



Examining Lebanon's Resilience Through a Water-Energy-Food Nexus Lens

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OPEN ACCESS

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Specialty section:

This article was submitted to
Social Movements, Institutions and
Governance,
a section of the journal
Frontiers in Sustainable Food Systems

Received: 27 July 2021

Accepted: 27 April 2022

Published: 20 May 2022

Citation:

Daher B, Hamie S, Pappas K and
Roth J (2022) Examining Lebanon's
Resilience Through a
Water-Energy-Food Nexus Lens.
Front. Sustain. Food Syst. 6:748343.
doi: 10.3389/fsufs.2022.748343

Lebanon faces a mix of underlying political and economic challenges, shocks, and triggering events that threaten the sustainability and resilience of its interconnected resource systems. The complex nature of these pressures begs for a systems approach to better understand the existing interconnections and to support the co-creation of cross-sectoral solutions to address them. This article specifically aims to: 1) conduct a scoping review of the existing literature and current events to identify interconnections between water-, energy-, and food-related challenges as they relate to the underlying conditions and triggering events at play in the context of Lebanon; 2) highlight ways in which the Water-Energy-Food (WEF) Nexus is a useful lens through which to understand and act upon issues at different scales; and 3) identify emergent themes including decentralization and systems thinking and their roles as catalysts toward more resilient resource systems. The examination concludes with two main recommendations: first, to create platforms and opportunities for interactive resource planning and decision making to facilitate systems-thinking for top-down WEF management; and second, to empower decentralized initiatives at the local level to build resilient, bottom-up solutions to WEF challenges.

Keywords: security, integrative planning, decentralized approaches, compound shocks, systems thinking

INTRODUCTION

Viewing water, energy, and food (WEF) resources as an interconnected system of systems has become an increasingly popular among researchers and policymakers during the past decade (Gain et al., 2015; Garcia and You, 2016; Hogeboom et al., 2021). At the same time, the WEF Nexus is still broadly defined and can be applied in many contexts. Through providing different conceptualizations and frameworks of the resource system interconnections, trade-offs and opportunities for cooperation between sectors can be identified. That is happening at a time of growing awareness and consideration among governments and international organizations about the role of the sustainability of interconnected resource systems in impacting security and resilience, at different scales. Resilience, a newly popularized term, has been defined in a variety of ways. Some see resilience as the potential of a system to maintain its functionality, structure, and feedbacks by reorganizing in response to disturbances (Walker et al., 2002, 2004), while others

define resilience as the ability of a system to remain within critical thresholds while adapting and changing (Folke et al., 2010). Resilience has been defined as a set of categorical reactions to disturbances (Béné and Doyen, 2017) or used to describe specific system features or specific types of shocks (Carpenter et al., 2001). The link between resilience and the interconnected resource systems warrants further delineation. For this research, we consider resilience as the ability of a system to withstand and recover from shocks, in this case, with a specific focus on the ability of water, energy, and food systems to recover from both natural and manmade shocks in Lebanon. As resilience becomes a topic of greater interest within WEF Nexus research, it is important to identify examples of resilience across the interconnected resource systems. It is also important to identify the connections between shocks and resource systems to determine when and how an integrated nexus approach is useful. The context of Lebanon is one with many challenges and factors affecting interconnected resource systems, and thus, it is an ideal case study for integrative evaluation of these resource systems as relates to the underlying political, economic, and social factors present in the country. The recent social, political, and financial shocks affecting Lebanon make it a unique study to see resilience, or lack thereof, in action.

This paper has three main objectives: first, it aims to conduct a scoping review of the existing literature and current events to identify interconnections between water-, energy-, and food-related challenges as these relate to the underlying conditions and triggering events at play in the context of Lebanon. Second, it will use the review to highlight the ways in which the WEF Nexus is a useful lens through which to understand issues at the national, local, and even individual level. Third, it identifies emergent themes including decentralization and systems thinking and their roles as catalysts toward more resilient resource systems by drawing from existing examples that highlight successful strategies and useful opportunities.

THE WATER-ENERGY-FOOD NEXUS

The past decade has seen a growth in the body of literature exploring water, energy, and food security interconnections (Sims and Dubois, 2011; Rogers, 2017; Simpson and Jewitt, 2019; Hogeboom et al., 2021). The concept first arose with a focus on water: understanding how the technical processes related to energy production utilize water, and how water management processes utilize energy (Siddiqi and Anadon, 2011). This interdependency soon spread to include the agricultural sector, which depends on both water and energy (Sims and Dubois, 2011; Rogers, 2017). Understanding the interconnectedness of these key resources provides valuable insights into the factors supporting human, social, and political security (World Economic Forum, 2017). Policy makers have increasingly recognized the value of a WEF Nexus approach in understanding complex resource challenges, even though its application remains limited (Gain et al., 2015; Garcia and You, 2016).

One trend over the past decade is the securitization of the WEF Nexus, as described by Leese and Meisch (2015).

This dialogue demonstrates a shift from a normative focus on distributional justice to a focus on the sustainability of water, energy, and food systems for the sake of long-term security. Security often describes the overarching durability of the WEF Nexus, while resilience describes the ability to endure and recover on a smaller scale (Allouche et al., 2014; Leese and Meisch, 2015; Simpson and Jewitt, 2019). Resilience is a term used in many disciplines and is applied to the WEF Nexus to describe systems that are sustainable and capable of quickly recovering from shocks. An in-depth review of WEF resilience literature by Hogeboom et al. (2021) found that resilience sometimes describes holistic sustainable ecological systems and, at other times, describes the specific resilience of a single feature of the system. Much of the literature focuses on creating theoretical conceptualizations of resilience for the WEF Nexus or describing management and infrastructure for resilience (Hogeboom et al., 2021). For this research, we consider resilience as an aspect of security that describes the ability of a system to withstand and recover from shocks.

In addition to the different systems with which the WEF Nexus interacts, there is the question of scale. Although the WEF Nexus was originally conceptualized with a normative focus on fair distribution of resources for the most vulnerable, much of the current literature emphasizes large-scale security issues at the national and international level (Leese and Meisch, 2015). Sustainability at the system level rarely incorporates sustainability of the livelihoods interacting with the nexus, although the literature has recently begun analyzing how it applies to smaller scales. Biggs et al. (2015) argue that the WEF Nexus approach often looks at “top-down,” large-scale resources, which may not predict results at the livelihood level. Consequently, the authors argue that incorporating a livelihood perspective can reveal bottom-up approaches and local opportunities to strengthen the operationalizing of nexus solutions. Simpson and Jewitt express concern that the “securitization” of the WEF Nexus has led to a neglect of livelihood and local-level results and reveal a tension between a security-oriented approach and an approach that considers fair distribution of resources. They argue that both perspectives must be considered to achieve the best results (Simpson and Jewitt, 2019). It is especially important at the local level, where the water, energy, and food systems may never have been conceptually separated (Allouche et al., 2015). WEF Nexus thinking is also vital for rural areas not reached by centralized systems (Leck et al., 2015; Terrapon-Pfaff et al., 2018).

Although the WEF Nexus focuses on supply and demand, resource limitation, and competition between the three sectors, analyzing small units of societal demand can clarify consumptive patterns and inform the most effective management policies and recommendations (Hussien et al., 2017). There has already been research done to this effect, both in developing models for understanding consumption and in regarding the usefulness of specific household-level recommendations (Hussien et al., 2017; Foden et al., 2019). In this study, we aim to build on the WEF Nexus literature and explore critical questions at the interfaces of the interconnected resource systems in the context of Lebanon, and to highlight both small- and large-scale themes.

METHODOLOGY

This research was carried out as a purpose-specific scoping review of Lebanon's current context. This method, based on the methodological framework described by Arksey and O'Malley (2005), prioritizes exploring a broad topic with a wide range of source types. The purpose of this review is to explore the usefulness of the WEF Nexus lens for understanding system interconnections and issues at different scales. This review identifies and maps key characteristics or factors (Munn et al., 2018) related to the WEF Nexus lens in Lebanon. In order to capture relevant literature from a broad set of topics related to our specific purpose, the characteristics and factors found in the initial reviews were mapped to inform additional review. The method can be broken down into two parts (Figure 1). First, reviews of topics related to water, energy, and food in Lebanon and to the underlying factors affecting water, energy, and food in Lebanon were done. Next, an evidence summary of more recent works on the current situation in Lebanon was done. Evidence summaries are part of the "continuum of rapid reviews" and are appropriate for this topic because they "serve as an informative brief that prepares stakeholders for discussion on a policy issue" (Khangura et al., 2012).

The methodology of a scoping review is to identify the research questions, identify relevant studies, select studies to review, and chart the data (Page et al., 2021). The questions that guided this review are: 1) what are the interconnections between water-, energy- and food challenges as they relate to the underlying conditions in Lebanon?; and 2) what are the interconnections between water-, energy-, and food challenges as they relate to the current situation and recent events in Lebanon? The process for identifying relevant studies to review was different for each part and is described further below.

Part 1: WEF and Underlying Factors

Relevant studies were identified to determine the characteristics of the interconnections related to the guiding questions. The Texas A&M EBSCO Discovery Service was used to find relevant academic literature. The search terms "water," "food," "agriculture," "energy," "electricity," and "WEF Nexus" were paired with "Lebanon." Reports from recognized international organizations, such as the International Monetary Fund (IMF), the United Nations (UN), and the World Bank that were related to the search terms and Lebanon, as well as documents from Lebanese government entities related to the search terms were also collected. Next, backward citation searching was used to identify additional relevant literature from the sources identified. If the authors identified gaps in the information or narrative, additional searches for relevant sources were done through Google Scholar. Literature that was not relevant to the search terms was excluded. Literature was not excluded based on year or document type. Only English language sources were used.

In addition to collecting literature relating to Lebanon's water, energy, and food, the authors mapped the underlying political and economic factors that were either identified in the literature or identified by the authors as longstanding challenges to WEF Nexus management in Lebanon. Lebanon's unique confessional

system of government has been highlighted in much of the academic literature on political factors in Lebanon (Bieber, 2000; Bordenkircher, 2020; Ramadan, 2020). By reviewing literature on the political system and the literature gathered from the WEF Nexus review of Lebanon, the authors identified additional themes, including reliance on external actors, corruption, and mismanagement. Once the authors agreed on the set of underlying political and economic factors affecting Lebanon, the same steps to identify relevant literature for the underlying challenges were done using the search terms "corruption," "management," "confessional," "political," and "economic," which were all paired with "Lebanon."

Part 2: Triggering Events, Impacts, and Outcomes

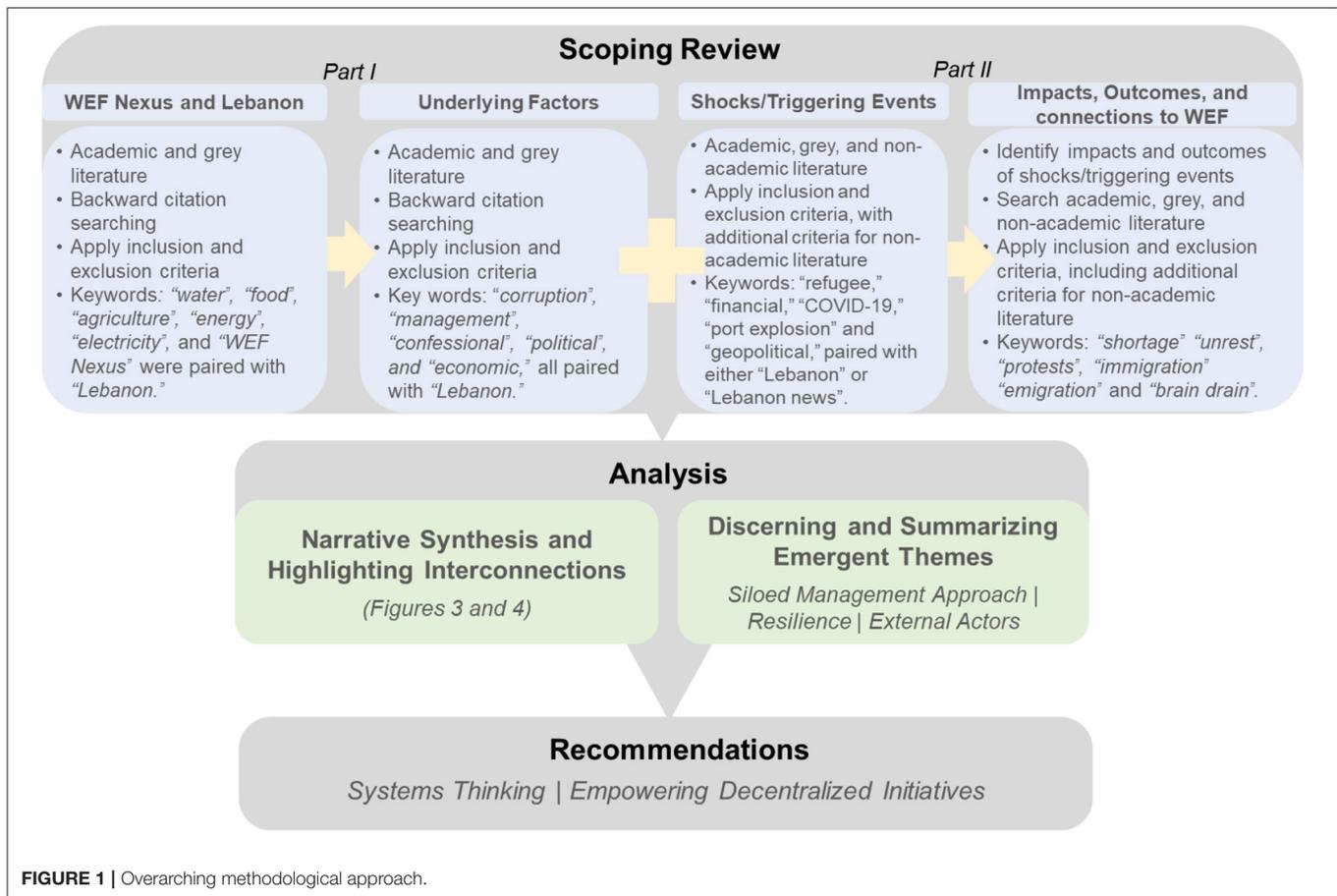
Next, the authors identified salient events that had triggered the multifaceted crisis in Lebanon. Many of these events were ongoing or recent, with new information being published daily. As a result, the authors concluded that a rapid scoping review was warranted to capture as much relevant, up-to-date information as possible. This part takes after elements of the method outlined by Khangura et al. (2012) to create an evidence summary, which include a systematic literature search, screening and selection of studies, and narrative synthesis.

