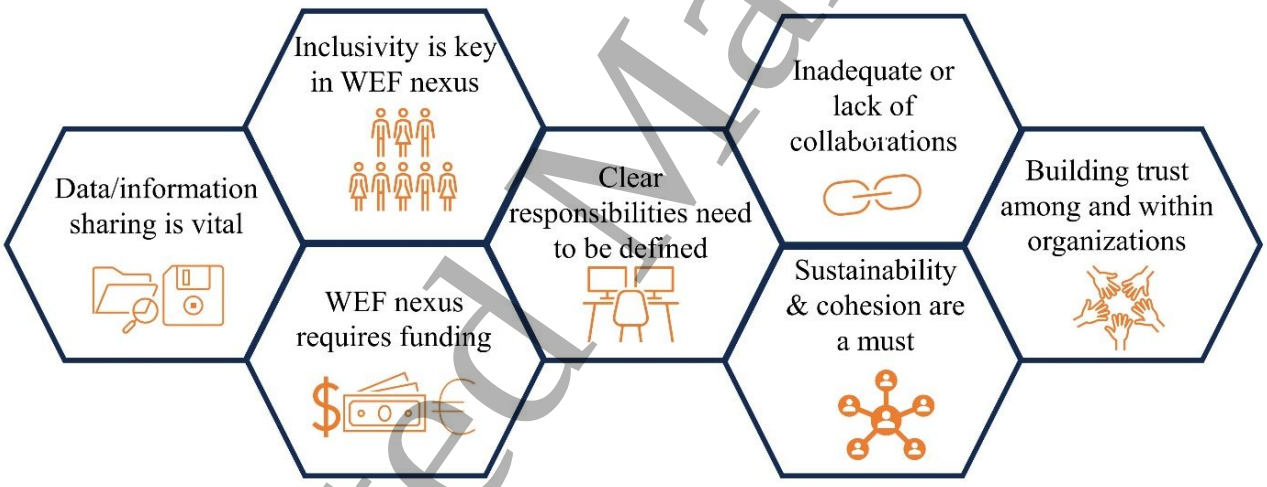

Figure 6: Key lessons learned in fostering WEF nexus approach for sustainable development in Jordan as identified by stakeholders.

6.1 Data/information sharing is vital

Data is essential for science-based informed decision making in all WEF sectors. Data availability means that data must be obtainable and accessible in its original form, whether numerical or categorical. However, it is currently extremely difficult across sectors to obtain the data necessary to carry out comprehensive assessments of threats to WEF security in Jordan. Some sectors or sub-sectors cannot collect adequate observations to document their WEF resources' current state or changes. Those who are collecting data seem not willing to share or distribute it with other sectors or experts for their use, even among government agencies and ministries in the country, let alone outside government or agencies. Those few who seem willing to share either charge a fee for official data or have ridiculous protocols, bureaucracy and red tape required to get the data from them, which is very exhausting and requires. This situation presents two concurrent tragedies; (i) data collection systems are inadequate and need to be upgraded or established and (ii) already collected data sharing is so constrained to be nearly impossible to access. These attitudes towards data exchange

and attempts to limit their sharing suggest that more proactive initiatives and policies on data exchange and alternative observational systems need to be developed to avert a strategic knowledge gap.

The effective implementation of a WEF nexus approach relies heavily on robust data and information availability, sharing mechanisms, and further sustainability. Data collection comes at a cost, and probably cost-sharing mechanisms for data collection are necessary, but these can be mutually offset as each sector requires data. Types of data can be categorized into water data, food and agriculture data, energy data, and cross-cutting or integrated data. The required water data includes water availability and sources, water demand and consumption, water quality, water infrastructure and trends in these variables. For energy, data on production, consumption, efficiency, energy security, availability and sustainability. In the food sector, the required information pertains to agricultural land use, crop and livestock production, supply chains, and food quality. Cross-cutting or integrated data include data on climate parameters, socioeconomic data, technology development and deployment, economic indicators and policy frameworks.

Earth observation data is crucial in fostering the WEF nexus approach by providing comprehensive, timely, and accurate information that helps integrate and manage these interdependent resources effectively. Earth observation data is useful in WEF initiatives for monitoring and assessment of quantity and quality of water, agriculture and energy resources. It also allows data to be seamlessly integrated across the water, energy, and food sectors in the country for decision-making. For example, it can be used to analyze the impacts of water usage in agriculture on energy consumption or the effects of energy production on water and food resources. Earth observation data also forms an important part as input for modeling and simulation necessary for decision support for policy making, risk management, resource allocation and response.

