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Drought, Fragility and Human Migration Analysis: Synthesis Report of Case Studies in Lebanon and Jordan

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A dry stream in Rechaya, Lebanon, November 2022 (*photo*: Nadim Farajalla)

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Executive Summary

Overview

This report synthesizes two case studies that concerned the interactions between drought, fragility and human migration. The case study areas we selected are predominantly agricultural and have high sensitivity to drought impacts: Rechaya in southeastern Lebanon and parts of the Zarqa Governorate in Jordan. We used a mixed methods and systems approach that allowed us to explore the local dynamics within national and Levantine regional socioeconomic, political and environmental contexts. We evaluated how drought events act as stress multipliers that contribute to fragility and human migration. In this report, we use our findings to provide recommendations that are aimed at informing policy and investment strategies to promote resilience to drought impacts.

This research was undertaken through MENAdrought, a project funded by the United States Agency for International Development (USAID) in Jordan, Lebanon and Morocco, which aims to build these countries' self-reliance in managing drought impacts on water and food security and thereby limit the social and economic losses resulting from these events.[1] This report supplements the MENAdrought synthesis assessment of drought impacts and vulnerabilities in Jordan and Lebanon (Fragaszy et al. 2022a, 2022b).

Key Definitions and Concepts

Fragility can be defined as "the combination of exposure to risk and insufficient coping capacity of the state, system and/or communities to manage, absorb or mitigate those risks" (OECD 2016). It is thus a contributing factor to vulnerability, as well as a result of vulnerability, when that is defined as "the predisposition to be adversely affected" (King-Okumu et al. 2020).

Fragility is a broad term that encompasses economic, societal, environmental, political and security dimensions. As such, it can have ramifications across numerous aspects of life including food security, national GDP growth, household-level access to work opportunities, education and health services, functionality of socioenvironmental management systems, exposure to corruption or conflict, state legitimacy, and access to justice and accountability. In short, fragility relates to complex and interdependent social-ecological systems.

Migration is defined as movement across an international border, or within a state away from habitual places of residence. This definition applies regardless of legal status, whether the movement is voluntary or involuntary, the causes for the movement, or the length of the stay. In this report, we use 'emigration' to signify international migration and 'out-migration' to signify internal migration, often from rural to urban areas.

Methodology

We conducted a literature review and then assessed—through surveys, key informant interviews and focus group discussions—local perceptions of drought and its effects on fragility and migration decisions. Participants in these interactions primarily included local officials, large and smallholder farmers and pastoralists, residents, and representatives of local farming groups. These research activities were undertaken in six villages in Rechaya (Lebanon) and three in Zarqa (Jordan). We undertook thematic analysis of the participatory research data and developed a fuzzy cognitive map (FCM). The Drought, Fragility and Human Mobility Analysis Framework guided our overall approach and thematic analyses (Nicol et al. 2022).

The purpose of our analysis was to understand the interactions between climatic and non-climatic drivers, intermediating factors and drought outcomes and how they influence decision-making, especially in relation to fragility and migration.

[1] https://menadrought.iwmi.org/

Key Findings

The capacity of communities within Lebanon and Jordan to manage and recover from major drought events is linked to their specific socioeconomic and governance context, agrarian base, geography and water management systems.

Drought and the series of drought effects that result in fragility and migration decisions have complex interactions. Droughts, water scarcity and associated climatic and environmental changes have the greatest impact on agricultural production, and thus on the livelihoods of rural agrarian communities. However, the precise effects of drought are obscured and/or mediated, even to those who are experiencing them, by a variety of intermediate factors such as water management systems, resource costs and socioeconomic circumstances within households and communities. These factors interact with one another to influence economic decisions, one of which is migration.

In both our case studies, farmers and pastoralists described an increase in temperature, changing patterns of precipitation and shifts in the seasonality of both temperature and rainfall over the past 10 years. These have contributed strongly to variability and instability in crop growth and agricultural production as well as increased water scarcity.

In Rechaya, the cost of water and fuel and the weak or absent public water services—leading to dependence on private water supply—greatly affect social and economic decisions in water-scarce conditions, which, coupled with the rising costs of agriculture and living, result in shifts away from agricultural investment. This can impact migration decisions.

In Zarqa, the costs of water and agriculture and declining revenues in the face of centralized water and agricultural regulation and management intermediate social and economic decisions in water-scarce conditions. They primarily result in shifts away from agricultural investments, which can impact migration decisions for the younger generation.

Our findings suggest that the economic impacts of drought—including reduced agricultural productivity and income as well as increased costs to access and use natural resources—contribute to the fragility of farming communities and influence their economic and migration decisions. Some resource management and socioeconomic conditions can increase sensitivity to drought impacts, and then communities adopt coping strategies that can affect their social cohesion, livelihoods or food security, including some in the community choosing to migrate in search of better opportunities.

However, participants in both Rechaya and Zarqa stated that even when drought or long-term climate change conditions lead to a decline in agricultural productivity and result in migration, the factors leading to poor socioeconomic conditions in rural areas are broader than climate drivers themselves. Migration decisions thus appear to be taken when government services are inadequate and household strategies to cope with economic hardship have been unsuccessful. In recent years, the rising costs of agriculture and living, which are closely linked to the energy-water-food nexus, have put great pressure on households and increased their vulnerability and wider societal fragility.

Recommendations

The recommendations resulting from this study seek to address aspects within the drought-related fragility and migration 'effect chain' that is elucidated by fuzzy cognitive mapping. They aim to promote resilience to drought impacts as synthesized from the findings of the case studies in Lebanon and Jordan. We consider them to be applicable elsewhere, at least in the MENA region, according to local policy contexts.

These recommendations primarily relate to preparedness and mitigation actions to be undertaken outside of a drought cycle. Some also relate to response actions to be undertaken once droughts occur. While key recommendations are listed below, the report following provides more detail, prioritization and links to existing policy mechanisms in Lebanon and Jordan:

Drought management:

- Support and improve drought monitoring and early warning systems.
- Develop and implement a drought risk reduction and recovery plan.

Sustainable agricultural development and resilience:

- Enhance agricultural extension services and empower agricultural cooperatives for climate-smart practices.
- Support marketing and domestic market access and infrastructure.
- Support the development and marketing of drought- and heat-tolerant seed and crop varieties.