The need for rapid study is based on the policy relevance of the findings and the recent nature of the events being analyzed. There is a need for a systematic organization of the many current and interconnected factors and characteristics outlined by the review. Furthermore, academic and gray literature is slow to capture many of the current details relating to the situation in Lebanon. The key allowance of the rapid review is the flexibility to use recent, non-academic sources, such as news articles to summarize the current context of Lebanon (Munn et al., 2018). The authors continued to search for information on current events through July of 2021, when the article was submitted.

To answer the second research question, the same steps were carried out to search for literature, this time using the search terms "refugee," "financial," "COVID-19," "port explosion" and "geopolitical," each paired with either "Lebanon" or "Lebanon news." Searches of well-known news sources (such as the New York Times, Al Jazeera, Reuters, and the Associated Press) and Google searches were done for additional relevant sources. Sources were excluded if they did not provide information relevant to the search terms. Only English language sources were used.

To determine the reliability of the non-academic sources, the authors determined if the source met one of three additional inclusion criteria: 1) The source written by a well-known news organization, non-profit organization, or research organization, 2) The facts provided by the literature were corroborated by at least one other piece of literature from a different author, or 3) If neither of the first two criteria were true, and the literature presented information that no other source had described, the authors evaluated if the source should be included.

Given the contemporary nature of the events covered in this part, there is a lack of up-to-date academic literature. As a result,



this review includes non-academic sources that may have bias. The authors limited bias in the report by 1) including a broad array of sources and 2) using the sources to gather facts or narrative details, rather than opinions or analysis. Despite the heavy reliance on news articles and gray literature, this evidence summary of the current crisis offers a significant contribution by organizing recent information that has not yet made its way into the academic realm.

Finally, the authors identified impacts and outcomes of the events based on the review. Because of the interconnectivity of recent events, factors could be both triggering events and impacts. Additional searches were then done pairing the identified impacts, outcome, and event terms with water, energy, and food terms to find sources that highlighted WEF Nexus connections. Additional terms were searched for relating to the impacts and outcomes. Terms included “shortage,” “unrest,” “protests,” “immigration,” “emigration,” and “brain drain.” Results were evaluated with the same inclusion and exclusion criteria.

The findings are presented according to Khangura et al.’s methodology, which calls for a narrative synthesis of the literature. The synthesis does not present information in the order it was found, instead, information is presented in the order that builds a cohesive narrative. This organization of existing knowledge is a key contribution that highlights connections

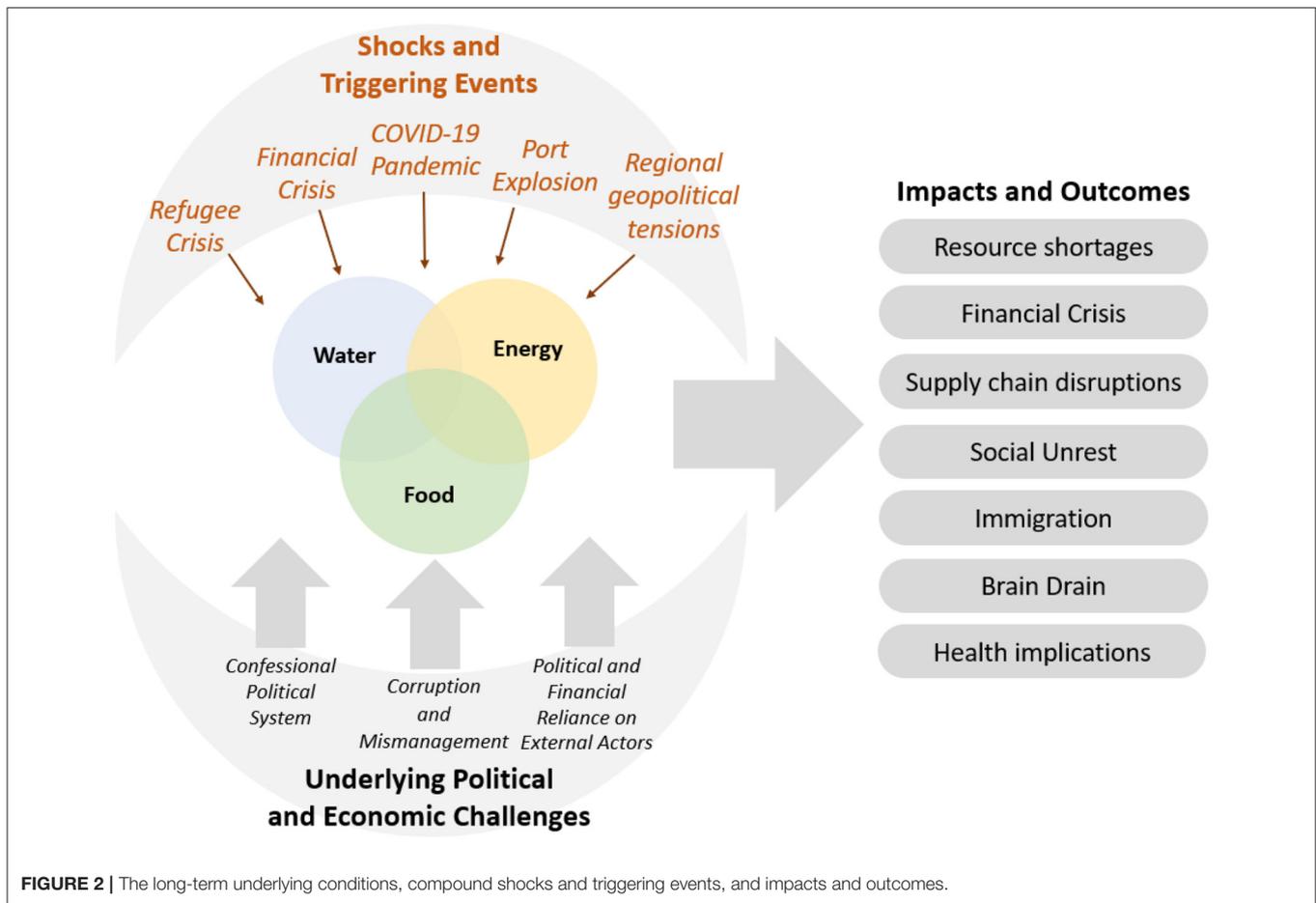
between complex and constantly changing issues in Lebanon. After the whole scope of the information was organized, prevalent emergent themes were highlighted, with a focus on themes that are relevant to policymakers.

THE CONTEXT OF LEBANON

The underlying political and economic challenges, shocks, and triggering events highlighted in **Figure 2** show the complex web of intertwined factors influencing the water, energy, and food sectors. The impacts and outcomes listed result from a culmination of many challenges. Addressing any of the issues affecting Lebanon requires a system-level understanding of the relevant interconnections.

Underlying Political and Economic Challenges in Lebanon

Although Lebanon faces many challenges in managing its water, energy, and food resources, underlying political and economic challenges lay the foundation of Lebanon’s current situation and continue to hinder the establishment of an integrated approach to natural resource management. Lebanon’s political structure is one such underlying factor: the **confessional system** requires the president, prime minister, and speaker of the parliament



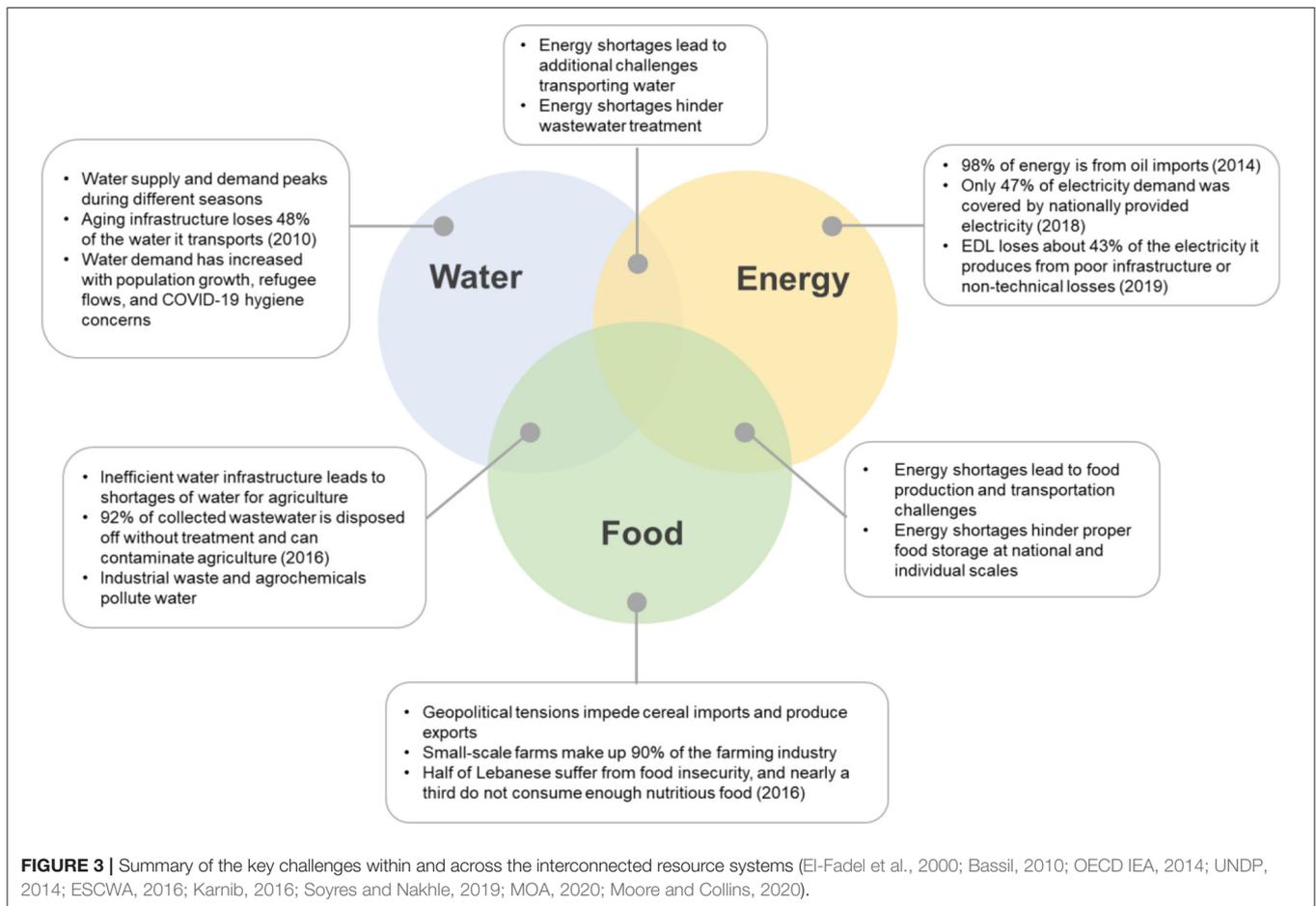
to be a Maronite Christian, Sunni, and Shi'a, respectively. An early attempt to strengthen national identity after the 1958 civil war failed because it was not backed by political reforms to address changing demographics and the balance of power between the confessions (Bieber, 2000). Although there were national dialogues during the 1975 Civil War, these did not establish permanent inter-confessional discussion platforms (Wählich, 2017). While national dialogues resumed in 2006, and have occurred more frequently since then, demographic and confessional identities are far stronger than the national identity, hindering political cohesion at all levels of government (Bieber, 2000; Wählich, 2017).