6.2 WEF nexus requires funding

Among the most limiting factors to achieving interlinkages in the water, energy and food sectors in the Jordan is limited funding resources for a WEF nexus approach. While investments in the WEF sectors have been increasing over the past years, there still remain financial gaps in managing the often-limited resources in an integrated manner. As in other countries, budgeting and resource allocation is centralized and facing increasing pressures from other economic sectors. As it stands, there are many projects planned for implementation in the separate water, energy and agriculture sectors of the country. For example, for the water sector the planned Aqaba-Amman Conveyor (AAC) project, which is crucial for boosting Jordan's water supply, will impose a substantial financial burden. Renewable energy (solar and wind) expansion in rural areas in conjunction with private sector players will also cost substantial investment. In the same manner, there are many capital projects on enhancing and new schemes for fish farming, fruit production, mushroom production, and the cultivation of new agricultural commodities to meet increasing demand and markets.

While these individual sector projects are important and budgeted for using various financial resources, there is a general lack of funding for collaboration projects among the sectors. For example, from the national planning and fiscal funding, there are hardly any allocations for nexus planning and implementation across sectors. The ministerial/sector allocations are not sufficient to cover needs for the sectors and therefore, there are no further resources that can be allocated for cross-sectoral engagement, planning and implementation. Thus, funding for cross-sectoral implementation is therefore limited and a hindrance to achieving a viable WEF nexus approach. In this regard, dedicated funding is an important pillar for implementation in Jordan.

6.3 Collaborations among actors are key

The current sector ecosystem lacks collaboration across players in the country in order to build an integrated approach to water, energy and food security. Many factors explain the lack of collaboration between partners in the WEF sectors. One of them is the lack of multi-disciplinary training in staff in line ministries, private sector workers and other stakeholders. Therefore, it is difficult for a water engineer to think along the lines of an agriculture specialist or electrical engineer. For many years people have been trained in specific disciplines and they carry their routines for the rest of their working lives according to their line training. It therefore becomes difficult to foster collaboration and cross-sector discourse between sectors due to a lack of understanding of each other as individuals, organizations and ministries continue to work in silos.

Secondly, there is a lack of a national WEF nexus platform to enhance stakeholder engagement and discussions on WEF nexus issues. Such a platform is necessary to build an understanding among people working in different sectors, appreciating each other's work and identifying potential areas of entry in each other's sector for national good. Thirdly, there is a lack of collaboration because the full understanding of the dynamic relationships between the entire WEF nexus sectors is limited, especially at regional and national scales. Thus, a new conceptual approach and a paradigm shift is required to foster collective working across WEF sectors.

Finally, many approaches and models used by WEF sectors have been developed for specific disciplines. Examples include hydrological models, crop models, climate models, econometric models, energy models, and biodiversity models. It takes considerable time and effort for

people to master the specific uses of these models. Therefore, expecting that other non-specialist users will understand and apply them is an over stretch. It is therefore only through inter-sectoral collaboration that model coupling across sectors can be made possible with backward and forward linkages.

6.4 Clear responsibilities and boundaries among stakeholders are needed

One of the key requirements for operationalization of the WEF nexus approach in Jordan is to have clear responsibilities and awareness about these responsibilities. This entails clearly specifying who is doing what and with whom. This enables the individual parts to work together to achieve common goals in Jordan and the region. However, the individual mandates at the ministerial/department/agency/company level are clearly defined and fairly understood, but the responsibilities in the broader framework of WEF are not clearly defined or understood. This is especially regarding what needs to be done beyond the current responsibilities. The concept of WEF is in its nascent phase; therefore, many aspects are not yet clearly understood by the sector players, limiting effectiveness and impact of these sectors on development. Therefore, clearly defining roles and responsibilities within WEF is fundamental to operationalize it.

6.5 Sustainability and cohesion of activities and initiatives is essential

Implementation of WEF activities in most cases follows project-based implementation and once the project is completed, there is no follow-up or uptake of the established systems to ensure sustainability. It is imperative that WEF activities be mainstreamed in local, regional and national development planning so that design and implementation can be sustained beyond the project periods. This requires capacity building, strong frameworks for continuity and long-term thinking beyond the 3-5 years usual project periods. Actors are also working in silos implementing scattered projects across the country and in some cases duplicating activities and services. In this regard, to truly benefit from WEF nexus initiatives, sustainability thinking and cohesion of efforts in both planning and implementing WEF programs are absolutely vital for impact.