Water management:

- Support equitable water demand management.
- Increase local water capture and storage.
- Scale up integration of renewable energy into water operations.
- Improve wastewater management and mainstream safe wastewater reuse.

Socioeconomic resilience:

- Support diversification of skills and off-farm income opportunities.

1. Introduction

1.1 Research Purpose

This report synthesizes the results, conclusions and recommendations from research case studies on the interactions between drought, fragility and human migration in Jordan and Lebanon. The research was undertaken through MENAdrought, a USAID-funded applied research-for-development project in Jordan, Lebanon and Morocco. This report supplements the MENAdrought synthesis assessment of drought impacts and vulnerabilities in Jordan (Fragaszy et al. 2022a) and Lebanon (Fragaszy et al. 2022b).

The MENAdrought project supports the Jordanian and Lebanese governments in managing drought risks and improving their drought management responses. This research serves that objective by evaluating how drought events act as stress multipliers that contribute to fragility and human migration. The findings provide the basis for our recommendations, which are aimed at informing policy and investment strategies to promote resilience to drought impacts.

1.2 Context of the Study

The Levant region of West Asia stretches from the eastern shores of the Mediterranean Sea in Lebanon, Syria, West Bank and Gaza, and Israel to the basins of the Tigris and Euphrates rivers in Iraq, forming the Fertile Crescent that has sustained the oldest recorded human settlements. The region is characterized by its complex and diverse history and topography which varies sharply from cool mountains to steppes to arid deserts (Assaf 2009).

The region's geography and global circulation patterns provide climatological and hydrological conditions conducive to an agrarian economy. The coastal mountain ranges of the eastern Mediterranean capture moisture from the westerlies wind system that moves across the region in winter (Assaf 2009). The Levant's water resources start as snowfall and surface runoff that feed aquifers storing the region's groundwater and give rise to rivers including the Jordan, the Litani and the Assi.

The Levant is a hotspot of climate change. It is projected to experience the highest decrease in precipitation and the highest increase in evaporation by the mid 21st century (Assaf 2009; IPCC 2023). This is projected to result in a decrease in river runoff and soil moisture that currently support agricultural activity (Assaf 2009). These changing or decreasing precipitation trends are projected to lead to higher drought severity and more consecutive dry days (IPCC 2023). In Lebanon, for example, projections indicate an almost 40% increase in the frequency and duration of droughts (MoE Lebanon and UNDP 2021).

Levantine countries already face major challenges due to scarce and overexploited water resources, especially in some parts of Syria and Jordan (Waha et al. 2017). Jordan and Lebanon are among the countries with "extremely high baseline water stress," while Iraq is among the countries with "high baseline water stress" (Hofste et al. 2019).

The region has historically experienced recurrent periods of drought, which have resulted in changes in agricultural and pastoral land, especially in the south and east. The droughts and desertification projected by climate models could have graver consequences yet (Waha et al. 2017). Literature has shown that drought in the Levant, and the Middle East and North Africa (MENA) region in general, can drive water and food insecurity (World Bank 2017), agricultural loss (Below et al. 2007; FAO 2015), armed conflict (Gleick 2014; Abel et al. 2019) and human migration (Wodon et al. 2014).

2. Literature Review

2.1 Conceptual Definitions of Fragility and Human Migration

Fragility can be defined as "the combination of exposure to risk and insufficient coping capacity of the state, system, and/or communities to manage, absorb or mitigate those risks" (OECD 2016). Thus defined, fragility is a broad term that encompasses economic, societal, environmental, political and security dimensions. It is the result of interactions between complex systems and can have ramifications across numerous aspects of those same complex systems including food security, national GDP growth, household-level access to work opportunities, education and health services, functionality of socioenvironmental management systems, exposure to corruption or conflict, state legitimacy, and access to justice and accountability.

Considering the complex pathways in which droughts impact migration (discussed below), it is useful to consider herein the broader concept of migration. It is defined by the United Nations International Organization for Migration (IOM) as movement across an international border or within a state away from habitual places of residence, regardless of legal status, whether the movement is voluntary or involuntary, the causes for the movement, or the length of the stay (IOM 2019).[2] In this report, we use the term 'emigration' to signify international migration and 'out-migration' to signify internal migration, often from rural to urban areas.

Conceptually, therefore, fragility and migration can be both contributing factors to 'vulnerability', as well as the results of vulnerability. In the natural hazard literature, vulnerability is often described as a function of exposure to a hazard, sensitivity to its effects and the coping capacity to deal with it (UNISDR 2015), with a straightforward definition being "the predisposition to be adversely affected" (King-Okumu et al. 2020).

The way we use the terms fragility, migration, vulnerability, sensitivity, resilience, etc. reflects our conceptualization of them as characteristics of social-ecological systems. Bouamrane et al. (2016) summarily define social-ecological systems as "interdependent and linked systems of people and nature that are nested." The use of FCMs helps us assess these linkages, interdependencies and nestedness.

2.2 Fragility in the Levant

The Levant has a rich culture and history of common ties shaped by significant sociopolitical, economic, ethnic, religious and geographical diversity. However, the region currently faces several sociopolitical and socioecological challenges including restricted state finances and service delivery, rising poverty, high levels of unemployment, poor natural resource management and institutional weaknesses, all of which are aggravated by turbulent geopolitical and security conditions (Ziade and El Khalil 2018).

In global assessments of state fragility, nations in this region all rank above the global average. Taken as a whole, the Levant ranks among the most fragile regions in the world due to historical and contemporary conflict and socioeconomic strain. Figure 1 shows the Fragile States Index (FSI) scores of several Levant countries between 2006 and 2022. These scores are calculated based on economic, political, social and cohesion indicators (FFP 2022).

Fragility levels in these countries are impacted by different vulnerabilities. Syria, for example, has the highest FSI score due to the past decade of high-intensity armed conflict. Similarly, Iraq, which emerged from war into medium-intensity conflict, also scores high on fragility. Lebanon and Jordan, on the other hand, suffer from institutional and social weaknesses in addition to spillover effects, including migration, from neighboring conflicts (Ahmad and Ranade 2021).

[2] Within the context of climate change, environmental migration is defined as "temporary or permanent displacement due to natural disasters, drought, crop failure and human-made changes to habitat" (Simonelli 2016; Daoudy et al. 2022). However, in this study we prefer to use the wider IOM definition precisely because we focus on the interplay between environmental, socioeconomic, political and other factors in relation to migration.