Politics in Lebanon have been characterized by many parties, but parties are often centered on a single leading politician, rather than on set structures or specific platforms. While the Lebanese electoral system recognizes politicians according to their religion, constituencies are regional. This makes politicians representative of one religious group but sometimes requires them to cater to other groups within their region. Although this arrangement sometimes fosters cooperation, it often weakens the legitimacy of politicians in the eyes of their constituencies. Because of this, the coalitions that form between parties are often the result of individual agreements between leading politicians rather than representative of broader political cooperation (Bieber, 2000).

The confessionalist system has many limitations; major policy decisions must be approved by the president, prime minister, and house speaker. Generating such consensus often leads to political impasse. Other features of the system, such as the ability of the cabinet minority to veto policy decisions, encourage political standstills and prevent the government from effective action (Ramadan, 2020).

Another related factor is the longstanding “patron-client syndrome,” common in Lebanese politics and dating back to Lebanon’s time under French mandate. Due in part to the lack of a cohesive national identity and in part to the general inefficiency of domestic institutions, **political groups rely on outside actors** for support and forego reliance on national enforcement mechanisms to strengthen the state’s legitimacy. As a result, inter-group conflicts and division are exacerbated: Lebanon is frequently involved in external actors’ interests, and political accountability and enforcement are weakened (Bordenkircher, 2020).

The weak state and confessionalist system have fueled **corruption**, which is common in Lebanon. Political elites have used political fragmentation to justify corrupt practices, arguing that corruption is necessary to ensure favorable distribution of resources and power (Kechichian and Cortes, 2021). Without existing ethical norms surrounding corruption in the political



system, corruption has become common among political elites, both as a practice and as an issue to decry (Kechichian and Cortes, 2021). The clientelism between firms and regulatory institutions has been shown to decrease job creation and productivity (Diwan and Haidar, 2019). In the face of the ineffective governance system, corruption in its many forms has become a remedy for bureaucratic stagnation. Petty bribery and corrupt arrangements are often seen as necessary mechanisms to function in the judicial and welfare systems, political administration, and regulatory institutions (Poverty Corruption in Lebanon, 2021).

Even during times when Lebanon has experienced economic growth, misrepresentative political elites, religious fragmentation, and classism have ensured that the economic benefits are not evenly distributed (Bieber, 2000). The central bank of Lebanon (BdL) has also played a significant role in bringing about Lebanon's economic situation. Until recently, the BdL has contributed to financial stability and surpassed many shocks and crises, in part due to deposit inflows, remittances, and an exchange rate that was consistently pegged to the dollar (IMF, 2017). However, at the same time the BdL **prioritized building foreign reserves** and drawing in foreign capital while weakening its balance sheet and risking exchange rate pressures (IMF, 2017). This "reserve Ponzi" financial engineering policy meant that the BdL was attracting dollars without the ability to

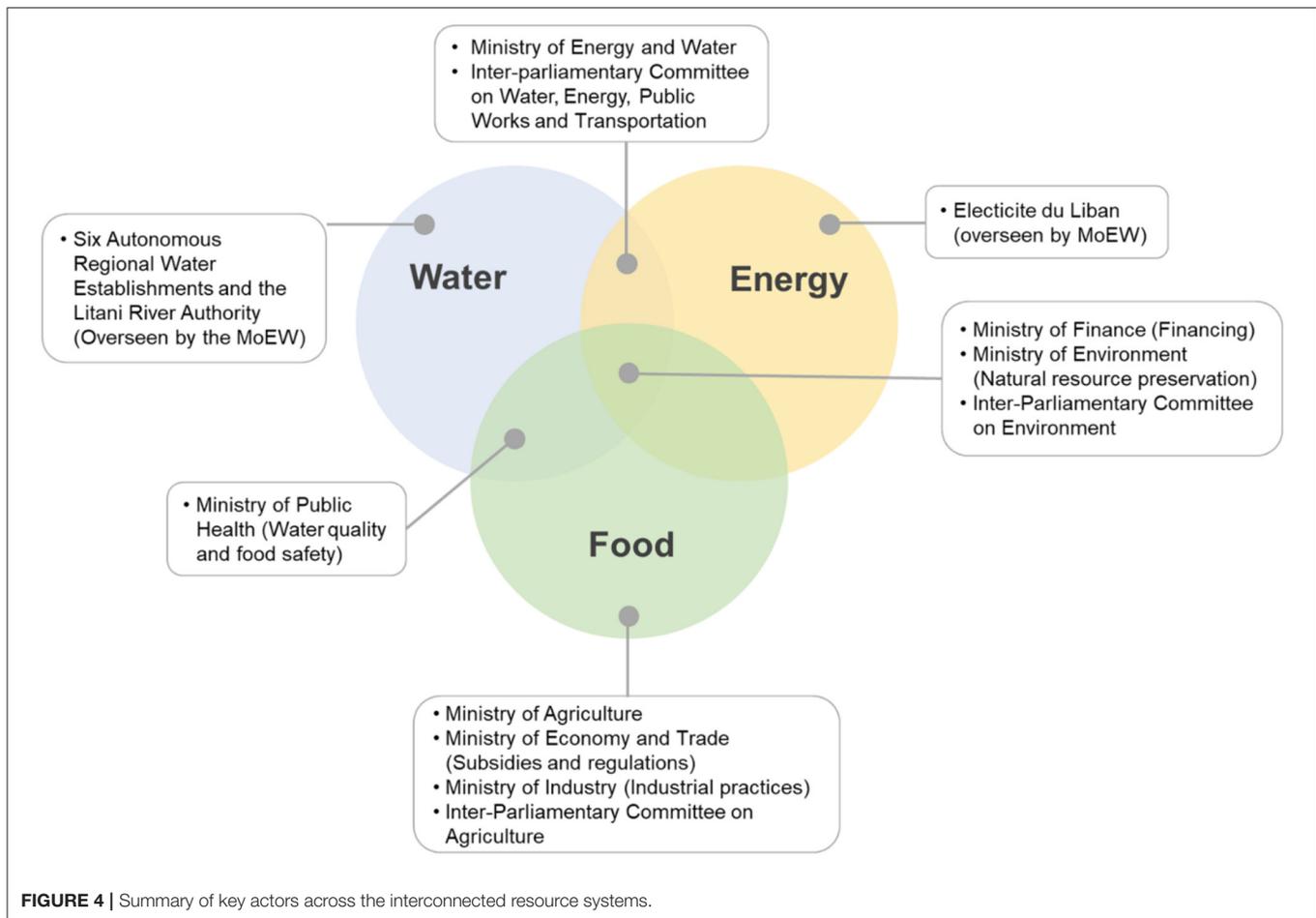
pay back the high interest rates (Panizza and Hassan, 2019). A 2017 IMF country report warned that severe scenarios of low growth or rising interest rates could lead to difficulty restoring capital and high liquidity stress (IMF, 2017).

WEF Nexus Challenges in Lebanon

Water, energy, and food systems have many inherent and man-made challenges in Lebanon, including poor governance, mismanagement, and economic challenges. Understanding the context of these challenges highlights how shocks, such as those affecting Lebanon recently, can have cascading effects on interconnected resource systems (Figure 3).

Water

Compared to other Middle Eastern countries, Lebanon has an abundant water supply. Despite this, it is considered to be a country experiencing water stress (Shaban, 2011; Shaban et al., 2021). Lebanon's water supply comes from precipitation, rivers, and springs that provided a water supply estimated at 1,350 m³ per capita, annually, in 2011. In contrast, water demand was <220 m³ per capita the same year (Shaban, 2011). Although there is no nation-level water stress quantification, UNDP environmental assessments have shown that water supply from springs and aquifers has decreased (UNDP, 2014; Jaafar



et al., 2020). One of the main reasons for the frequent water shortages experienced in Beirut and the surrounding areas is the inability and lack of infrastructure to capture water from mountains and store or transport the water to other areas. Lebanon's aging water infrastructure has resulted in 48% losses according to the most recent National Water Strategy, released in 2010 (Bassil, 2010). Additionally, demand for water has increased due to population growth, and other activities affecting water replenishment conditions, such as over pumping or deforestation, have diminished supply (El-Fadel et al., 2000; UNDP, 2014; Shaban et al., 2021).

Lebanon is fortunate to have two rivers—the Orontes and Litani—that originate in the agricultural Bekaa valley and support agriculture in the region (Quba'a et al., 2017; Conker and Hussein, 2020). To utilize the water from these sources, water is harvested through mountain lakes, dams, and individual storage (Shaban et al., 2021). However, these processes are underutilized and often less efficient than they could be. The lack of appropriate infrastructure to cater to the semi-arid and agricultural regions of Lebanon and general mismanagement have increased water stress (Sujud and Hamieh, 2018), with implications for both individual-level water needs in rural areas and for food production. Another underlying cause of Lebanon's

water scarcity is that water supply peaks in the winter while demand peaks in the summer. With poor storage capacity, Lebanon experiences water shortages and rationing in the summer (UNDP, 2014).

Lebanon's focus on managing its water supply has drawn out long standing national challenges with wastewater management (Geara-Matta et al., 2010). In 1991, only 4 of 165 Mm³ of raw sewage generated each year was treated; as of 2016, 92% of collected wastewater in Lebanon is disposed of without treatment (Karam et al., 2013; Karnib, 2016). Estimates in 2013 indicate that 35-50% of untreated urban sewage was filtering into aquifers, eventually making its way into marine environments (Karam et al., 2013). Furthermore, many areas are not connected to a sewer system and use open sewers, septic tanks, or no disposal infrastructure at all (World Bank, 2011). Therefore, many rivers and well sources are contaminated at the source by sewage disposal and by pollution from industrial waste and agrochemicals (El-Fadel et al., 2003). This contamination has repercussions for most water applications, including the availability of safe water for agriculture. Through agriculture, water contamination can negatively affect the health of domestic consumers and favor of international markets, which often have their own standards for produce. Water salination is another

problem that occurs when low water tables cause salt-water intrusion during the summer's high water demand (El-Fadel et al., 2000).

Water quality issues affect both rural and urban areas. A 2010 study on rural water supplies found that although water gathered directly from a local spring was free of bacteria, water from private wells or stored in storage tanks was well above recommended WHO bacteria levels (Massoud et al., 2010). A 2008 study on water quality in Beirut found that all three water sources catering to the sampling site (well water, municipality water, and bottled water) were contaminated with fecal matter and had less than ideal physiochemical profiles (Korfali and Jurdi, 2009). In nearly all settings, residents rely on multiple sources of water, both informal and formal, to fulfill their water needs (Korfali and Jurdi, 2009; Massoud et al., 2010; Yassin et al., 2016).

Energy

Lebanon's extreme reliance on imported energy has implications and tradeoffs that affect all other systems dependent on it, including water and agriculture. Lebanon gets 98% of its energy from oil imports, and half of the oil imported is used for electricity production (Ibrahim et al., 2013; OECD IEA, 2014). Energy supply in Lebanon has been unable to meet demand since the civil war, and since then, population growth has continued to exacerbate the disparity. Historically, Lebanon imported much of its fuel from Syria, but this fuel source has been disrupted by the latter's civil war. As a result, Lebanon has turned into an "electricity island," where disruptions to imports and growing demand has led to significant shortages (Bouri and El Assad, 2016, 1). In 2013, Lebanon rented two Turkish power-generating ships to address the decreasing imports and continued demand for electricity (Bouri and El Assad, 2016). Lebanon's quickly aging energy infrastructure produces far below its intended capacity and was never repaired after damage during the civil war (Julian et al., 2020). Aside from private generators, most of the energy generated in Lebanon is from thermal power plants, with a small amount from hydraulic power plants (Ibrahim et al., 2013). Initiatives to find alternative sources of energy have been rare: there have been few attempts to search for oil within Lebanon, and none have seen results (Ibrahim et al., 2013; Azhari, 2020). Lebanon has opportunities to generate renewable energy, especially solar, wind, and hydro power, but these options have not been explored (Ibrahim et al., 2013).

Electricity is subsidized in Lebanon, but due to insufficient supply, only 47% of electricity demand was covered by nationally provided electricity in 2018 (Moore and Collins, 2020). Insufficient supply and poor infrastructure cause frequent power outages, and private diesel generators, technically illegal, are normal and necessary for adequate power provision (Julian et al., 2020). Power outages vary from daily three-hour blocks in Beirut to eight-hour or longer blocks in districts outside of Beirut. Outages are exacerbated at times when there is additional demand, such as during the heat of summer or when Lebanon's large diaspora community returns over holidays (Abi Ghanem, 2018). A 2017 study found that 66% of Lebanese use energy from diesel generators, either renting from a municipal generator

or from an informal neighborhood electricity provider (IEP) (Harajli and Chalak, 2018).