6.6 Building trust among and within organizations is a primary ingredient for a successful WEF nexus approach

Related to the lack of collaboration and limited understanding, mistrust between and among players in the WEF sector is breeding. There are many justified reasons for mistrust to limit cooperation among players in WEF. One of the key reasons is the rent-seeking setup among players, where organizations only see each other as potential clients and not as partners. For example, water sector players may see people in agriculture as clients that pay water abstraction tariffs, and energy sector players see those in agriculture as customers of energy and agriculture players consider both energy and water sectors as value chain suppliers for their business.

The backward and forward linkages beyond these supplier-client relationships are difficult to foster as the other always feels exploited by the other, and any attempts to build relationships are considered avenues to expand extractive opportunities. While this is rife between and among private sector players in Jordan that seek to maximize returns, this also happens in public sector agencies and utilities. Thus, the long road of building trust among and within the organizations is therefore needed to achieve the WEF nexus in the country.

6.7 Inclusivity is necessary for WEF project design

As a key sustainable development facet, WEF sectors are a mirror of society and therefore, the reality is that many marginalized groups bear the brunt of inaccessibility to both services and wheels of power. These marginalized individuals and groups do not have a voice or agency regarding WEF issues. Exclusion happens on the facets of their identity such as ethnicity, social status, gender, and/or disability status, increasing their obstacles to access and decision making. For example, women and other marginalized groups are absent from decision-making roles in WEF sectors in Jordan. Thus, the management of water, energy and food sectors can be conduits of exclusion and disparity. This is especially interesting for Jordan, a country with a significant number of refugees from regional strife and conflict. These may represent an important pool of talent in managing water, energy and agriculture, but they find themselves in the unfortunate circumstances of being excluded. It is critical for WEF success that all voices are heard, listened to, and respected, as this is the first step towards building trust.

While stakeholders may have different perspectives, values, or priorities on WEF issues, they can still work together towards a common goal. The lack of inclusivity is rooted in the fact that WEF governance and institutions, processes, and practices at all scales involve multistakeholder dialogue that then reflects on societal order and limits the ability to understand underrepresented communities. Inclusivity holds so much potential to unlock impact of WEF for widespread and prolonged impact for sustainable development in Jordan.

7. Discussion

In this paper, we described the status, experiences and lessons learned in fostering the WEF approach in Jordan to highlight the focus areas and themes for Jordan and countries

on a similar path. We draw these from a pool of diverse stakeholders working in various sectors being representative of the WEF landscape in Jordan. Collecting such information on experiences and views is imperative for a more integrated approach to sustainable development as envisioned in the WEF nexus approach. With such insights, the WEF stakeholders in Jordan, the region and elsewhere can possibly understand and ultimately find each other by addressing the observed issues that limit current practices.

We observe that many stakeholders are involved in the WEF nexus approach in Jordan. These go beyond the sector-specific government ministries and agencies to the private sector, academia, non-governmental organizations, and individual farmers, among other cross-sectoral players. These diverse stakeholders bring to WEF nexus vast cumulative experiences and a plethora of often divergent interests and perspectives. This is not surprising and somewhat expected as finding convergence for such a wide range of stakeholders can be daunting, as already reported elsewhere (Daher et al., 2020; Markantonis et al., 2019; Sušnik & Staddon, 2022). While this can be challenging, we posit that understanding these dynamics provides for the development of counter-strategies for engaging public, private and civil society stakeholders in WEF nexus decision-making processes (Ghodsvali et al., 2019; Kipruto, 2024). Therefore, from an implementation perspective, as proposed by Warner (2005), boundaries between use, functions, disciplines, experts and lay people need to be torn down, while administrative boundaries must give way to unified management of resources for integrated management to be successful.