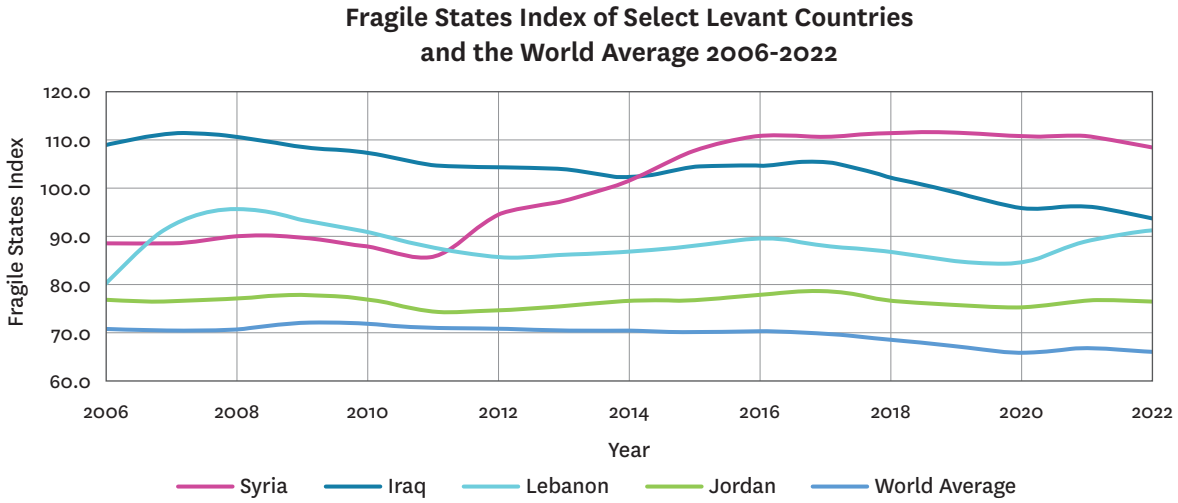

Figure 1. Fragile States Index scores of Lebanon, Jordan, Iraq and Syria and the world average between 2006 and 2022. (*Note:* Based on data from Fund For Peace.)

National fragility in the Levant also results from strained economies, refugee influxes and high levels of 'group grievances', which reflect social and political divisions among various groups in society, as well as how these divisions affect the groups' access to services and resources. Even before the Covid-19 pandemic, Levant countries faced significant macroeconomic challenges. These difficulties have been exacerbated by large (and growing) public debt, slow (or even negative) economic growth and high unemployment, particularly among youth and women. The influx of a large number of refugees into Iraq, Jordan and Lebanon has put tremendous financial strain on provision of governmental services, which has aggravated the political deadlock. Together, these and other factors contribute to group grievances.

In the MENA region generally, the legal and institutional frameworks for drought management are weak and nascent, which can be a source of fragility. However, in both Jordan and Lebanon, draft Drought Action Plans (Jobbins et al. 2022; MWI Jordan 2022) have proposed decision-making and governance structures to support timely action in response to drought, as well as a series of actions to undertake outside of drought cycles. These include preparedness, mitigation and response actions related to a range of sectors including water, agriculture, human health and the environment.

2.3 Interplay between Climate Change and Fragility and Migration

If we consider climate change as immanent, which is amply evidenced in analysis of drought in the MENA region (e.g., Bergaoui et al. 2015), we must consider in particular its effects on short-lived extreme events such as drought, as well as long-term averages. Given the intertwined social-ecological systems of relevance, a vicious cycle is expected to arise in the Levant involving drought, climate change and fragility whereby increasing extreme events and long-term climatic shifts exacerbate fragility, which, in turn, obstructs climate adaptation actions and improved natural resource management (Ahmad and Ranade 2021).

2.3.1 Climate Change, Drought and Macro-level Impacts

Risks connected to extreme weather events are expected to have a wide range of socioeconomic consequences in the Levant, threatening stability, peace and economic prosperity (Ahmad and Ranade 2021; Jedd et al. 2021). Long-term impacts are expected to include degradation or destruction of infrastructure; increased morbidity and mortality rates; decreased productivity; increased demand for energy; weakened tourism; increased malnutrition; and migration (Ahmad and Ranade 2021).

The effects of climate change on economic output are context-dependent, and there is evidence that reactions to climate change will be non-linear (see Burke et al. 2015). In the Levant, non-linear reactions to socioeconomic climate-change impacts can occur as a result of uneven initial conditions (such as labor type and location), varying capital requirements, and the magnitude of uptake and effectiveness of resilience and adaptation measures.

2.3.2 Extreme Events and Migration

The international community is increasingly worried about migration that is induced by worsening extreme events associated with climate change as a prominent contributor to conflict and fragility (Nicol et al. 2022). However, there is still no international legal and/or normative framework that addresses international migration in the context of climate and environmental change (Thompson 2013).

Droughts amplify water stress and competition for limited resources, which, coupled with declining agro-pastoral production, can trigger or worsen conflicts and exacerbate migration (von Uexkull 2014). Indeed, an empirical study analyzing the correlation of droughts and out-migration in Syria using satellite nighttime light intensity found a significant correlation between meteorological drought in 2006-2010 and a wave of out-migration (Ash and Obradovich 2020). Large-scale migration, whether internal or international, puts pressure on destination areas and host communities that can contribute to conflict (an aspect of fragility) depending on the economic and social structures of the destination areas (Reuveny 2007; Raleigh et al. 2008).

However, the literature also affirms that extreme events are mediated by human institutions and actions, which means that ultimate outcomes such as fragility and migration are several degrees separated from climate drivers (Feitelson and Tubi 2017; Adger et al. 2014; Döll et al. 2015). Further, socioeconomic and climatic factors may result in migration as either (or both) a mechanism to cope with the outcomes of environmental change, or fragility and economic instability (Wodon et al. 2014). Migrating people often view migration as an opportunity to improve their employment and earning prospects, and that of their families through remittances, as well as access better public services (Wodon et al. 2014).

2.3.3 Conclusion and Research Questions

In sum, viewing extreme events or even climate change as an exclusive driver of migration or fragility obfuscates critical variables and contextual factors such as legal regimes, market factors, human and social capital, government policies, property rights, etc., especially in the MENA region (Daoudy et al. 2022). Again, this reflects their placement within complex social-ecological systems. Hence, in the Levant and the wider MENA region, drought and climate change can be viewed as risk multipliers, especially in relation to the water and agricultural sectors, which are already affected by wider problems related to fragility.