On an individual scale, managing the routine power outages involves a complex array of alternative power sources, preparing specific chores to be done when power is available and managing which appliances use power when IEP electricity is in use (Abi Ghanem, 2018). Electricity cuts have been shown to negatively impact economic growth on a national level and add significant strain on individual finances (Dagher and Yacoubian, 2012; Bouri and El Assad, 2016; Abi Ghanem, 2018). The financial strain caused by having to pay multiple electricity bills creates pressures and trade-offs at the household level, including ability to afford more nutritious food or quality water. Much of the literature considers the effect of power outages on Beirut specifically. Abi Ghanem analyzes the junctions of living with power outages in Beirut—the rearranging of physical surroundings, adjusted their routines, and embedded IEP infrastructure—noting that these mitigation strategies normalize the everyday interactions with IEPs. This entrenchment is such that the public does not expect the formal system to improve, thus normalizing the dysfunctionality of official infrastructure (Abi Ghanem, 2018). Furthermore, Verdeil finds that the effects of sectarian splits on politics and urban demographic distribution both exacerbate and reinforce Beirut's current electricity arrangements by reinforcing reliance on neighborhood IEPs and perpetuating political stagnation that prevents power system reforms (Verdeil, 2016).

Food

Food and agricultural production offer a significant opportunity for Lebanon: about a quarter of Lebanon's land is agricultural and its climate is ideal for many crops (UNEP, 2005). Over time, Lebanon has transitioned from low-input extensive farming to intensive high value-added crops (Ghadban et al., 2013; MOA, 2014). The result of this transition has been twofold: more intensive farming has led to soil quality degradation; and the focus on high value-added crops has made Lebanon more dependent on imports to fulfill food demands. Currently, Lebanon's most common cultivated crops are fruits, such as tomatoes, oranges, apples, lemons, bananas, and grapes, as well as potatoes, cucumbers, wheat, and olives (MOA, 2014; Skaf et al., 2019). Lebanon is self-sufficient in fruits and close to being self-sufficient in vegetables but is highly dependent on imports for cereal products (ESCWA, 2016). Lebanon is self-sufficient in poultry but imports almost all its dairy and other meat products (UNEP, 2005).

Lebanon has a paradoxical comparative advantage in fruits and vegetables: climate and water availability make fruits and vegetables the ideal produce, while cereals and livestock are less cost-efficient, more water- and land-intensive, and provide fewer micronutrients (ESCWA, 2016). Consequently, it is generally agreed that Lebanon should not focus on full self-sufficiency in food production and should focus on strategically managing food production and decreasing import-shock vulnerabilities (Ghadban et al., 2013; ESCWA, 2016).

At the farm-level, the agricultural sector suffers from lack of planning, outdated technologies, and the use of untreated water for irrigation. Farms are either large-scale commercial

agriculture (<25%), or non-commercial smallholder farms partly focused on subsistence agriculture (MOA, 2020). As input and production costs increase, small-scale farming becomes a less sustainable form of employment. As a result, 90% of the industry comprises small-scale farms that are unorganized and rarely participate in international value chains (MOA, 2020). Agricultural and livestock market infrastructure is poorly managed, with unimplemented international agreements hindering efficient foreign trade (MOA, 2014).

Small-scale rural farmers often grow wheat, subsidized by the government. A 2014 survey found that of 63 farmers in West Bekaa growing wheat, only 8.5% would continue growing wheat if the government stopped subsidizing it. Many of the poorest farmers cannot wait for the slow bureaucratic process to disperse payments for subsidized wheat and are forced to sell directly to the market. Without cooperatives to help rural farmers with marketing and communication, it is difficult for farmers to get the best prices for direct-to-market sales or alternative crops. This dynamic reveals that the most vulnerable farmers are often producing the least efficient crops and are motivated mainly by government subsidies. Additionally, 83% also grow livestock or other crops in addition to wheat (Tawk et al., 2019). Through local cooperatives or initiatives, the government of Lebanon could improve the efficiency of wheat production to mitigate import dependency, or facilitate the transition to more valuable crops, but is currently doing neither.

Because Lebanon is dependent on food imports, it is vulnerable to food price shocks that directly affect consumers. After the food price crisis of 2007/2008, Lebanon introduced national food subsidies for consumers on flour, wheat, and bread, and non-processed foods have value-added tax (VAT) exemptions (Makdissi and Edine, 2020). The results of a 2016 ESCWA survey found that half of Lebanese suffered from food insecurity and nearly a third were unable to consume enough nutritious food (ESCWA, 2016). Analysis of the 2004 and 2008 food crises also found that food price increases led to decreased consumption of macronutrients, micronutrients, and vitamins (Zaki et al., 2014). Although some have argued that social transfer programs would be preferable to food subsidies, food subsidies are currently the most functional solution, given Lebanon's government structure (Makdissi and Edine, 2020).

Water, Energy, and Food Management in Lebanon

The institutional responsibility for water, energy, and food in Lebanon is distributed around multiple organizations (Figure 4). The Ministry of Energy and Water (MoEW) manages and plans for water and energy sectors and some related projects. Laws, codes, and strategies for water management have been frequently implemented and reformed, but approval is often delayed. Existing policies often lead to fragmented decision making and overlapping responsibilities (Gharios et al., 2020). Within the MoEW, the General Directorate of Hydraulic and Electric Resources (GDHER) houses the Department of Planning, which has three units: water planning, energy planning, and a unit for projects, which usually works alongside external organizations such as the Council for Development and Reconstruction and the UNDP (Farajalla et al., 2016). As of 2016, the Department of

Planning was 90% vacant, and the GDHER was 85% vacant. The department makes up for these vacancies by outsourcing their staff (Farajalla et al., 2016).

The MoEW also oversees the Electricité du Liban (EDL), the state-owned electricity company responsible for providing 90% of the nation's energy needs, among other responsibilities (Farajalla et al., 2016). EDL electricity tariffs are based on 1996 fuel prices and consequently do not cover the cost of electricity production (Kinab and Elkhoury, 2012; Julian et al., 2020). In 2018, tariffs only covered about 37% of EDL's operating costs (Moore and Collins, 2020) and EDL takes on huge operating losses (\$1.4 billion USD between 2008 and 2017) and relies on government subsidies to keep from going bankrupt (El-Jamal et al., 2014; Moore and Collins, 2020). Energy sector subsidies cause significant financial stress to Lebanon's public finance, accounting for nearly half of Lebanon's overall external debt (World Bank, 2019; Moore and Collins, 2020). Additionally, EDL loses 43% of the electricity it produces: 17% are technical losses stemming from poor infrastructure, 21% are non-technical losses from incorrect billing, energy theft, and meter tampering, and 5% are losses from uncollected payments (Soyres and Nakhle, 2019).

In contrast, water operations are less centralized. Water supply and wastewater treatment are run by four autonomous regional authorities and the Litani River Authority. These entities have no policy-making authority, and their relationship with the MoEW is unclear because of the lack of implementation decrees (Farajalla et al., 2016).

The Ministry of Agriculture (MoA) manages the food sector through a handful of departments including the Lebanese Agricultural Research Institute, the Green Plan, and the Higher Council for Agriculture. The ministry's work ranges from scientific research to agricultural production strategies and methods (Farajalla et al., 2016). The MoA administers the agriculture sector, including setting crop safety and quality standards, overseeing international trade, and laying out natural resource management guidelines. There are various planning committees and groups that work under the MoA, but compared to the MoEW, there is less applicable oversight at the ground level for agriculture. From the household and individual perspective, the Ministry of Economy and Trade (MoET) has more impact on food provision, as the MoET decides and manages food subsidies.

Throughout the three sectors, it is common to see overlapping strategies, plans, and jurisdictions, as well as delayed approval of proposals. These bureaucratic hindrances make policy implementation difficult and stymie system reform.

The MoEW and MoET subsidize electricity and flour production, respectively, by subsidizing the purchase of fuel and wheat from international markets. The MoET also purchases flour and bread from local firms and sets prices for wheat products (ESCWA, 2016). In 2019, the MoET subsidized basic food goods and essential products such as fuel and medicine for consumers. The subsidy arrangement, though impactful during the financial crisis, has been criticized as unable to target poorer households. Due to the higher purchasing power for more affluent households, subsidies benefit affluent households more than the poorest (ESCWA, 2016). MoET also subsidizes wheat by purchasing wheat from international markets and selling it

to flour mills at low prices (ESCWA, 2016). These subsidies are costly and have only been sustainable by lowering the mandatory foreign reserve threshold to maintain the subsidy programs (Chehayeb, 2021).

Inter-parliamentary committees exist to discuss proposals and amendments, such as the Committee on Water, Energy, Public Works and Transportation; the Inter-parliamentary Committee on Environment; and the Inter-parliamentary Committee on Agriculture. Other water, energy and food-related entities include the Lebanese Center for Energy Conservation, the Ministry of Environment, the Ministry of Finance, and the Ministry of Public Health (which oversees food safety, and water quality). These entities often work at the intersection of water and food or water and energy, but usually only facilitate a bilateral connection (either water and food or water and energy), or focus on specific programs and jurisdictions, such as natural resource preservation or financing (Farajalla et al., 2016).

Entities that facilitate dialogue and coordination between multiple sectors are critical for nexus-oriented management, but most entities have limited authority to make policy, and slow approval processes inhibit timely and effective policy implementation at the regional and local levels.

Shocks and Triggering Events

Given the turbulent situation in Lebanon, it is important to consider how recent shocks have triggered additional issues. One notable shock that has affected Lebanon for over a decade is the **Syrian Refugee Crisis** which, in addition to its humanitarian aspects, has strained both supply and demand for water, energy, and food. Recently, COVID-19 and related supply chain disruptions have made government assistance more necessary for vulnerable refugees and Lebanese citizens. Lebanon's recent financial crisis has drastically affected consumers' ability to buy food and the government's ability to subsidize essential goods and services.

The conflict in Syria, although no longer a recent event, has had unexpected and long-lasting effects on Lebanon. Primarily, demand for water, energy, and food has increased with the growing population of refugees from Syria. Lebanon hosts more refugees per capita than almost any other country in the world, with an estimated 1.5 million Syrian refugees living in Lebanon as of 2019 (Vulnerability Assessment of Syrian Refugees in Lebanon, 2020). Refugees have high unemployment rates and consequently represent a population highly vulnerable to food insecurity, unsanitary living conditions, and poor health (ESCWA, 2016). Vulnerable refugee populations have contributed especially to water demand and, in cases where wastewater infrastructure is poor, to water quality issues.

The Syrian conflict also represents a geopolitical tension with significant impacts on the supply side for many industries. Prior to the conflict, around 20% of exports and many imports passed through Syria (ESCWA, 2016). Lebanon imported up to 7.5% of electricity demand from Syria and Egypt through the regional grid (Bouri and El Assad, 2016). The resulting import disruptions had significant and long-lasting impacts on the energy sector. Food trade was also impacted: before the conflict, about 6% of agricultural imports flowed through Syria (ESCWA, 2016). These

supply routes continue to be inaccessible, in part due to the continued conflict in Syria and in part due to the U.S.'s Caesar Syria Civilian Protection Act of 2019, which imposes sanctions on anyone doing business with the Syrian government.

More recently, the **financial crisis** in Lebanon has exacerbated nearly every other strain. Lebanon's financial policy began to break down when depositors started moving their funds out of Lebanon in 2017 (Panizza and Hassan, 2019). As foreign confidence—and deposits—declined, interest rates increased, bank lending declined, and GDP growth dropped (Panizza and Hassan, 2019). Banks limited dollar withdrawals to maintain liquidity. The government passed reforms to address the crisis, but these were harsh to citizens and failed to address the widespread corruption present in Lebanon (Panizza and Hassan, 2019). This led to social unrest, frustration with the government, and a perilous financial situation, which have continued to the present day.

The **COVID-19 pandemic** has been harsh in Lebanon, with lockdowns still common and vaccination rates low (Lebanon Goes into COVID-19 Lockdown for Orthodox Easter Weekend, 2021). Lockdowns have been particularly harsh as electricity has become less consistent (McCaffrey and Todman, 2021). Health professionals left the country as the health system struggled to manage the pandemic. Few people can afford healthcare, many hospitals are unable to afford staff or supplies (McCaffrey and Todman, 2021). Water supply and quality have become especially important, as COVID-19 made sanitation and hygiene practices more vital.

The August 2020 **Beirut port explosion** is another noteworthy shock that triggered social demonstrations against corruption and poor management. To understand the full results of the port explosion, an analysis of Lebanon's food supply chains is instructive. In 2016, when the Syrian crisis began, Lebanon's food supply, which had largely arrived over Syrian land routes, faltered briefly. Much of the trade transitioned to maritime routes, and Lebanon's food availability soon returned to pre-crisis levels (ESCWA, 2016). In 2020, the Beirut port explosion damaged grain silos and disrupted imports coming through the Port of Beirut. However, food stores in Beirut had already been low, and maritime trade had already slowed along with the slowing economy. Additionally, the port in Tripoli was able to receive imports for the week it took to bring the Port of Beirut back into service, so the impact of the explosion on food was brief (Ibrahim, 2020). More importantly, the explosion publicly and globally underscored the gross mismanagement of the nation's largest port and vital gateway for international trade. The explosion was the result of highly dangerous material that had sat, neglected, at the port for seven years. The blast killed more than 190 people, injured thousands, and caused significant infrastructure damage (Hubbard et al., 2020). In the aftermath of the explosion, social unrest led to the resignation of Lebanon's cabinet (Hubbard, 2020). The IMF and western donors showed unwillingness to assist Lebanon until it addresses finances and establishes a new cabinet (Dahan and El, 2021).