We also find that fostering the WEF nexus in Jordan could be more complicated because of many geographic and historical factors, which may not be an issue in other countries or regions. For example, Jordan is a very arid country with limited water resources against rising demand (Radaideh, 2022; Ramirez et al., 2022), and therefore every drop counts. Consequently, the demand for water far exceeds the current supply for agriculture, domestic use, industry and others (Ministry of Water and Irrigation, 2019). Key agricultural areas such as the Jordan often face water shortages for crop production with downstream impacts on food security, employment, export earning and other aspects of the agricultural value chain. There is increasing reliance on non-renewable groundwater resources (Al-Omari et al., 2015; Odeh, 2019). The implications of water management therefore, extend beyond agricultural production and cascade down the economy. This could be different from water-abundant tropical countries where availability is not limiting to sectoral development, but other aspects such as climate change, quality, or distribution are an issue (Botai et al., 2021; Nhamo et al., 2018).

The lessons learned from the challenges in fostering WEF are certainly not peculiar to Jordan but perverse in many countries aiming for sustainable development. For example, Verhagen et al. (2021) have showed that in the eastern Nile Basin, conventional resource management involve very limited data and information sharing among stakeholders and yet coordinating WEF resources regionally by sharing river flow data and trade information can increase economic returns by over 15%. Some of the data sharing challenges identified in WEF identified by McCarl et al. (2017), such as proprietary interests, scale differences in analysis, model requirements, representation of unexplored possibilities, assembly cost and representation of stochastic variation, with visualization are also rife in Jordan. The 'silos' approach to water issues is also perverse in many other countries (Mabhaudhi et al., 2018; Markantonis et al., 2019).

Similarly, lack of limited funding resources (Sušnik & Staddon, 2022), inadequate or lack of collaborations (Kipruto, 2024; Pahl-Wostl, 2019), lack of clear responsibilities/awareness and unspecific terms of references (Liu et al., 2017; Yillia, 2016), sustainability/scattered activities and initiatives (Pahl-Wostl, 2019), mistrust among and within organizations (Daher et al., 2020; Kipruto, 2024), lack of inclusivity (Imburgia, 2024; Villamor et al., 2020) are also common challenges for sustainable development. While these are significant challenges to achieving WEF targets, they are not insurmountable, as Jordan is on a path to sustainable development. Olawuyi and Oche (2022), looking at a case in West Africa, reported many bottlenecks to investment and funding the WEF nexus approach. Similarly, the funding issue has been discussed with suggestions to tap into global funding for WEF in South Africa (Mabhaudhi et al., 2018) and in Central and South Asia (Akram et al., 2024).

Future studies focusing on WEF challenges in other regions of the world are encouraged. Among many other things, these should consider tailored assessments of data collection mechanisms, stakeholder engagement, and policy and regulatory frameworks. Comparative studies on capacity building initiatives, technologies and innovative solutions, international collaborations and monitoring and evaluation systems to track the progress of WEF initiatives are needed. These are important in order to address the unique conditions in regions and fully realize the WEF concept, which will contribute to sustainable development and resilience. Thus, fostering WEF in Jordan should be considered beyond securing water for agriculture but as a framework for the sustainable socio-economic development of the country. While attempts were made to ensure all key stakeholders were represented in this study, there were still some groups that might not have been represented in the study. Future studies can therefore, extend the scope of the study to include those.

8. Conclusions

In this paper, the characteristics of Jordan that make it special regarding fostering proper water, energy and agricultural water management is provided. The status of the water, energy and food sectors are described with potential, and opportunities are identified in all of them amid growing internal and external challenges. We conclude that with the challenges that Jordan is facing, an integrated approach to the management of water, energy and food resources across all levels of government that is in sync with local and international partners is needed. Such a framework should play alongside investment in technology, infrastructure development, and capacity building, especially for arid and resource limited countries such as Jordan, where a fall in one of the pillars of WEF affects other sectors. Therefore, the WEF framework can and should be applied beyond the narrow scope of agricultural water management to realize the full benefits. This is especially so in the context of climate change and other anthropogenic challenges that increase pressure on water, energy and food resources.

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Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

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Author contribution statement

XXX.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this study.

References

Abdulla, F., van Veen, W., Qdais, H. A., van Wesenbeeck, L., & Sonneveld, B. (2018). The impact of climate change on water availability and recharge of aquifers in the Jordan River Basin. *Climate Change and Global Warming, 10*. 50

Abu-Rumman, G., Khdair, A. I., & Khdair, S. I. (2020). Current status and future investment potential in renewable energy in Jordan: An overview. *Heliyon, 6*(2). 37

Akram, H., Mohazzam, S., & Ali, S. H. (2024). Water-Energy-Food (WEF) Nexus and the SDGs in Central and South Asia. In *The Water, Energy, and Food Security Nexus in Asia and the Pacific* (pp. 191-205): Springer, Cham.