Therefore, to inform policy and investment strategies that would promote resilience to drought impacts and thereby reduce their likelihood of resulting in fragility, this study set out to examine linkages between drought, fragility and migration through two case studies and answer the following key questions:

I. Do droughts exacerbate fragility and conflict between groups? If so, how?
II. How does drought contribute to human migration? How are decisions to relocate (or stay) made?
III. What influences these decisions? How can policies mitigate the consequences on migrants and host communities?

3. Case Studies

3.1 Study Locations as Microcosms of Agrarian Communities in the Countries and the Wider Levant Region

To assess the interconnections between drought, fragility and migration, case studies were conducted in two areas that are vulnerable to drought and have other symptoms of socioeconomic stress. Based on findings from the MENAdrought vulnerability assessments (Fragaszy et al. 2022a, 2022b), the Rechaya district in southeastern Lebanon and parts of the Zarqa Governorate in Jordan were selected for the study because they reflect conditions in their respective country and are at the same time socioeconomically, geographically and morphologically similar to rural

agrarian areas in the wider Levant. A mixed methods and systems approach was adopted as it allowed us to explore the local dynamics within the national as well Levantine socioeconomic, political and environmental contexts.

Lebanon's rugged topography results in a moderate climate with an average annual precipitation of 600-800 mm and a climatological gradient allowing for many microclimates conducive to diverse agrarian livelihoods (MoE Lebanon and UNDP 2021). It is the cool and wet western limit of the Fertile Crescent. The Jordanian badia, extending east from the mountains of the Jordan Valley, on the other hand, is characterized by wide and flat valleys at an elevation of 700-1,100 masl, with a predominantly semi-arid or arid climate with an average annual rainfall of less than 200 mm (BRP-NCRD 2011). Despite this, the badia contains some of Jordan's most important surface and groundwater resources, including the Disi aquifer and the Zarqa River basin. Rechaya and Zarqa are microcosms of Lebanon and Jordan, respectively, representing localities where the economic and climatic stressors of agricultural economies interact, and where communities have experienced histories of social and demographic change. Annexes A and B provide a more detailed geographic and socioeconomic context for Rechaya and Zarqa, respectively, and Jobbins et al. (2022) provide drought management policy reviews. Figures A1 (in Annex A) and B1 (in Annex B) show the case study areas.

3.2 Methods: Data Collection

At both locations, we conducted a phone survey, focus group discussions and additional key informant interviews with people from key stakeholder groups including local officials, farmers and pastoralists, and residents. However, due to local cultural practices, we were not able to interview women farmers/laborers.

The phone survey was targeted at local authorities (mayors, mukhtars, or community elders, national research institute staff and government officials) with the aim of gaining a general understanding of the local demography, socioeconomic conditions and water management issues. The key informant interviews explored aspects of local livelihoods, farming practices, household conditions and drought-related coping strategies. The interviewees were drawn from participants in the focus group discussions.

Focus group discussions were organized in six villages in Rechaya (Tannoura, including Ain Hirsha, Beit Lehia, Bakkifa, Kaoukaba, Dahr el Ahmar and Aaqabe) and three municipalities in Zarqa (Hallabat, Hashemiyeh and Bani Hashem). Participants included large and smallholder farmers, pastoralists, residents, representatives of local farming groups or associations and local and national authorities.

The groups discussed water issues, infrastructure, social stability, economic activity, migration and socioeconomic conditions in the village. In Lebanon, we also conducted additional face-to-face key informant interviews with local officials during field visits.

Tables A1-A3 (in Annex A) and B1 (in Annex B) provide more details on participants in the various research activities in Lebanon and Jordan, respectively.

3.3 Methods: Thematic and Narrative Analysis

We then conducted a thematic and narrative analysis of the data obtained from the survey, interviews and focus group discussions. We summarized participants' perceptions, attitudes and experiences on migration—from both perspectives, as hosts or migrants—and fragility in relation to drought events, environmental change and climate change. These responses were contextualized by the literature review and data collected on the demographics of migrant and non-migrant locals, socioeconomic conditions, aspects of livelihood strategies, assets, land use and productivity and response strategies.

This dual-track approach supported the conceptualization of decision-making strategies and enabled the identification of the most prominent drivers and mediating factors in conflict, tension and migration decisions. Our analysis was guided, as much as possible, by the framework used by Nicol et al. (2022) in a study on water, climate change and migration in Morocco (Figure 2). In particular, we used their categories—climate and non-climate drivers, intermediating factors and outcomes—as the structure for our thematic analysis and interpretation of FCM results.