Geopolitical tensions play a complex role in Lebanon. Tensions with geographic neighbors lead to trade barriers and supply shortages, some of which directly impact

water, energy, and food management. Given Lebanon's historic ties with a variety of external actors, it is often affected by outside conflicts. These geopolitical tensions have recently been exacerbated by the financial crisis, the weak value of the Lira, and the turbulent state of Lebanon's economy, leading to a general international hesitancy to do business with Lebanon. Tensions between Lebanon and the international community, including international organizations, have stalled infrastructure maintenance, and inhibited international assistance.

Impacts and Outcomes

The results of recent events and shocks in Lebanon have been broad. Understanding the full effects of the impacts and outcomes will take long-term attention, as many are still evolving. However, an overview of the outcomes and how they connect to preexisting challenges in Lebanon is instructive for identifying WEF Nexus resilience opportunities.

The outcomes and impacts of recent events in Lebanon are tightly interconnected. One of the most evident is the collection of **resource shortages** in water, energy, and food that Lebanon is experiencing, which is especially connected to the financial crisis and geopolitical tensions. The **financial crisis** is both a shock affecting the WEF Nexus and an outcome of other shocks and underlying factors. As conceptualized above, the financial crisis is the result of many years of financial engineering that has impacted the functionality of the interconnected resource systems. Simultaneously, the crisis can be conceptualized as an outcome of other shocks, such as geopolitical tensions and the COVID-19 pandemic. The financial crisis has connections to other outcomes. For example, COVID-19 has exacerbated financial struggles at both the national level and the individual level, and social unrest has been fueled by continuation of the financial crisis.

Of the sectors, water was least affected by the financial crisis as it is not an imported resource. Although water prices have increased drastically, much like other essential goods, the quality and quantity of water available has not been significantly reduced by recent events. In contrast, energy in Lebanon is almost entirely import-dependent, and the financial crisis has exacerbated energy challenges greatly. In March 2021, Lebanon's parliament approved a loan of \$200 million to be used for fuel because the EDL had run out of funds. The loan was only fully approved in June, when power plants had shut down and outages were exacerbated due to lack of fuel (Houssari, 2021; Reuters, 2021; Reuters Staff, 2021). Additionally, the Turkish energy company that rented power-generation ships to Lebanon shut off supply following 18 months of outstanding payments totaling \$100 million.

Food has been substantially affected by the financial crisis, the conflict in Syria, and geopolitical tensions. The refugee crisis has not only increased overall demand for food, it has impacted the amount of agricultural land available for food cultivation. A 2014 evaluation predicted that informal tented settlement growth would eventually encroach on agricultural lands and that the wastewater discharges created by Syrian refugee would add to untreated wastewater and would eventually

contaminate crops (UNDP, 2014). The COVID-19 pandemic increased unemployment and household expenditures generally, making it more difficult to afford food and leading to the creation of subsidies for basic goods, which many now rely on. As the financial crisis lingers, Lebanon's ability to continue to fund these subsidies decreases; the Minister of Finance argued in April 2021 that subsidies for fuel and food would soon need to be restricted, leading to fears that both food production and consumption in Lebanon would soon face major strains (Mathur-Ashton, 2021). On the consumer side, many with limited access to dollars are unable to afford the food that is available. These business and **supply chain disruptions** have also affected infrastructure functionality, especially in the energy sector, where power plants now sit unused.

The government's reactions to COVID-19, the financial crisis, and the resulting impacts have drawn much criticism from the public, who have voiced protests that the government is not addressing fundamental problems of corruption and mismanagement. The protests and general **social unrest** were heightened following the port explosion. Protesters have demanded many changes, but generally call for the removal of the corrupt government officials and reform of ineffective institutional systems (Sherlock, 2020). The effects of COVID-19 and the government's slow response to the pandemic have also led to heightened unrest, frustration, and increasing emigration from Lebanon (Pearlman, 2013; Nakhoul, 2020). The government has been accused of using COVID-19 as an excuse to shut down protests (Rose, 2020).

The pandemic, financial crisis, and resource shortages have all led to increased **emigration**. While emigration from Lebanon is not uncommon, recent shocks have increased and shaped emigration. There are indicators that the more vulnerable demographics are seeking ways to leave Lebanon, sometimes despite significant risks (Hendrix and Durgham, 2020). Furthermore, Lebanon's vast diaspora and largely well-educated populace make emigration an attractive option to find better opportunities, especially as the financial crisis continues. **Brain drain**, or the movement of the most educated out of the country, has significant long-term repercussions for Lebanon. This outcome is connected to each of the others, as strains on health, food and water availability, and financial stability are all highly motivational factors that push residents toward emigration.

The **health implications** of recent shocks, though broader than many of the other outcomes analyzed here, are highly interconnected and offer a useful picture of impacts at the individual and local levels. Health implications are often traced to issues with the underlying water, energy, and food sectors. Most evident is COVID-19, which also impacted water supply, food availability, and energy, all of which affect sanitation, nutrition, and the population's ability to adhere to lockdowns. Lebanon's health sector was especially affected by emigration: medical professionals in Lebanon found themselves without pay and inadequate supplies to face the global pandemic, disrupted supply chains, and the financial crisis. Many Lebanese medical professionals took advantage of high demand to relocate outside of the

country (Abdallah and Nakhoul, 2020; Karam and Tawil, 2021).

Analysis of water intake, infant health, and the prevalence of waterborne diseases in Lebanon indicate that water availability and affordability in Lebanon are also connected to health outcomes (El-Fadel et al., 2003, 2012; Korfali and Jurdi, 2009; Jomaa et al., 2016; Schuster et al., 2020). Because Lebanon is experiencing food shortages, particularly in cereal crops like wheat, inaccessibility of macronutrients will have increasing effects on health. Although Lebanon's domestic produce is nutritionally rich, much of the food grown in Lebanon is exported (ESCWA, 2016). Electricity shortages strain existing health infrastructure. Reliance on diesel generators leads to frequent exposure to airborne carcinogens: a study on carcinogenic emissions found that the use of generators for only 3 hours a day creates damage equivalent to smoking a few cigarettes per day (Shihadeh et al., 2013).

The port explosion was another notable trigger that compounded existing issues and exposed clear health implications: the explosion damaged more than half of health facilities in Beirut, making them non-functional, and injuries from the blast caused the remaining facilities to consume months of medical supplies within days (Landry et al., 2020). Damage to housing forced many into unsafe living situations (Abouzeid, 2021). The explosion is a specific example of the interconnectedness of many shocks and highlights the myriad of health implications.

DISCUSSION AND RECOMMENDATIONS

The review portion of this work covers a wide scope of information relevant to Lebanon's current situation and organizes this information into three categories—underlying challenges, shocks and triggering events, and impacts and outcomes. From this review, we highlight three recurring, emergent themes, and consider their implications for water, energy, and food policy. Finally, two recommendations are presented based on our findings.

Emergent Themes

The expanse of information presented here underscores many recurring themes in the case of Lebanon. There are a handful of salient themes that can be useful for the purpose of exploring WEF Nexus resilience and considering policy reactions to the current situation.

Siloed Approaches to Management

Considering themes of resilience in Lebanon can point out both areas of resilience and areas where resilience is lacking. The current context of Lebanon and its longstanding issues highlight the WEF Nexus's lack of resilience: the current systems of management are neither sustainable, nor have they facilitated recovery from the many shocks Lebanon has faced. In exploring the many causes of this lack of resilience, one theme is most apparent: Lebanon's water, energy, and food systems are managed within silos, run by many actors with differing priorities, capabilities, and jurisdictions. The Ministry of Economy and

Trade, for instance, purchases wheat from international markets and sells it to flour mills at low prices while also purchasing local flour at fixed prices (ESCWA, 2016; Tawk et al., 2019). The result is that local farmers grow a different, hardier but less valuable wheat (ESCWA, 2016). The Ministry of Agriculture, which should manage agricultural production strategies, has no formal way of influencing these subsidies. Perhaps the most obvious split is the management of water supply for agricultural purposes, which is run largely by autonomous regional authorities. The role of the Ministry of Energy and Water is unclear, and the role of the Ministry of Agriculture is minimal (Farajalla et al., 2016). These artificial splits in management underscore the siloed approach to water, energy, and food administration before even considering the excessive bureaucracy, corrupt politics, and challenges with staffing public service roles. Although entities exist to facilitate cross-sector dialogue, most entities have limited power, or are focused on specific aspects of management. There are many layers of disconnect, which results in a siloed approach.

Pockets of Resilience

In contrast, resilience can be seen in Lebanon in areas where water, energy, and food systems continue to function despite numerous challenges. In cases where governance is necessary but absent, corruption and informal systems allow Lebanese society to continue to function without addressing bureaucratic issues. Farajalla et al. (2017) highlight that informal systems are highly resilient, adaptable, and can provide useful examples for policy makers. Prime examples are Lebanon's informal electricity grids and transportation system, which make up for areas where official systems have failed to provide adequate services. It is worth noting that not all informal systems are illegal or corrupt, but they are intrinsically linked to the underlying factors of corruption and inefficient legitimate governance. As it stands, there are many entrenched informal systems between society and business that maintain functionality of the water, energy, and food sectors. While these systems are imperfect, they provide examples of possible resilient resource management initiatives.

One example of decentralization in practice is Electricité de Zahlé (EDZ) in the city of Zahle, Bekaa Governorate. Zahle faced long power outages after the local power plant was destroyed in the civil war. Rather than continuing to wait for the EDL to address shortages, EDZ built its own power plant in 2015 (Naylor, 2016) and now provides 24-hour electricity to Zahle and the surrounding municipalities at about 40% of the cost compared to other areas of Lebanon (Euronews, 2018). Several factors contributed to the success of the EDZ power grid. On a bureaucratic level, Zahle is unique in Lebanon: local power companies are authorized to distribute, but not generate, electricity. To overcome this issue, EDZ drew on a 1920s era law enacted before EDL existed, which permitted EDZ to generate electricity. Although other cities have applied for a similar ability to generate power, requests have thus far been refused (Euronews, 2018).

Another major hurdle was pushback from local generator owners who profited from the power outages and threatened both the authorities and customers to hinder the adoption of the new system. This hurdle was overcome by collective action

and persistence. Local sector-specific initiatives, such as EDZ, also strengthen connections with other sectors in the community. One result of 24-hour electricity in Zahle is that farmers are now able to pump water consistently, thereby improving their crop production (Naylor, 2016). The EDZ also took advantage of solar power to provide electricity at a much lower cost than alternative providers.

Another instructive example of small-scale resilience is provided by Water Users' Associations (WUAs) in Lebanon. Tegoni et al. (2016) analyzed five of these WUAs and determined that the WUAs, which work to collectively manage local water resources, are not particularly resilient (Tegoni et al., 2016). WUAs are not official legal entities under the MoEW, although the MoEW has an unimplemented plan in place to involve WUAs in decision making. Instead, the WUAs rely on the MoA to recognize them as agricultural cooperatives, which are also not well supported, and keeps the role of WUAs in Lebanon informal. However, despite the lack of institutional recognition, many of the WUAs successfully distribute water resources and foster cooperation among farmers in their communities. In particular, the WUAs analyzed by Tegoni et al. (2016) succeed in governing and maintaining water infrastructure such as wells and irrigation networks. Additionally, these organizations can tailor water management to their constituents by choosing how to distribute and charge for water usage. Replicating the success of informal WUAs across Lebanon would require giving them legal recognition, authority to enforce regulations, and decision-making power at higher levels. This arrangement is already used in other MENA countries, where WUAs and private water companies are formally recognized, regulated, and supported (Farajalla et al., 2017).

The Role of External Actors

A third relevant theme of this review is the significant role outside actors play in Lebanon. The patron-client syndrome described by Bordenkircher (2020) reflects Lebanon's historic political and social reliance on outside benefactors. Similarly, BdL's reliance on foreign reserves and the general national reliance on remittances demonstrate the same trends in the financial sector. Lebanon's import-dependence has only become as critical as it is because of Lebanon's historic dependence on other countries for fuel and food; it's reliance on Turkish energy generating ships is one such example. The prevalence of external actors to support infrastructure at the local level for WUAs highlights the continuation of this underlying trend: four out of five WUAs analyzed by Tegoni et al. (2016) manage infrastructure built with the help of international donors or organizations, a local example of Lebanon's historic reliance on external support.