Al-Addous, M., Bdour, M., Alnaief, M., Rabaiah, S., & Schweimanns, N. (2023). Water Resources in Jordan: A Review of Current Challenges and Future Opportunities. *Water, 15*(21), 3729. 30

Al-Ansari, N., Ibrahim, N., Alsaman, M., & Knutsson, S. (2014). Water demand management in Jordan. *Engineering, 6*(1), 19-26. 31

Al-Bakri, J. T., Salahat, M., Suleiman, A., Suifan, M., Hamdan, M. R., Khresat, S., & Kandakji, T. (2013). Impact of climate and land use changes on water and food security in jordan: Implications for transcending “the tragedy of the commons”. *Sustainability, 5*(2), 724-748. 33

Al-Masri, R. A., Chenoweth, J., & Murphy, R. J. (2019). Exploring the status quo of water-energy nexus policies and governance in Jordan. *Environmental Science & Policy, 100*, 192-204. 60

Al-Muqdadi, S. W., Khalaifawi, A., Abdulrahman, B., Aziz Kittana, F., Zaki Alwadi, K., Humam Abdulkhaleq, M., . . . Al Dahmani, R. (2021). Exploring the challenges and opportunities in the Water, Energy, Food nexus for Arid Region. *Journal of Sustainable Development of Energy, Water and Environment Systems, 9*(4), 1-30. 59

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*(4), 1176-1188. 75

Al Qatarneh, G. N., Al Smadi, B., Al-Zboon, K., & Shatanawi, K. M. (2018). Impact of climate change on water resources in Jordan: a case study of Azraq basin. *Applied Water Science, 8*, 1-14. 64

Al Qudah, A., Rusan, M. J., Al-Qinna, M. I., & Abdulla, F. A. (2021). Climate change vulnerability assessment for selected agricultural responses at Yarmouk River Basin Area, Jordan. *Mitigation and Adaptation Strategies for Global Change, 26*, 1-21. 66

Albatayneh, A., Hindiyeh, M., & AlAmawi, R. (2022). Potential of renewable energy in water-energy-food nexus in Jordan. *Energy Nexus, 7*, 100140. 39

Albrecht, T. R., Crootof, A., & Scott, C. A. (2018). The Water-Energy-Food Nexus: A systematic review of methods for nexus assessment. *Environmental Research Letters, 13*(4), 043002. 2

Alrbai, M., Al-Dahidi, S., Al-Ghussain, L., Alahmer, A., & Hayajneh, H. (2024). Minimizing grid energy consumption in wastewater treatment plants:

Towards green energy solutions, water sustainability, and cleaner environment. *Science of the Total Environment, 926*, 172139. 86

Anbar, A. H., Abu-Dalhoum, M., Maslamani, A., Al Antary, T. M., & Sawwan, J. (2020). Agricultural Patterns in Jordan: a new analytical approach. *Fresenius Environmental Bulletin, 29*(12), 11006-11016. 42

Apeh, O. O., & Nwulu, N. I. (2024). The water-energy-food-ecosystem nexus scenario in Africa: Perspective and policy implementations. *Energy Reports, 11*, 5947-5962. 101

Biggs, E. M., Bruce, E., Boruff, B., Duncan, J. M., Horsley, J., Pauli, N., . . . Curnow, J. (2015). Sustainable development and the water–energy–food nexus: A perspective on livelihoods. *Environmental Science & Policy, 54*, 389-397. 1

Botai, J. O., Botai, C. M., Ncongwane, K. P., Mpandeli, S., Nhamo, L., Masinde, M., . . . Murambadoro, M. D. (2021). A review of the water–energy–food nexus research in Africa. *Sustainability, 13*(4), 1762. 125

D'Odorico, P., Davis, K. F., Rosa, L., Carr, J. A., Chiarelli, D., Dell'Angelo, J., . . . Suweis, S. (2018). The global food-energy-water nexus. *Reviews of geophysics, 56*(3), 456-531. 3

Daher, B., Hannibal, B., Mohtar, R. H., & Portney, K. (2020). Toward understanding the convergence of researcher and stakeholder perspectives related to water-energy-food (WEF) challenges: The case of San Antonio, Texas. *Environmental Science & Policy, 104*, 20-35. 25