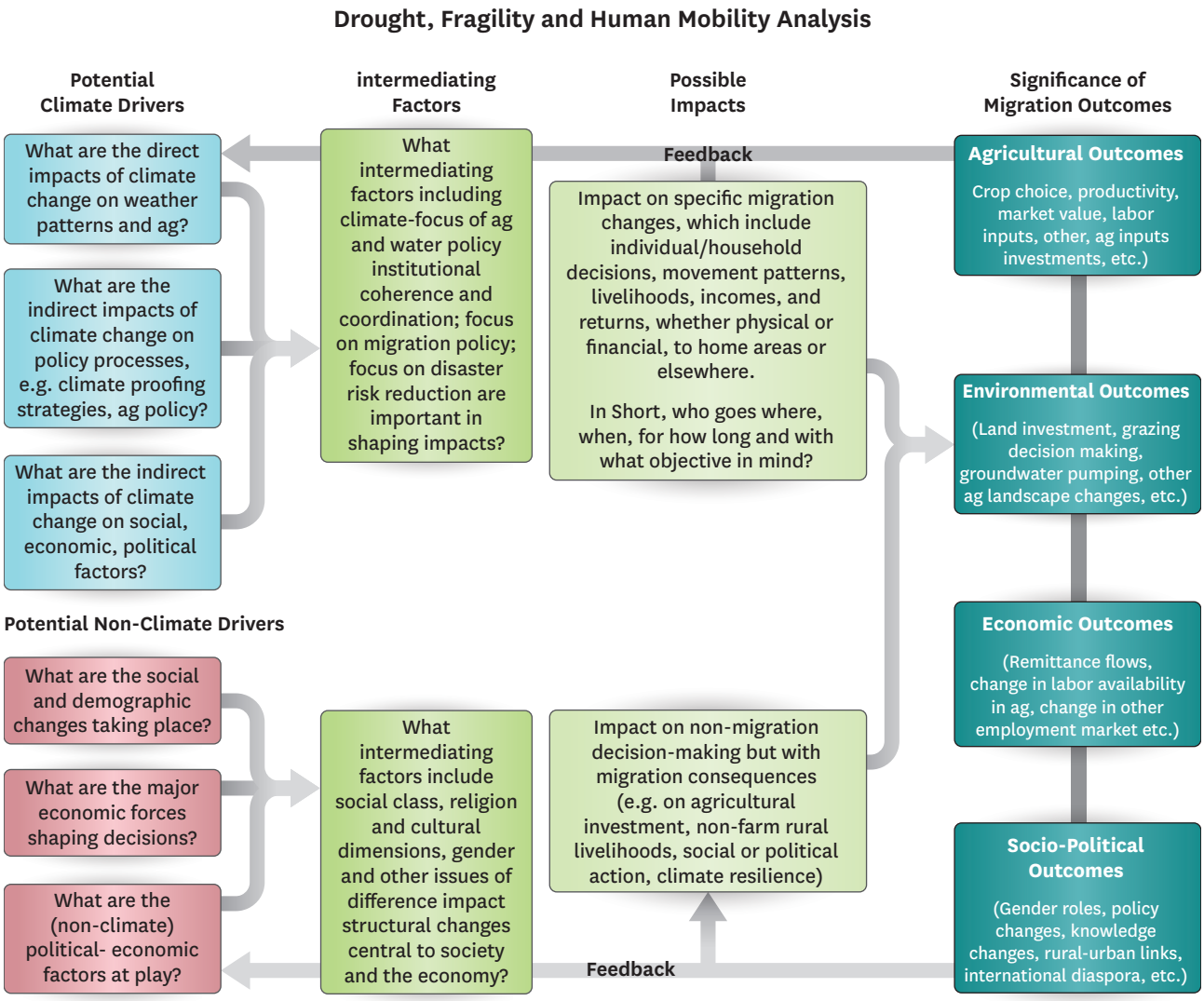

Figure 2. *The drought, fragility and human mobility analysis framework (based on Nicol et al. 2022).*

Climate drivers included themes related to changes in temperature, precipitation and seasonality, which entailed heatwaves, unseasonal cold snaps and early or late onset of frosts. These drivers also included droughts and water scarcity events as a separate theme, given their specific impacts on water availability.

Non-climate drivers included social and economic factors that impact decision-making and environmental and economic outcomes, such as income, educational availability, demographic changes and cultural traditions.

Intermediating factors are pathways between climatic or non-climatic drivers and subsequent outcomes, and can either drive or deter specific outcomes or decisions.

3.4 Methods: Fuzzy Cognitive Mapping

These themes and associated data were used to develop an FCM for each country. The map is illustrated by nodes (themes) that represent the concepts and main elements of the system, and directional connections that represent relationships between concepts (Meliadou et al. 2012). We assigned equal weights (+1 or -1) to the concepts, with a positive weight indicating an excitatory relationship, and a negative weight representing an inhibitory relationship (Kok 2009).

Fuzzy cognitive maps are based on graph theory, which provides a way to analyze the structure of a network based on centrality measures. These include three measures of centrality:

Degree centrality describes the number of connections a node or concept has in a network, whether outgoing or incoming. The higher the number of connections a node has, the higher its centrality will be. Degree centrality can indicate the strength or importance of the connection of a node in the network. It is calculated for each node by summing direct connections (Obiedat et al. 2011).

Betweenness centrality describes the number of other nodes that must pass through a specific node to reach their final path (typically, an outcome). This indicates concepts that act as hubs or pivot points within the network. The betweenness centrality of a node is determined by the number of paired nodes within a network, the shortest distance between each pair of nodes, and the proportion of shortest paths that pass through a specific node (Obiedat et al. 2011).

Eigenvector centrality describes the degree of connection to important or highly connected nodes, indicating the degree of influence on the network (Bonacich 2007).

4. Results and Discussion

The FCMs resulting from our case studies in Lebanon and Jordan are shown in Figures 3 and 4, respectively, and the list of themes and centrality measure values for both locations are presented in Tables C1 and C2 (in Annex C). The findings reveal commonalities in:

- the pathways and factors that influence the fragility and migration of agricultural households;
- perceptions of climate change and droughts; and
- the coping strategies of agricultural communities to deal with drought, and their interactions with fragility and migration.

In the subsections below, we describe the results in relation to climatic and non-climatic drivers of, and intermediating factors in, fragility and migration.

Whether through declining rangeland productivity as reported by pastoralists in Zarqa in Jordan, or changing seasonality as experienced by smallholder farmers in Rechaya, Lebanon, the impacts of droughts and climate change were evident in both case study locations in terms of declining agricultural production, revenue and profit and increasing production costs, especially that of water supply. These impacts can impair the financial security of agricultural households, and our findings indicate that they are the most prominent push factors in economic and migration decisions in both cases, and that education, healthcare and employment opportunities are the most prominent pull factors. However, differences in water governance and socioeconomic and cultural factors in Zarqa and Rechaya allow us to draw broader conclusions and recommendations for resilience to drought impacts in the Levant.

4.1 Climatic Drivers of Fragility and Migration

Climate change presents a direct threat to agricultural livelihoods in the Levant (Waha et al. 2017; Farajalla et al. 2022). Farmers, pastoralists and residents all described to us increases in temperatures, changing patterns of precipitation and shifts in the seasonality of both temperature and rainfall over the past 10 years. Farmers in both locations reported facing serious challenges due to seasonal variations in water availability including extension of the dry season, reduced rainfall during the growing season and often heavy showers or storms during the flowering season. Droughts and/or shifts in rainfall patterns affect farmers through variability and instability in crop growth and agricultural production, diminished water flows and damage to certain tree species. Damage to trees such as olives are costly to offset and can affect production in future seasons, placing a financial burden on farmers.

Our interviewees and focus group participants widely reported having experienced increased water scarcity in the past decade despite high precipitation levels in some years. The impacts of water scarcity and climate irregularities—such

as heatwaves, cold snaps and early or late onset of frosts—on agricultural production was described as severe, with some participants reporting 50-60% losses in crop yield.