Lebanon's cooperation with outside actors is not an innately negative factor, rather, the balance between national sovereignty and international cooperation represents an important policy consideration for Lebanon. Becoming more resilient to geographic tensions and shocks such as the financial crisis would require shifting toward national ownership of local solutions and seeking out opportunities that do not require external support. At the same time, external collaboration is a source of necessary stability during a time of turbulence. One clear representation

of the value of international cooperation is Lebanon's position with food: by choosing to produce valuable fruits and vegetables, Lebanon selects to heavily rely on imported cereals. Lebanon's position as a country that will likely always rely to some extent on international cooperation highlights a complex theme that warrants further research and clear, intentional policy.

Recommendations: Opportunities in Systems Thinking and Empowering Decentralized Initiatives

The high level of interconnectivity between water, energy, and food systems and the impact of multiple underlying factors, shocks, and outcomes points to the need for a systems approach. In addition to the many triggering events and natural challenges, poor governance has exacerbated resource scarcity and failed to address complex resource security issues. In practice, systems-thinking can facilitate the understanding and quantification of these interconnections to better support evidence-based decision making and integrative resource governance. The developed recommendations, following analysis of the complex situations described above, include a broad, long-term shift in the governance approach. The first focuses on creating a system-thinking approach to water, energy, and food systems management. This approach utilizes a cross-sectoral platform to encourage dialogue and analyze policy that reflects the entirety of the interconnected resource systems. The second recommendation is to further decentralized management and empower communities to manage their own resources in accordance with local needs. Systems-thinking can incorporate the connections between sectors while considering the economic, political, and social circumstances affecting Lebanon at national and local levels.

A Systems-Thinking Approach to Lebanon's Resource Management

Applying systems-thinking to resource planning and governance in Lebanon would require a shift away from disconnected governance. The confessionalist system, siloed management of water, energy, and food, and unintegrated informal systems underscore the norms of fragmentation in Lebanon. Ministries and offices are often focused on their own priorities, which prevents holistic, nexus-oriented policymaking.

A platform for facilitating dialogue between different stakeholders is needed: one that is oriented toward identifying the links between sectors, evaluating policy, highlighting tradeoffs, and discovering vulnerabilities within the nexus (Mohtar and Daher, 2016). Such a platform would allow for dialogue around complex issues without necessarily making major reforms to existing ministries and departments. Additionally, the platform could facilitate cross-sectoral legislation, address overlooked issues, and integrate additional actors into decision making.

An important piece of this platform would be its ability to encourage system-level analysis. Rather than analyzing issues and solutions as they pertain to only one sector, encompassing multiple factors and sectors can produce more relevant recommendations. For example, addressing food shortages must

consider the availability and quality of water, the current geopolitical climate, domestic nutritional needs, and the financial ability to provide subsidies. A solution that addresses each of these features must encompass more than only the agricultural sector. The proposed platform would use systems-thinking to develop analytics that can inform holistic policy formulation.

Additionally, this platform could create avenues for dialogue between the main actors affecting interconnected resource systems: society, business, and government. A framework for facilitating dialogue between Lebanese government, society, and businesses needs to begin with building the legitimacy of the government in the eyes of the other players and facilitating dialogue within the government. There is a lack of clear mechanisms that facilitate cross-institutional communication and cooperation, and consequently, there is little communication between actors and little opportunity for thorough discussion of possible tradeoffs. The heads of MoEW and MoA often have different priorities, and although government actors rarely work together, the system often requires consensus to approve legislation. As a result, the government's management of the links between the water, energy, and food sectors is often antiquated or outdated. Focusing on multi-stakeholder dialogue and cross-sectoral policy formulation offers many opportunities for overcoming these barriers to achieve system-oriented management.

Systems-thinking is also useful for considering effects at different levels to ensure that policy is coherent and effective across different scales. In particular, research should consider trends and resilience strategies at the local and household levels to identify effective strategies and bring more actors into the dialogue. As it stands, household-level recommendations are often tone deaf and ineffective. Last year, politicians urged Lebanese to grow their own food amidst the shortages, a recommendation that was far from a large-scale solution and came with no assistance (Yee, 2020). Although growing food at home has become more common, the effect has been slight. During the 2014 water crisis, the MoEW ran an awareness campaign to encourage residents to conserve water: the \$243,000 campaign asked the public to conserve water, but did not provide education on how to do so, nor was it paired with incentives (Nash, 2014). At the same time, the MoEW announced plans to drill new wells and take control of illegal ones, but none of these actions promised long-term solutions to water shortages and the campaign was received poorly by the public (Cousins, 2014). Household-level initiatives can help mitigate resource scarcity and strengthen government legitimacy, but they must be evaluated carefully (Traboulsi and Traboulsi, 2017).

Empowering Decentralized Initiatives

In addition to suggesting broad reforms at the higher levels of government, this paper argues for decentralized solutions that empower local governance and formalize existing local water, energy, and food management systems. Decentralized initiatives are valuable opportunities because they can bypass some of the underlying challenges at the national level while tailoring solutions to local contexts. The existing national system has led to endemic corruption that further complicates

effective governance. Lebanon's consensus-based government is a complex, slow, long-standing structure; supporting decentralized initiatives where research and analysis suggest effective outcomes may offer quicker, small-scale ways to take advantage of pockets of resilience.

Local management encompasses both resource allocation and resource stewardship. For example, local management of electricity could include setting up electric grids that cater fairly to all residents, and local management of water resources could include public information campaigns to address water pollution. There are already local systems in Lebanon, such as informal credit agreements between farmers and suppliers and informal electricity providers. Local initiatives have the potential to lower transportation costs, bypass corruption, and strategically maximize comparative advantages. Research supports the potential of local cooperatives to help with marketing, advise on new farming methods, and organize community support for useful infrastructure such as storage and refrigeration facilities (Maalouf and Chalak, 2019; Tawk et al., 2019). The use of digital resources also has much potential to effectively link sellers and buyers (Bahn et al., 2021). A small-scale example of this came about in late 2020, when artisan producers in South Lebanon came together through the "From the Villages" e-commerce platform to sell their goods to buyers in Beirut and other metropolitan areas. Initiatives such as this could have added effects of shifting the public mindset to favor domestic products. Local communities do not exist in a vacuum: areas that rely on imported water, energy, and food would still need to coordinate with other authorities. Nonetheless, learning from existing small-scale successes, and providing national support where success is possible, is a useful way to build resilience.

Bridging Systems-Thinking and Decentralized Initiatives

The case of Lebanon highlights the usefulness of applying a systems approach to complex challenges at different scales. Implementing such approach requires both: top-down long-term strategy toward effective governance of national resources, while empowering decentralized initiatives which can guide the scaling up of successful models at local scales.

Empowering decentralization does not imply fragmentation; rather, direction provided at the national level can guide decentralized management to prioritize actions and maximize national outcomes. According to the steps developed by Terrapon-Pfaff et al. (2018), a methodology to apply WEF Nexus thinking to a local setting must include qualitative analysis of water, energy, and food linkages; quantification of the linkages; and identification of the most critical linkages. Finally, these findings should be leveraged to "generate synergies and avoid trade-offs" (Terrapon-Pfaff et al., 2018). National-level research and policy making can be used to accomplish and publicize the first three of these steps, while the final step of leveraging results and applying findings could be implemented by local communities.

This system is especially applicable to Lebanon's current context, which faces strains at all levels. Broad, systems-based

reform reflects a top-down management framework that improves resource system resilience at the national level, while decentralized initiatives improve resilience from the bottom up. In both cases, applying the WEF Nexus lens amplifies potential impacts by taking advantage of insights from critical connections between sectors.

CONCLUSIONS

Considering the case of Lebanon through a Water-Energy-Food Nexus lens is a complex undertaking that reveals many interconnections, not only between water, energy, and food systems, but also between the underlying political and economic challenges and recent shocks. Some connections, such as the one between the financial crisis and increased emigration, are obvious. Other connections can only be thoroughly understood by considering the complex relations between historic trends and contemporary issues. For example, current resource shortages, even in sectors with adequate supply to match national demand such as water, can only be fully understood by drawing connections between Lebanon's historic reliance on external actors and long-standing ineffective governance. WEF Nexus insecurity stems from a variety of underlying challenges and complicated shocks, but also from longstanding poor governance of Lebanon's natural resources.

The provided recommendations highlight the benefit of using the WEF Nexus lens at the national and local levels. Nationally, a WEF Nexus approach would benefit from a platform that facilitates systems-thinking across the water, energy, and food sectors and enables improved communication between relevant stakeholders, including society, businesses, and government. The most impactful contribution of such a platform would be the facilitation of communication between decision making actors within the Lebanese government, which frequently finds itself in political standstills and interconfessional conflicts. Additionally, analysis at the national level could provide more integrative recommendations for resource management through a systems-thinking approach.

REFERENCES

- Abdallah, S., and Nakhoul, I. (2020). *Hundreds of Disillusioned Doctors Leave Lebanon, in Blow to Healthcare*. Reuters. Available online at: <https://www.reuters.com/article/us-lebanon-crisis-healthcare-insight-idUSKBN27S14W> (accessed November 12, 2020).
- Abi Ghanem, D. (2018). Energy, the city and everyday life: living with power outages in post-War Lebanon. *Energy Res. Soc. Sci.* 36, 36–43. doi: 10.1016/j.erss.2017.11.012
- Abouzeid, R. (2021). *After the Blast*. *The Atlantic*. Available online at: <https://www.theatlantic.com/magazine/archive/2021/04/beirut-lebanon-explosion/618074/> (accessed March 12, 2021)
- Allouche, J., Middleton, C., and Gyawali, D. (2014). *Nexus nirvana or nexus nullity? A dynamic approach to security and sustainability in the water-energy-food nexus*. STEPS Working Paper 63. Brighton, MD: STEPS Centre
- Allouche, J., Middleton, C., and Gyawali, D. (2015). Technical veil, hidden politics: interrogating the power linkages behind the nexus. *Water Altern.* 8, 610–626.
- Arksey, H., and O'Malley, L. (2005). Scoping Studies: Towards a Methodological Framework. *Int. J. Soc. Res. Methodol.* 8, 19–32. doi: 10.1080/1364557032000119616
- Azhari, T. (2020). *Lebanon's First Offshore Gas Drill Is a Huge Disappointment*. Available online at: <https://www.aljazeera.com/economy/2020/4/27/lebanons-first-offshore-gas-drill-is-a-huge-disappointment> (accessed April 27, 2020).
- Bahn, R. A., Yehya, A. A. K., and Zurayk, R. (2021). Digitalization for sustainable agri-food systems: potential, status, and risks for the MENA region. *Sustainability*. 13, 3223. doi: 10.3390/su13063223
- Bassil, G. (2010). *National Water Sector Strategy*. MoEW. Available online at: <http://www.databank.com.lb/docs/National%20Water%20Sector%20Strategy%202010-2020.pdf>

Using a WEF Nexus lens at the community level can reveal opportunities for local initiatives that may produce more resilient results to the many national-level challenges. Furthermore, initiatives at the local level will be better able to analyze tradeoffs and select management practices tailored to the needs of their constituents, thus improving the sustainability of resources at a more refined scale.

There is also room for a WEF Nexus perspective at the household and individual levels. Understanding consumption trends at the household level can inform the recommendations and policies directed at individuals, which can lead to behavioral shifts and social awareness. These contexts are vital for implementing a timely, bottom-up approach and highlight the importance of empowering local institutions and actors to manage their own sectors. Together, these recommendations combine top-down and bottom-up approaches to improve resilience in Lebanon's WEF Nexus while accounting for the nation's unique context.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

BD, SH, and KP worked on conceptualizing the paper, wrote sections of the manuscript, and supervision. BD developed the manuscript figures. JR wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

FUNDING

This research was made possible through the support of the Texas A&M Energy Institute Seed Grant Program and the U.S. National Science Foundation (NSF) Sustainable Regional Systems research Network (SRS-RN) grant #2115442.