Daoud, I. Y. H., Dehnavi, S., & Ribbe, L. (2022). Towards good water governance: An analysis of Jordan's National Water Strategy. *Environmental Management, 69*(5), 847-860. 48

Dargin, J., Daher, B., & Mohtar, R. H. (2019). Complexity versus simplicity in water energy food nexus (WEF) assessment tools. *Science of the Total Environment, 650*, 1566-1575. 23

El-Zubi, F., & Shuaibi, E. (2021). Jordan's Role in A Regional Food Hub. *Jordan Journal of Agricultural Sciences, 17*(3), 171-185. 69

Ghodsvali, M., Krishnamurthy, S., & de Vries, B. (2019). Review of transdisciplinary approaches to food-water-energy nexus: A guide towards sustainable development. *Environmental Science & Policy, 101*, 266-278. 73

Givati, A., Thirel, G., Rosenfeld, D., & Paz, D. (2019). Climate change impacts on streamflow at the upper Jordan River based on an ensemble of regional climate models. *Journal of Hydrology: Regional Studies, 21*, 92-109. 49

Government of Jordan. (2022). *National strategies for Water, Energy, and Food Security*. Retrieved from Amman, Jordan:

Haddaway, N. R., Bethel, A., Dicks, L. V., Koricheva, J., Macura, B., Petrokofsky, G., . . . Stewart, G. B. (2020). Eight problems with literature reviews and how to fix them. *Nature Ecology & Evolution, 4*(12), 1582-1589. 89

Hammouri, N., Adamowski, J., Freiwan, M., & Prasher, S. (2017). Climate change impacts on surface water resources in arid and semi-arid regions: a case study in northern Jordan. *Acta Geodaetica et Geophysica, 52*, 141-156. 51

Hoff, H. (2011). Understanding the nexus. 17

Hussein, H. (2018). Lifting the veil: Unpacking the discourse of water scarcity in Jordan. *Environmental Science & Policy, 89*, 385-392. 28

Imburgia, L. (2024). Secured WEF and Gender: Better Data for Equality and Resilience. In *The Water, Energy, and Food Security Nexus in Asia and the Pacific: The Pacific* (pp. 281-295): Springer International Publishing Cham.

Jemmali, H., & Abu-Ghunmi, L. (2016). Multidimensional analysis of the water-poverty nexus using a modified Water Poverty Index: A case study from Jordan. *Water Policy, 18*(4), 826-843. 94

Jordan Strategy Forum. (2023). *The Energy Sector: Jordan's Economic Vision Roadmap*. Retrieved from Amman, Jordan:

Juaidi, A., Abdallah, R., Ayadi, O., Salameh, T., Hasan, A. A., & Ramahi, A. (2022). Wind energy in Jordan and Palestine: Current status and future perspectives. *Renewable Energy Production and Distribution*, 229-269. 53

Kipruto, B. (2024). Challenges and Counter-Strategies for Engaging Stakeholders in Water-Energy-Food Nexus Decision-Making Processes. In.

Lazaro, L. L. B., Bellezoni, R. A., Puppim de Oliveira, J. A., Jacobi, P. R., & Giatti, L. L. (2022). Ten years of research on the water-energy-food nexus: An analysis of topics evolution. *Frontiers in Water, 4*, 859891. 19

Liu, J., Yang, H., Cudennec, C., Gain, A. K., Hoff, H., Lawford, R., . . . Zheng, C. (2017). Challenges in operationalizing the water–energy–food nexus. *Hydrological Sciences Journal, 62*(11), 1714-1720. 14

Mabhaudhi, T., Simpson, G., Badenhorst, J., Mohammed, M., Motongera, T., Senzanje, A., . . . Mpandeli, S. (2018). Assessing the state of the water-energy-food (WEF) nexus in South Africa. *Water Research Commission (WRC): Pretoria, South Africa, 76*. 126

Markantonis, V., Reynaud, A., Karabulut, A., El Hajj, R., Altinbilek, D., Awad, I. M., . . . Lamaddalena, N. (2019). Can the implementation of the water-energy-food nexus support economic growth in the Mediterranean region? The current status and the way forward. *Frontiers in Environmental Science, 7*, 84. 99