Pastoralists reported a decline in rangeland productivity owing to decreasing food availability for grazing animals, and the associated increasing need to purchase and provide fodder. The decline in rangeland vegetation was perceived to be a result of low precipitation, seasonal irregularities or drought events. Pastoralists reported a substantial decline in milk production. This is consistent with findings from previous fieldwork and literature (e.g., Nori et al. 2009) in which pastoralists reported changes in the quality of rangelands and shifts in seasonal availability, herd mobility and livestock nutritional patterns, leading to an increase in animal health problems, exacerbating the decline in production and increasing veterinary costs.

In response to these drought and climate-change impacts, farmers and pastoralists do adopt coping strategies, sometimes in the absence of official or governmental agricultural outreach, support or insurance. Farmers reported several such strategies including diversifying crops, altering the crop planting schedule, changing the irrigation pattern and shifting to rainfed crops such as cereal and olives.

Drought- and/or climate change-driven loss of production pushed some smallholder farmers into subsistence agriculture or forced them to shift away from investment in larger-scale commercial agriculture. In many cases, income from agricultural or animal production was not enough to encourage continued investment. Some farmers failed to break even or could not cover costs and service debt. Such outcomes can influence migration decisions, as shown in Figures 3 and 4. Shifts away from agriculture could entail seeking other forms of employment and out-migration or emigration (see Grant et al. 2014; Wodon et al. 2014).

4.2 Factors Mediating in Fragility and Migration

While climate and water scarcity drivers present a direct challenge to agricultural productivity, stakeholders including farmers, pastoralists, residents and local authorities emphasized that intermediating factors relating to water management too influence their decisions. These factors include availability or accessibility of water sources and water or wastewater infrastructure, distribution of water resources and the cost of water services.

In the absence of effective plans or oversight, management of water services and resources can fall to municipalities or local groups, as in the case of villages in Rechaya. This can have impacts beyond water costs. Overextraction of groundwater can result in a drop in the water table, which can limit water availability or negatively impact its quality. Lack of oversight on well drilling and use can exacerbate this situation and create conditions for unequal access to, or distribution of, water resources, which in turn can cause tensions or conflict between local populations or with authorities.

Farmers and pastoralists reported that access to water has become increasingly costly, in some cases, prohibitively so. Water supply entails the costs of (1) well-digging, (2) operation and maintenance (including deepening), (3) pumping to fields or herds, and (4) collecting tariffs and/or taxes. The first three of these are increasingly being impacted by climatic factors, and the fourth indirectly so. Dry seasons increase the need for irrigation and, therefore, the need for pumping water. When droughts reduce groundwater recharge, deeper wells are needed and more energy to pump water to the surface. This is one of the most important ways in which drought impacts farmers and pastoralists economically.

Energy plays an important role in the water sector insofar as it is needed for critical functions such as powering pumps for extracting groundwater, distributing water to households and other institutions, and operating existing water and wastewater treatment plants. Farmers and pastoralists expressed concerns related to energy costs such as having to incur additional costs on supplemental or alternative power supply to pump or transport water for irrigation and livestock consumption. Access to and cost of fuel for power generators or pumps increases the cost of agriculture, as does the cost of supplementary water supply by private tankers. Fuel costs also have an impact by way of higher costs of transporting water, material and equipment to and from the field.

Fuel shortages leading to power outages or impeded mobility exacerbate the difficulties of accessing water or reduce profits from agricultural produce, resulting potentially in greater dependence on rainfed agriculture, or a decline in agricultural investment. In some cases, such as in Rechaya, the absence of agricultural roads or infrastructure limits connectivity between farmers and their fields, thereby amplifying the impact of fuel costs. Given the high costs of agrochemicals, equipment and feed and the unsupported or volatile markets for agricultural goods, high costs and limited income from agriculture may result in a shift away from agriculture.

4.3 Non-climatic Drivers of Fragility and Migration

4.3.1 Costs of Living and Food Security

The impacts of energy (especially fuel) and water costs are not limited to the field or livestock rearing. They affect farmers, pastoralists and local people at the household level too. The high or rising cost of basic services puts additional pressure on households that are already struggling to balance their income and expenditure. In many households, access to food is becoming increasingly difficult. Coping strategies for this include modifying diet away from meats and increasing reliance on grain and vegetables. In some cases, households have had to borrow money to meet dietary needs or turn to the limited food aid provided by the government or nongovernmental organizations. It is not uncommon for landowners to sell portions of their land to supplement household income.

4.3.2 Social Cohesion

Social cohesion, which was self-reported by participants using a word akin to 'solidarity', is a prominent non-climatic intermediating factor in fragility and migration. Participants in both locations described social cohesion in relation to common values and a civic culture, social order and social control, strong social networks and social capital, and attachment to place and identity (IOM and ESCWA 2019; Forrest and Kearns 2001). In both Lebanon and Jordan, social cohesion was shown to have an inhibitory impact on emigration. However, it was also negatively affected by other intermediating factors and outcomes such as local tensions or small disputes over water access, pressures on services stemming from population growth and group grievances, which are complaints arising from issues that affect a specific community as a collective. In both our case studies, the increase in foreign migrants was not discussed negatively or very frequently, indicating that it was not a negative issue for participants (none of whom was a refugee).

Other studies (Fragaszy et al. 2022a, 2022b) have noted gender-specific drought-related issues that reduce social cohesion: Examples include changing marriage practices (such as acceptance of polygamy and child marriage) and increasing casualization of the agricultural labor force which disproportionately affects women. This study did not assess gendered aspects of drought and its interactions with fragility and migration, but previous efforts (Fragaszy et al. 2022a, 2022b) have highlighted that due to socioeconomic status and educational levels, women disproportionately occupy the lower rungs of the agricultural workforce, are paid less than men, and are far less likely to own the means of production (land, livestock and partial produce transformation). As such, women and female-headed households are particularly sensitive to impacts of drought in relation to cost of living increases and effects on farming profitability as female farm laborers are typically the first to be let go during a downturn.