- Béné C., and Doyen, L. (2017). From resistance to transformation: a generic metric of resilience through viability. *Earth's Fut.* 6, 979–996. doi: 10.1002/2017EF000660
- Bieber, F. (2000). Bosnia-herzegovina and Lebanon: historical lessons of two Multireligious States. *Third World Q.* 21, 269–81. doi: 10.1080/01436590050004355
- Biggs, E. M., Bruce, E., Boruff, B., Duncan, J. M. A., Horsley, J., Pauli, N., et al. (2015). Sustainable development and the water–energy–food nexus: a perspective on livelihoods. *Environ. Sci. Policy* 54, 389–97. doi: 10.1016/j.envsci.2015.08.002
- Bordenkircher, E. (2020). 'Lebanonization': Framing policy for the puzzles of the Middle East. *Middle East Policy* 27, 41–55. doi: 10.1111/mepo.12473
- Bouri, E., and El Assad, J. (2016). The lebanese electricity woes: an estimation of the economical costs of power interruptions. *Energies* 9, 583. doi: 10.3390/en9080583
- Carpenter, S., Walker, B., Anderies, J. M., and Abel, N. (2001). From metaphor to measurement: resilience of what to what? *Ecosystems* 4, 765–781. doi: 10.1007/s10021-001-0045-9
- Chehayeb, K. (2021). *The Weight of Lebanon's Unsustainable Subsidies Program*. TIMEP. Available online at: <https://timep.org/commentary/analysis/the-weight-of-lebanons-unsustainable-subsidies-program/> (accessed April 30, 2021).
- Conker, A., and Hussein, H. (2020). Hydropolitics and issue-linkage along the orontes river basin: an analysis of the lebanon–syria and syria–turkey hydropolitical relations. *Int. Environ. Agreements Politics Law Econ.* 20, 103–121. doi: 10.1007/s10784-019-09462-7
- Cousins, S. (2014). *Lebanon Sceptical of 'save Water' Effort*. Aljazeera. Available online at: <https://www.aljazeera.com/news/2014/8/24/lebanon-sceptical-of-save-water-effort> (accessed August 24, 2014).
- Dagher, L., and Yacoubian, T. (2012). The causal relationship between energy consumption and economic growth in lebanon. *Energy Policy* 50, 795–801. doi: 10.1016/j.enpol.2012.08.034
- Dahan, S. N., and El, M. (2021). *Analysis: Lebanon Frozen by Political Intransigence as It Hurtles towards Collapse*. Reuters. Available online at: <https://www.reuters.com/article/us-lebanon-crisis-scenario-idUSKBN2B11YY> (accessed March 26, 2021).
- Diwan, I., and Haidar, J. I. (2019). "Clientelism, Cronyism, and Job Creation in Lebanon," in *Crony Capitalism in the Middle East*, by Ishac Diwan and Jamal Ibrahim Haidar. Oxford University Press, 119–45.
- El-Fadel, M., Ghanimeh, S., Maroun, R., and Alameddine, I. (2012). Climate change and temperature rise: implications on food- and water-borne diseases. *Sci. Total Environ.* 437, 15–21. doi: 10.1016/j.scitotenv.2012.07.041
- El-Fadel, M., Maroun, R., Semerjian, L., and Harajli, H. (2003). A health-based socio-economic assessment of drinking water quality: the case of Lebanon. *Manag. Environ. Qual. Int. J.* 14, 353–368. doi: 10.1108/14777830310479441
- El-Fadel, M., Zeinati, M., and Jamali, D. (2000). Water resources in Lebanon: characterization, water balance and constraints. *Int. J. Water Resour. Dev.* 16, 615–638. doi: 10.1080/713672540
- El-Jamal, G., Ibrahim, H., and Ghandour, M. (2014). "Investigation of the technical-economic contribution of renewable energy and energy efficiency: lebanese context," in edited by *IEEE Industrial Electronics Society and Institute of Electrical and Electronics Engineers*. Beirut, Lebanon: IEEE.
- ESCWA (2016). *Strategic Review of Food and Nutrition Security in Lebanon*. UN. Available online at: https://www.unescwa.org/sites/www.unescwa.org/files/page_attachments/escwa_food_and_nutrition_security_in_lebanon_final_version_high_res_en.pdf. (accessed May 10, 2021).
- Euronews (2018). *Meet the Man Trying to Fight the Electricity Crisis in Lebanon*. Euronews. sec. news_news. Available online at: <https://www.euronews.com/2018/11/23/meet-the-man-trying-to-fight-the-electricity-crisis-in-lebanon> (accessed November 23, 2018).
- Farajalla, N., Badran, A., El Baba, J. T., Choueiri, Y., El Hajj, R., Fawaz, M., et al. (2017). *The Role of Informal Systems in Urban Sustainability and Resilience*. Issam Fares Institute for Public Policy and International Affairs. Available online at: https://www.aub.edu.lb/ifi/Documents/publications/research_reports/2016-2017/20170706_informal_systems.pdf. (accessed May 13, 2021).
- Farajalla, N., Haydamou, P., and El Hajj, R. (2016). *Water, Energy, Food Nexus: An Outlook on Public Institutions in Lebanon*. Working Paper. American University Beirut.
- Foden, M., Browne, A. L., Evans, D. M., Sharp, L., and Watson, M. (2019). The water–energy–food nexus at home: new opportunities for policy interventions in household sustainability. *Geogr. J.* 185, 406–418. doi: 10.1111/geoj.12257
- Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., and Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. *Ecol. Soc.* 15, 20–29. doi: 10.5751/ES-03610-150420
- Gain, A. K., Giupponi, C., and Benson, D. (2015). The Water–Energy–Food (WEF) security nexus: the policy perspective of Bangladesh. *Water Int.* 40, 895–910. doi: 10.1080/02508060.2015.1087616
- Garcia, D. J., and You, F. (2016). The Water-Energy-Food nexus and process systems engineering: a new focus. *Comput. Chem. Eng.* 91, 49–67. doi: 10.1016/j.compchemeng.2016.03.003
- Geara-Matta, D., Moilleron, R., El Samarani, A., Lorgeoux, C., and Chebbo, G. (2010). "State of art about water uses and wastewater management in Lebanon," in *Presented at the World Wide Workshop for Young Environmental Scientists: 31 May - 2 June 2010* (Arcueil). Available online at: <https://hal.archives-ouvertes.fr/hal-00521446/file/13-WWW-YES-Geara-Paper-2010-04-08.pdf>
- Ghadban, E., Talhouk, S., Chedid, M., and Hamadeh, S. K. (2013). "Adapting a European Sustainability Model to a Local Context in Semi-Arid Areas of Lebanon," in *Methods and Procedures for Building Sustainable Farming Systems*, eds Marta-Costa, A. A and da Silva, E. L. D. G. S. (Dordrecht: Springer Netherlands), 251–58.
- Gharios, G., Farajalla, N., and El Hajj, R. (2020). *Lebanon's Water Laws: Bridging Policy Frameworks to Address New Challenges*. AUB. Available online at: https://www.aub.edu.lb/ifi/Documents/publications/policy_briefs/2019-2020/20200512_lebanon_water_laws.pdf (accessed June 13, 2021).
- Harajli, H., and Chalak, A. (2018). *Energy Efficient Home Appliances: Perspectives from Lebanese Consumers*. UNDP. Available online at: <https://www.cedro-undp.org/publications/energy-efficient-home-appliances>
- Hendrix, S., and Durgham, N. (2020). *Lebanese Refugees Flee Economic, Political Crises in Smugglers' Boats - The Washington Post*. The Washington Post. Available online at: https://www.washingtonpost.com/world/middle_east/lebanon-crisis-migrants-refugees/2020/09/25/246295fc-fe4c-11ea-b0e4-350e4e60c91_story.html (accessed September 26, 2020).
- Hogeboom, R. J., Borsje, B. W., Deribe, M. M., van der Meer, F. D., Mehvar, S., Meyer, M. A., et al. (2021). Resilience meets the water–energy–food nexus: mapping the research landscape. *Front. Environ. Sci.* 9, 630395. doi: 10.3389/fenvs.2021.630395
- Houssari, N. (2021). *Aoun Okays \$197 Million Treasury Loan to Avoid Blackout in Lebanon*. Arab News. Available online at: <https://arab.news/2fvp3> (accessed June 8, 2021).
- Hubbard, B. (2020). *Lebanon's Government Resigns Amid Widespread Anger Over Blast*. The New York Times. sec. World. Available online at: <https://www.nytimes.com/2020/08/10/world/middleeast/lebanon-government-resigns-beirut.html>. BBC News. (accessed August 10, 2020).
- Hubbard, B., Abi-Habib, M., El-Naggar, M., McCann, A., Singhvi, A., Glanz, J., et al. (2020). *How a Massive Bomb Came Together in Beirut's Port*. The New York Times. sec. World. <https://www.nytimes.com/interactive/2020/09/09/world/middleeast/beirut-explosion.html> (accessed September 9, 2020).
- Hussien, W. A., Memon, F. A., and Savic, D. A. (2017). An integrated model to evaluate water-energy–food nexus at a household scale. *Environ. Model. Softw.* 93, 366–380. doi: 10.1016/j.envsoft.2017.03.034
- Ibrahim, A. (2020). *How Tripoli's Port 'Stepped in' after 'Apocalyptic' Beirut Blast*. Aljazeera. Available online at: <https://www.aljazeera.com/economy/2020/8/28/how-tripolis-port-stepped-in-after-apocalyptic-beirut-blast> (accessed August 28, 2020).
- Ibrahim, O., Fardoun, F., Younes, R., and Louahlia-Gualous, H. (2013). Energy status in Lebanon and electricity generation reform plan based on cost and pollution optimization. *Renew.Sustain. Energy Rev.* 20, 255–278. doi: 10.1016/j.rser.2012.11.014
- IMF. (2017). *Lebanon Financial System Stability Assessment*. Country Report 17/21. Washington D.C.: International Monetary Fund (IMF).
- Jaafar, H., Ahmad, F., Holtmeier, L., and King-Okumu, C. (2020). Refugees, water balance, and water stress: lessons learned from Lebanon. *Ambio* 49, 1179–1193. doi: 10.1007/s13280-019-01272-0