Mauer, B., & Venecek, J. (2022). Writing the Literature Review. *Strategies for Conducting Literary Research, 2e*. 92

McCarl, B. A., Yang, Y., Srinivasan, R., Pistikopoulos, E. N., & Mohtar, R. H. (2017). Data for WEF nexus

analysis: A review of issues. *Current Sustainable/Renewable Energy Reports, 4*, 137-143. 78

Ministry of Energy and Mineral Resources. (2022). *Annual Reports*. Retrieved from Amman, Jordan:

Ministry of Water and Irrigation. (2019). *Water Budget for Year 2019*. Retrieved from Amman, Jordan:

Ministry of Water and Irrigation. (2023a). *Jordan water sector facts and figures*. Retrieved from Amman:

Ministry of Water and Irrigation. (2023b). *National Water Strategy: 2023 - 2040: Summary*. Retrieved from Amman:

Mishra, B. K., Kumar, P., Saraswat, C., Chakraborty, S., & Gautam, A. (2021). Water security in a changing environment: Concept, challenges and solutions. *Water, 13*(4), 490. 9

MoEnv. (2020). *Agriculture Sector Green Growth National Action Plan 2021-2025*. Retrieved from Amman, The Hashemite Kingdom of Jordan.:

Mugagga, F., & Nabaasa, B. B. (2016). The centrality of water resources to the realization of Sustainable Development Goals (SDG). A review of potentials and constraints on the African continent. *International Soil and Water Conservation Research, 4*(3), 215-223. 98

Myyas, R. e. N., Tostado-Véliz, M., Gómez-González, M., & Jurado, F. (2023). Review of bioenergy potential in Jordan. *Energies, 16*(3), 1393. 84

Nhamo, L., Ndlela, B., Nhemachena, C., Mabhaudhi, T., Mpandeli, S., & Matchaya, G. (2018). The water-energy-food nexus: Climate risks and opportunities in southern Africa. *Water, 10*(5), 567. 87

Noria Research. (2022). Agriculture in Jordan at the Time of Climate Change: Identifying Causalities between Imperialism and Environmental Degradation. *Middle East*. 40

Odeh, O. (2019). Water Shortage in Jordan. *International Journal of Engineering and Management Sciences, 4*(4), 277-286. 76

Olawuyi, D. S., & Oche, A. (2022). WEF nexus and sustainable Investments in West Africa: The case of Nigeria. In *Water-Energy-Food Nexus and Climate Change in Cities* (pp. 243-258): Springer.

Orimoloye, I. R. (2022). Water, energy and food nexus: Policy relevance and challenges. *Frontiers in Sustainable Food Systems, 5*, 824322. 100

Pahl-Wostl, C. (2019). Governance of the water-energy-food security nexus: A multi-level coordination challenge. *Environmental Science & Policy, 92*, 356-367. 81

Pahl-Wostl, C., Bhaduri, A., & Bruns, A. (2018). Editorial special issue: the nexus of water, energy and food–an environmental governance perspective. *Environmental Science & Policy, 90*, 161-163. 18

Paré, G., & Kitsiou, S. (2017). Methods for literature reviews. In *Handbook of eHealth evaluation: An evidence-based approach [Internet]*: University of Victoria.

Purwanto, A., Sušnik, J., Suryadi, F. X., & de Fraiture, C. (2021). Water-energy-food nexus: Critical review, practical applications, and prospects for future research. *Sustainability, 13*(4), 1919. 102

Qtaishat, T. (2020). Water policy in Jordan. *Water policies in MENA countries*, 85-112. 34

Qtaishat, T. H., Al-Karablieh, E. K., Salman, A. Z., Tabieh, M. A., Al-Qudah, H. F., & Seder, N. (2017). Economic analysis of brackish-water desalination used for irrigation in the Jordan Valley. *Desalination and water treatment, 72*, 13-21. 96

Radaideh, J. (2022). Status of groundwater resources in Jordan. *Am J of Water Resour, 10*(2), 59-67. 35

Ramirez, C., Almulla, Y., Joyce, B., Huber-Lee, A., & Nerini, F. F. (2022). An assessment of strategies for sustainability priority challenges in Jordan using a water–energy–food Nexus approach. *Discover Sustainability, 3*(1), 23. 43

Rasul, G., & Sharma, B. (2016). The nexus approach to water–energy–food security: an option for adaptation to climate change. *Climate policy, 16*(6), 682-702. 56

Rother, E. T. (2007). Systematic literature review X narrative review. *Acta paulista de enfermagem, 20*, v-vi. 91

Rountree, V., Baldwin, E., & Hanlon, J. (2021). A review of stakeholder participation studies in renewable electricity and water: does the resource context matter? *Journal of Environmental Studies and Sciences*, 1-16. 24

Salameh, R. O., Al-Jamrah, A., & Roehrig, J. (2009). *Water and Wastewater Management Guide for Jordan's Industrial Sector*: University of Jordan.