4.3.3 Government Services Provision

Government and public services can play a role in limiting emigration and out-migration, both directly and indirectly. Directly, this would include provision of local education, healthcare and livelihood services, which were found to be major factors in maintaining local populations while also attracting migration to rural areas. This was seen in Hashmiyeh district of Zarqa Governorate, where these services, in addition to expansion of local markets and employment opportunities, have provided a safety net for Jordanian and foreign migrants alike. According to local authorities, this area attracts people escaping the high cost of living in metropolitan areas like Amman, while also attracting investment in local tourism, especially rental farms and ranches.

Access to education, healthcare, employment opportunities and other services appears to be the most direct pull factor impacting migration decisions. In Lebanon, for example, many households or families migrating internally move to urban or suburban areas in Mount Lebanon to seek better education for their children or wider employment opportunities for household earners. Economic, social or political turmoil experienced on a national scale often drives men, women and families to emigrate, seeking employment or educational opportunities in various regions, including North America, Europe and the Persian Gulf region. In Jordan, emigration is not as common, with movement predominantly seen toward employment opportunities in cities, including the capital, Amman.

Likewise, government agricultural extension services, irrigation schemes, feed policies and subsidies play a major indirect role in limiting migration through protecting livelihoods and agricultural investments. State-led

interventions are seen as important factors in triggering and shaping agricultural development and rural demographics (Nori et al. 2009). In Jordan, for example, national policies aiming at settling pastoral groups through supporting irrigation or subsidized water and feed programs have provided incentives for a large demographic to settle and develop agriculture in Zarqa.

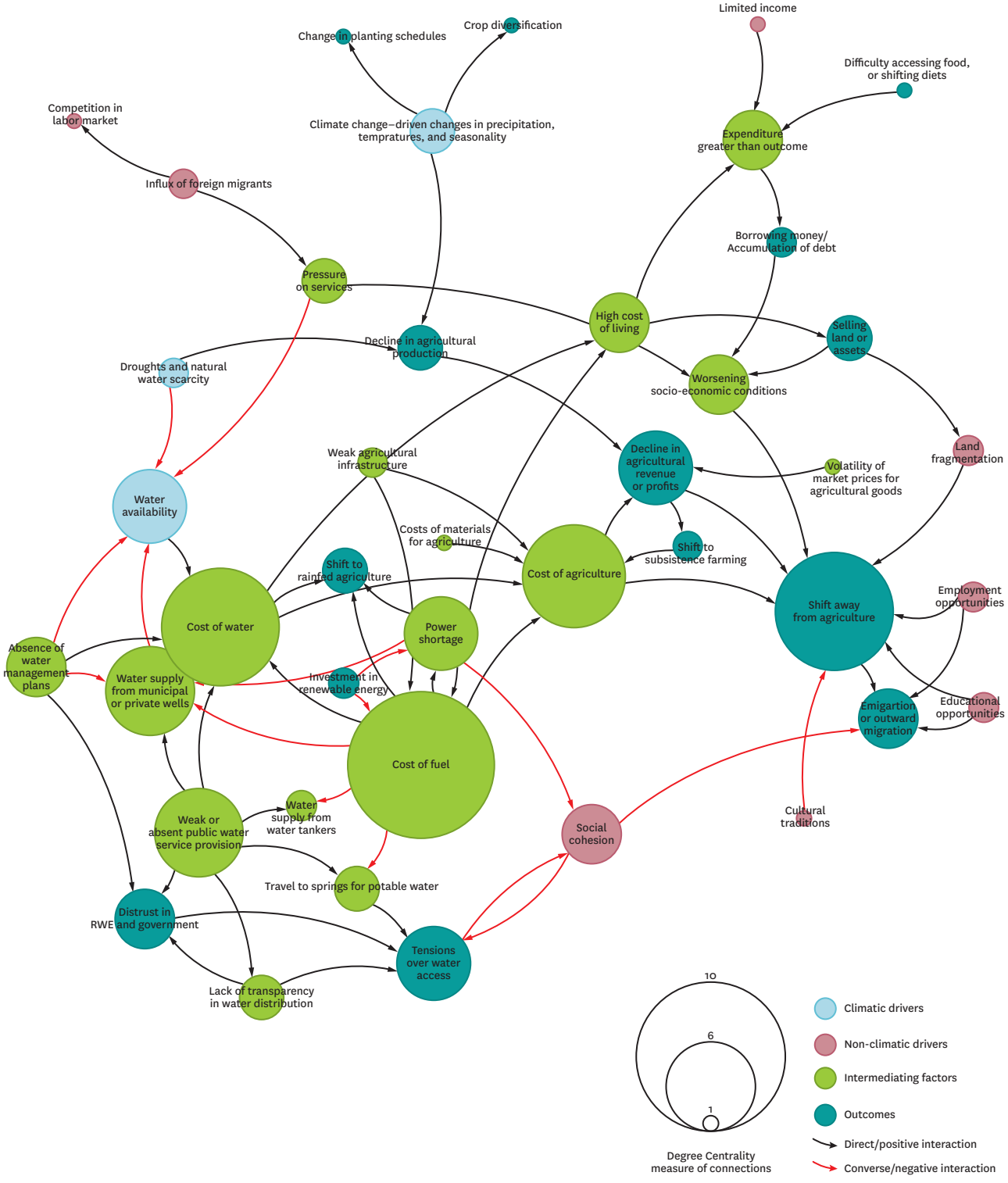

Figure 3. *Fuzzy cognitive map showing the interactions between drivers, intermediating factors and outcomes in Lebanon. The size of the nodes represents degree centrality, and their color represents the thematic categorization. Black arrows represent positive interactions and red arrows represent negative interactions.*