- Jomaa, L., Hwalla, N., Constant, F., Naja, F., and Nasreddine, L. (2016). Water and beverage consumption among children aged 4–13 years in Lebanon: findings from a national cross-sectional study. *Nutrients* 8, 554. doi: 10.3390/nu8090554
- Julian, M., Bassil, N., and Dellagi, S. (2020). Lebanon's electricity from fuel to solar energy production. *Energy Rep.* 6, 420–429. doi: 10.1016/j.egyr.2020.08.061
- Karam, F., Mouneimne, A. H., El-Ali, F., Mordovanaki, G., and Roupheal, Y. (2013). Wastewater management and reuse in Lebanon. *J. Appl. Sci. Res.* 9, 2868–2879. Available online at: <http://www.databank.com.lb/docs/wastewater%20and%20reuse%20in%20lebanon.pdf>
- Karam, Z., and Tawil, F. (2021). *No More Kidney Dialysis? Lebanese Hospitals Issue Warning*. AP NEWS, sec. Dialysis. Available online at: <https://apnews.com/article/beirut-middle-east-lebanon-business-health-7ff67b0bc6154b0fc1eaca63c04baa21> (accessed June 10, 2021).
- Karnib, A. (2016). Assessing Population coverage of safely managed wastewater systems: a case study of Lebanon. *J. Water Sanit. Hyg. Dev.* 6, 313–319. doi: 10.2166/washdev.2016.009
- Kechichian, J. A., and Cortes, F. S. B. (2021). The practice of corruption in Lebanon. *Middle East Policy* 27, 119–135. doi: 10.1111/mepo.12530
- Khangura, S., Konnyu, K., Cushman, R., Grimshaw, J., and Moher, D. (2012). *Syst. Rev.* 1. doi: 10.1186/2046-4053-1-10 [Epub ahead of print].
- Kinab, E., and Elkhoury, M. (2012). Renewable energy use in Lebanon: barriers and solutions. *Renew. Sustain. Energy Rev.* 16, 4422–4431. doi: 10.1016/j.rser.2012.04.030
- Korfali, S. I., and Jurdi, M. (2009). Provision of safe domestic water for the promotion and protection of public health: a case study of the city of Beirut, Lebanon. *Environ. Geochem. Health* 31, 283–295. doi: 10.1007/s10653-008-9218-1
- Landry, M. D., Alameddine, M., Jesus, T. S., Sassine, S., Koueik, E., and Raman, S. R. (2020). The 2020 Blast in the Port of Beirut: Can the Lebanese Health System 'Build Back Better'? *BMC Health Serv. Res.* 20, 1040. doi: 10.1186/s12913-020-05906-y
- Lebanon Goes into COVID-19 Lockdown for Orthodox Easter Weekend. (2021). Arab News. Available online at: <https://arab.news/ykvp7> (accessed April 29, 2021).
- Leck, H., Conway, D., Bradshaw, M., and Rees, J. (2015). Tracing the water–energy–food nexus: description, theory and practice. *Geogr. Compass* 9, 445–460. doi: 10.1111/gec3.12222
- Leese, M., and Meisch, S. (2015). Securitising Sustainability? Questioning the 'Water, Energy and Food-Security Nexus.' *Water Altern.* 8, 695–709.
- Maalouf, A., and Chalal, A. (2019). Farmers' willingness to pay for establishing a collective postharvest refrigeration unit: evidence from an eastern Mediterranean rural community. *J. Agric. Food Syst. Community Dev.* 9, 89–99. doi: 10.5304/jafscd.2019.091.012
- Makdissi, P., and Edine, M. S. (2020). Is the elimination of food subsidies the right policy to address Lebanon's public finance crisis? *Rev. Middle East Econ. Finance.* 16, 1–17. doi: 10.1515/rmeef-2020-0016
- Massoud, M. A., Al-Abady, A., Jurdi, M., and Nuwayhid, I. (2010). The challenges of sustainable access to safe drinking water in rural areas of developing countries: case of Zawtar El-Charkieh, Southern Lebanon. *J. Environ. Health* 72, 24–30. Available online at: <https://www.thefreelibrary.com/The+challenges+of+sustainable+access+to+safe+drinking+water+in+rural...+a0227353478>
- Mathur-Ashton, A. (2021). *Lebanon's Finance Minister: Country Must Ration Subsidies Before Reserves Run Out | Voice of America - English, sec.* Middle East. Available online at: <https://www.voanews.com/middle-east/lebanons-finance-minister-country-must-ration-subsidies-reserves-run-out> (accessed April 2, 2021).
- McCaffrey, A., and Todman, W. (2021). *Navigating Collapse in Lebanon's Covid-19 Response*. CSIS. Available online at: <https://www.csis.org/analysis/navigating-collapse-lebanons-covid-19-response> (accessed May 12, 2021).
- MOA (2014). *Ministry of Agriculture Strategy*. MOA. Available online at: <http://extwprlegs1.fao.org/docs/pdf/leb149670.pdf>. (accessed May 10, 2021).
- MOA (2020). *Lebanon National Agriculture Strategy*. MOA. Available online at: <http://www.agriculture.gov.lb/getattachment/Ministry/Ministry-Strategy/strategy-2020-2025/NAS-web-Eng-7Sep2020.pdf?lang=ar-LB> (accessed May 10, 2021).
- Mohtar, R. H., and Daher, B. (2016). Water-energy-food nexus framework for facilitating multi-stakeholder dialogue. *Water Int.* 41, 655–661. doi: 10.1080/02508060.2016.1149759
- Moore, H. L., and Collins, H. (2020). Decentralised renewable energy and prosperity for Lebanon. *Energy Policy* 137, 111102. doi: 10.1016/j.enpol.2019.111102
- Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., and Aromataris, E. (2018). Systematic review or scoping review? guidance for authors when choosing between a systematic or scoping review approach. *BMC Med. Res. Methodol.* 18. doi: 10.1186/s12874-018-0611-x [Epub ahead of print].
- Nakhoul, S. (2020). *The Blast That Blew Away Lebanon's Faith in Itself*. Reuters. Available online at: <https://www.reuters.com/article/us-lebanon-crisis-witness-insight-idUSKBN28Y0QX> (accessed December 24, 2020).
- Nash, M. (2014). *Water Shortage: Turn off the Tap*. *Executive Magazine*. Available online at: <https://www.executive-magazine.com/economics-policy/water-turn-off-the-tap> (accessed July 31, 2014).
- Naylor, H. (2016). *In a Country Where Outages Are the Norm, a Lebanese Town Now Has Power 24/7*. Washington Post, sec. Middle East. Available online at: https://www.washingtonpost.com/world/middle-east/a-lebanese-town-has-electricity-247-and-thats-a-big-deal-for-the-middle-east/2016/08/26/1d71aa42-63de-11e6-b4d8-33e931b5a26d_story.html (accessed August 28, 2016).
- OECD and IEA (2014). *Energy Imports, Net (% of Energy Use)*. IEA Statistics. Available online at: <https://data.worldbank.org/indicator/EG.IMP.CON.SZS?locations=LB> (accessed April 12, 2021).
- Page, M. J., McKenzie, J., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C., et al. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 372, n71. doi: 10.1136/bmj.n71
- Panizza, U., and Hassan, F. (2019). *Understanding the Lebanese Financial Crisis*. Available online at: <https://www.ft.com/content/282eba28-9ed9-4b8f-8cc8-50d2096a400a> (accessed December 20, 2019).
- Pearlman, W. (2013). Emigration and the resilience of politics in Lebanon. *Arab Stud. J.* 21, 191–213. doi: 10.1177/0032329212473088
- Poverty and Corruption in Lebanon (2021). *The Borgen Project*. Available online at: <https://borgenproject.org/poverty-and-corruption-in-lebanon/> (accessed February 23, 2021).
- Quba'a, R., El-Fadel, M., Najm, M. A., and Alameddine, I. (2017). Comparative assessment of joint water development initiatives in the Jordan River Basin. *Int. J. River Basin Manag.* 15, 115–31. doi: 10.1080/15715124.2016.1213272
- Ramadan, K. (2020). Confessionalism in Lebanon: the costs of seeking consensus through fragmentation. *Va. J. Int. Law* 61, 138–158. Available online at: <https://static1.squarespace.com/static/5f0a3654a47d231c00ccd14f/t/5fa697104f8f02449aa4ec0a/1604753168986/Ramadan%5EJ+Confessionalism+in+Lebanon+-+EIC+Final+Read+%5BMcCraw+Edit%5D.pdf>
- Reuters Staff. (2021). *Lebanese Parliament Approves \$200 Million Loan for Power Generation*. Reuters. Available online at: <https://www.reuters.com/article/lebanon-crisis-parliament-int-idUSKBN2BL11H> (accessed March 29, 2021).
- Reuters. (2021). *Lebanon's Lights May Go off as Cash for Electricity Runs Out*, sec. Middle East. Available online at: <https://www.reuters.com/world/middle-east/lebanon-could-gradually-go-dark-cash-electricity-runs-out-2021-05-06/> (accessed May 6, 2021).
- Rogers, P. (2017). "The Triangle: Energy, Water and Food Nexus for Sustainable Security in the Arab Middle East," in *Water, Energy and Food Sustainability in the Middle East: The Sustainability Triangle*, edited by Elias Baydoun, Nuhaad Dagher, and Sohail Murad, 1st ed. (Cham: Springer International Publishing: Imprint: Springer), 21–43.
- Rose, S. (2020). *Lebanon: Decision to Dismantle Protest Camps over Coronavirus Fears Causes Controversy*. The National, sec. Available online at: <https://www.thenationalnews.com/world/mena/lebanon-decision-to-dismantle-protest-camps-over-coronavirus-fears-causes-controversy-1.999165> (accessed March 30, 2020).
- Schuster, R. C., Butler, M. S., Wutich, A., Miller, J. D., Young, S. L., Household Water Insecurity Experiences-Research Coordination Network (HWISE-RCN). (2020). 'If there is no water, we cannot feed our children': the far-reaching consequences of water insecurity on infant feeding practices and infant health across 16 low- and middle-income Countries. *Am. J. Hum. Biol.* 32. doi: 10.1002/ajhb.23357 [Epub ahead of print].

- Shaban, A. (2011). Analyzing climatic and hydrologic trends in Lebanon. *J. Environ. Sci. Eng.* 5, 483–492. doi: 10.17265/1934-8932/2011.04.014
- Shaban, A., Drapeau, L., Telesca, L., Amacha, N., and Ghandour, A. (2021). Influence of snow cover on water capacity in the qaraaoun reservoir, Lebanon. *Arab. J. Geosci.* 14, 10. doi: 10.1007/s12517-020-06295-6
- Sherlock, R. (2020). *Mass Protests Have Followed The Beirut Explosion. What's Next?* NPR. Available online at: <https://www.npr.org/2020/08/14/901651660/mass-protests-have-followed-the-beirut-explosion-whats-next> (accessed August 14, 2020).
- Shihadeh, A., Al Helou, M., Saliba, N., Jaber, S., Alaeddine, N., Ibrahim, E., et al. (2013). *Effect of Distributed Electric Power Generation on Household Exposure to Airborne Carcinogens in Beirut*. Climate Change and Environment in the Arab World. Available online at: https://www.aub.edu.lb/ifi/Documents/publications/research_reports/2012-2013/20130207ifirsr_cc_effect%20Diesel.pdf (accessed April 4, 2022).
- Siddiqi, A., and Anadon, L. D. (2011). The water–energy nexus in middle east and North Africa. *Energy Policy* 39, 4529–4540. doi: 10.1016/j.enpol.2011.04.023
- Simpson, G. B., and Jewitt, G. P. W. (2019). The development of the water-energy-food nexus as a framework for achieving resource security: a review. *Front. Environ. Sci.* 7, 8. doi: 10.3389/fenvs.2019.00008
- Sims, R. E. H., and Dubois, O. (2011). *Energy-Smart Food For People and Climate*. Issue Paper. Food and Agriculture Organization of the United Nations. Available online at: <http://www.fao.org/3/i2454e/i2454e.pdf> (accessed May 22, 2021).
- Skaf, L., Buonocore, E., Dumontet, S., Capone, R., and Franzese, P. P. (2019). Food security and sustainable agriculture in Lebanon: an environmental accounting framework. *J. Clean. Prod.* 209, 1025–1032. doi: 10.1016/j.jclepro.2018.10.301
- Soyres, C., and Nakhle, N. (2019). *Lebanon: Selected Issues. Country Report 19/313*. Washington D.C.: International Monetary Fund (IMF).
- Sujud, H., and Hamieh, T. (2018). The assi dam project: priority issue of the community's sustainable rural development in Semi-Arid Northern Region of Bekaa, Hermel Caza, Lebanon. *Int. J. N. Technol. Sci. Eng.* 5. Available online at: <https://www.ijntse.com/papers.php?sid=55&cid=8>
- Tawk, S. T., Chedid, M., Chalak, A., Karam, S., and Hamadeh, S. (2019). Challenges and sustainability of wheat production in a levantine breadbasket: the case of the West Bekaa, Lebanon. *J. Agric. Food Syst. Community Dev.* 1–17. doi: 10.5304/jafscd.2019.084.011
- Tegoni, C., Mulazzani, L., and Setti, G. (2016). Water governance under uncertainty: the case study of users' associations in Lebanon. *New Media* 15, 62–71. Available online at: https://newmedit.iamb.it/bup/wp-content/uploads/2019/11/1055_62tegoni.pdf
- Terrapon-Pfaff, J., Ortiz, W., Dienst, C., and Gröne, M. C. (2018). Energising the WEF nexus to enhance sustainable development at local level. *J. Environ. Manag.* 223, 409–416. doi: 10.1016/j.jenvman.2018.06.037
- Traboulsi, H., and Traboulsi, M. (2017). Rooftop level rainwater harvesting system. *Appl. Water Sci.* 7, 769–775. doi: 10.1007/s13201-015-0289-8
- UNDP. (2014). *Lebanon Environmental Assessment of the Syrian Conflict and Priority Interventions*. UNDP, MOE, EU.
- UNEP. (2005). *Effects of Trade Liberalization on Agriculture in Lebanon, With Special Focus on Products Where Methyl Bromide Is Used*. UNDP, ENVIROTECH. Available online at: <https://wedocs.unep.org/bitstream/handle/20.500.11822/8914/-Effects%20of%20Trade%20Liberalization%20on%20Agriculture%20in%20Lebanon%20-%20With%20special%20focus%20on%20products%20where%20methyl%20bromide%20is%20used-2005470.pdf?sequence=3&disAllowed=y> (accessed May 10, 2021).
- Verdeil, E. (2016). “Beirut, Metropolis of Darkness - The Politics of Urban Electricity Grid,” in *Energy, Power and Protest on the Urban Grid: Geographies of the Electric*, eds Luque-Ayala, A., and Silver, J. (London: Routledge), 155–175. doi: 10.4324/9781315579597-8
- Wählisch, M. (2017). *The Lebanese National Dialogue: Past and Present Experience of Consensus-Building*. Berghof Foundation. Available online at: https://berghof-foundation.org/files/publications/NDH_Lebanon.pdf
- Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G. S., Janssen, M., et al. (2002). Resilience management in social-ecological systems: a working hypothesis for a participatory approach. *Conserv. Ecol.* 6. doi: 10.5751/ES-00356-060114 [Epub ahead of print].
- Walker, B., Holling, C. S., Carpenter, S. R., and Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecol. Soc.* 9. doi: 10.5751/ES-00650-090205 [Epub ahead of print].
- World Bank (2019). *Lebanon Electricity Transmission Project*. P170769. World Bank. Available online at: <http://documents.worldbank.org/curated/en/235831562864951356/text/Concept-Project-Information-Document-PID-Lebanon-Electricity-Tra%20nsmision-Project-P170769.txt> (accessed May 8, 2021).
- World Bank. (2011). *Republic of Lebanon Country Environmental Analysis*. 62266-LB. Sustainable Development Department Middle East and North Africa Region (MNSSD). Available online at: <http://documents1.worldbank.org/curated/en/360011468265768992/pdf/622660ESW0Gray0c060601100BOX361480B.pdf> (accessed May 8, 2021).
- World Economic Forum (2017). *Migration and Its Impact on Cities*. 061017. World Economic Forum. Available online at: <https://www.weforum.org/reports/migration-and-its-impact-on-cities>
- Yassin, N., Stel, N., and Rassi, R. (2016). Organized chaos: informal institution building among palestinian refugees in the maashouk gathering in South Lebanon. *J. Refug. Stud.* 29, 341–362. doi: 10.1093/jrs/few016
- Yee, V. (2020). ‘Agricultural Jihad’: A Hungry Lebanon Returns to Family Farms to Feed Itself. *The New York Times*. sec. World. Available online at: <https://www.nytimes.com/2020/09/05/world/middleeast/lebanon-economic-crisis-farming.html> (accessed September 5, 2020).
- Zaki, S. A., Chaaban, J., Nasreddine, L., and Chalakh, A. (2014). The impact of food price increases on nutrient intake in Lebanon. *Agric. Food Econ.* 2. doi: 10.1186/s40100-014-0003-4 [Epub ahead of print].

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