Shatnawi, N., Abu-Qdais, H., & Abu Qdais, F. (2021). Selecting renewable energy options: an application of multi-criteria decision making for Jordan. *Sustainability: Science, Practice and Policy, 17*(1), 209-219. 83

Shevah, Y. (2015). Water resources, water scarcity challenges, and perspectives. *Water Challenges and Solutions on a Global Scale*, 185-219. 54

Siam, D., Alkasrawi, M., Abdelsalam, E., Salameh, T., Nawafah, H., & Al-Shannag, M. (2022). *Hydro Power Production in Jordan: Possibilities and Challenges.* Paper presented at the 2022 Advances in Science and Engineering Technology International Conferences (ASET).

Simpson, G. B., & Jewitt, G. P. (2019). The development of the water-energy-food nexus as a framework for achieving resource security: a review. *Frontiers in Environmental Science, 7*, 8. 8

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of business research, 104*, 333-339. 90

Sušnik, J., & Staddon, C. (2022). Evaluation of water-energy-food (WEF) nexus research: Perspectives, challenges, and directions for future research. *JAWRA Journal of the American Water Resources Association, 58*(6), 1189-1198. 71

Sylvester, A., Tate, M., & Johnstone, D. (2013). Beyond synthesis: Re-presenting heterogeneous research literature. *Behaviour & information technology, 32*(12), 1199-1215. 27

Talozi, S., Al Sakaji, Y., & Altz-Stamm, A. (2017). Towards a water–energy–food nexus policy: realizing the blue and green virtual water of agriculture in Jordan. In *The Water-Energy-Food Nexus in the Middle East and North Africa* (pp. 173-194): Routledge.

Tawfik, M. H., Al-Zawaidah, H., Hoogesteger, J., Al-Zu'bi, M., Hellegers, P., Mateo-Sagasta, J., & Elmahdi, A. (2023). Shifting waters: the challenges of transitioning from freshwater to treated wastewater irrigation in the northern Jordan Valley. *Water, 15*(7), 1315. 41

UNHCR. (2024). *Jordan Operational Data Portal (ODP)*. Retrieved from Amman, Jordan:

Verhagen, J., van der Zaag, P., & Abraham, E. (2021). Operational planning of WEF infrastructure: quantifying the value of information sharing and cooperation in the Eastern Nile basin. *Environmental Research Letters, 16*(8), 085006. 77

Villamor, G. B., Guta, D. D., & Mirzabaev, A. (2020). Gender specific differences of smallholder farm households perspective of food-energy-land nexus frameworks in Ethiopia. *Frontiers in Sustainable Food Systems, 4*, 491725. 80

Wang, X.-C., Jiang, P., Yang, L., Van Fan, Y., Klemeš, J. J., & Wang, Y. (2021). Extended water-energy nexus contribution to environmentally-related sustainable development goals. *Renewable and sustainable energy reviews, 150*, 111485. 97

Warner, J. (2005). Multi-stakeholder platforms: integrating society in water resource management? *Ambiente & sociedade, 8*, 4-28. 74

Waughray, D. (2011). *Water Security, the Water-Food-Energy-Climate Nexus: The World Economic Forum Water Initiative*: Island press Washington, DC.

Yillia, P. T. (2016). Water-Energy-Food nexus: framing the opportunities, challenges and synergies for implementing the SDGs. *Österreichische Wasser- und Abfallwirtschaft, 68*(3-4), 86-98. 21

Zawahri, N. (2023). Jordan. In *Routledge Handbook of Water and Development* (pp. 116-124): Routledge.

Zhang, C., Chen, X., Li, Y., Ding, W., & Fu, G. (2018). Water-energy-food nexus: Concepts, questions and methodologies. *Journal of Cleaner Production, 195*, 625-639. 4