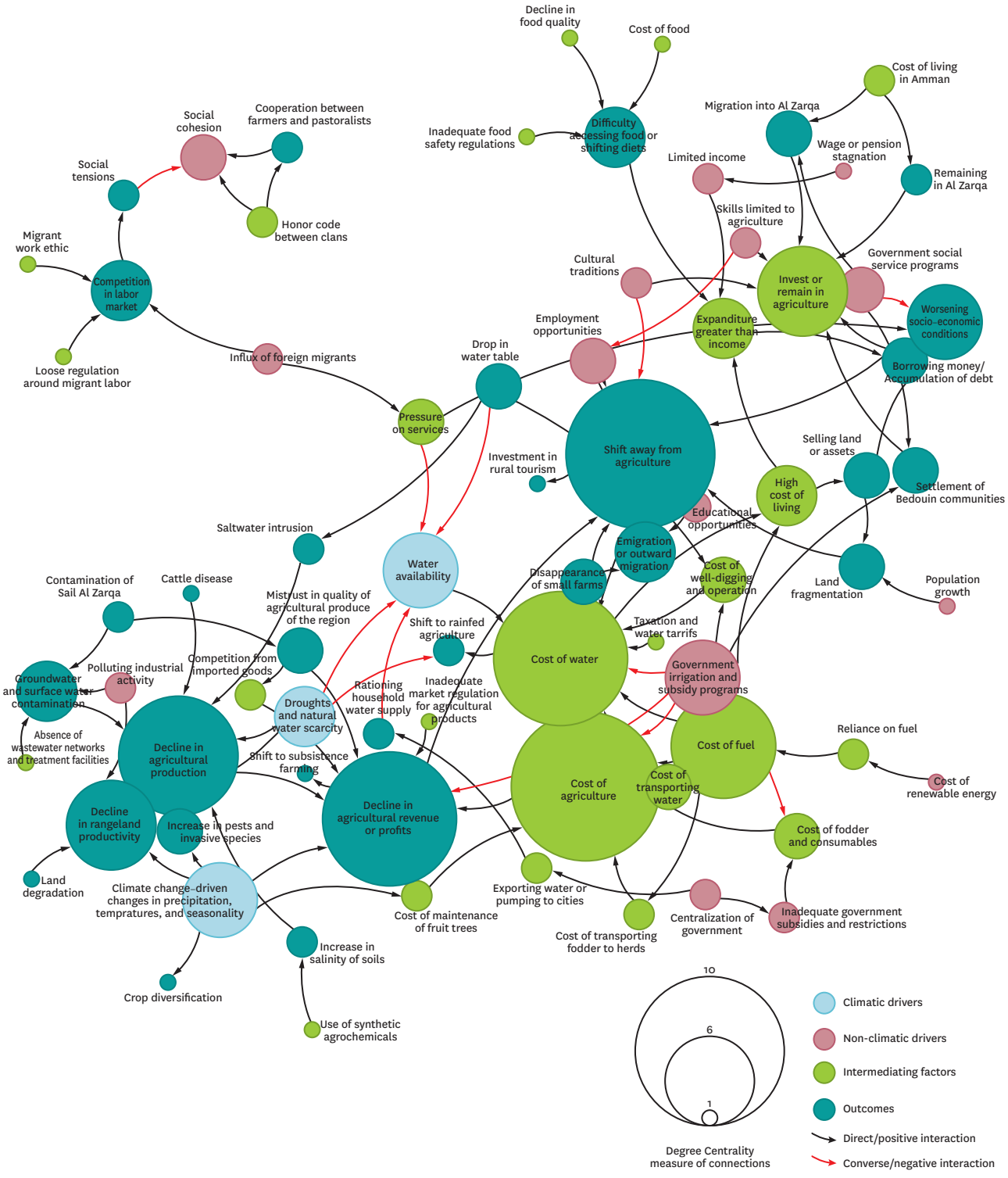

Figure 4. *Fuzzy cognitive map showing the interactions between drivers, intermediating factors and outcomes relating to fragility and migration in Jordan. The size of the nodes represents degree centrality, and their color represents the thematic categorization. Black arrows represent positive interactions and red arrows represent negative interactions.*

4.4 Conclusions

To draw conclusions from the research findings presented above, we return to our first two research questions:

- Do droughts exacerbate fragility and conflict between groups and, if so, how?
- How does drought contribute to human migration? How are decisions to relocate (or stay) made?

We deal with the third research question—What influences these decisions? How can policies mitigate the consequences on migrants and host communities?— in Section 5 on recommendations.

Do droughts exacerbate fragility and conflict between groups? If so, how?

Our study indicates that the extent to which drought exacerbates fragility is dependent on mediating factors, non-climatic drivers and coping capacity—the ability of a community to manage, absorb or mitigate those risks. In both our case study areas in Lebanon and Jordan, the answer clearly was that drought does exacerbate fragility. Findings from other case studies in these countries suggest that the answer is generalizable (Fragaszy et al. 2022a, 2022b; Belhaj Fraj et al. 2022).

These other studies particularly highlight the interacting effects of drought on smallholders in relation to (1) incomes, financial indebtedness including the ability to restart production after a drought year, and inability to invest, whether in relation to commercial growth or climate change adaptation; (2) food insecurity; and (3) water resources management. In turn, these potential impacts are especially mediated by global commodity prices (energy and food in particular), governance arrangements, market access and human capital.

Whether these matters are particularly severe, and whether drought exacerbates conflict between groups, depends on the extent to which fragility increases and drought impacts materialize. They are a function of sensitivity as well as the magnitude of the drought event.

The Lebanese case study showed a greater proclivity for drought to intensify intracommunal conflict over water resources, whereas the Jordanian case study suggested disagreements between smallholder farmers and pastoralists and the state in relation to broader agriculture, water and environmental policy and regulatory enforcement, with drought amplifying the magnitude of these concerns.

Findings from earlier fieldwork in Baalbeck-Hermel, Lebanon, were somewhat starker, with smallholder farmers describing much more significant exacerbation of intra- and intercommunal conflict due to drought (Fragaszy et al. 2022b). But that study area had a different socioeconomic, agroecological, governance and demographic profile that, while not specifically assessed in this manner, presumably reflected greater fragility. For example, in that study area, remittances from family members in Beirut or abroad were not viewed as a significant form of financial support. Further, when some participants brought up the issue of social cohesion, it was always in a narrow sense of neighboring households rather than the wider community.

Assessment of drought impacts in Tafilah Governorate in Jordan indicated social cohesion as being a core element of the coping capacity for drought. However, it also described its limitations: for example, communal pasture management was adequate to reduce vulnerability and associated tensions to a certain point, but as drought progressed, this cohesion was insufficient to avoid impacts, which necessitated additional relief measures to be introduced (Belhaj Fraj et al. 2022).

How does drought contribute to human migration? How are decisions to relocate (or stay) made? What influences these decisions?

In sum, these results largely concur with past studies which showed that, in the MENA region, socioeconomic factors are likely to be as important as drought-related or climate change-related factors in determining migration (e.g., Wodon et al. 2014; Grant et al. 2014).

Participants in the Rechaya and Zarqa case studies, like those in focus group discussions conducted by Grant et al. (2014) across the MENA region, stated that even when drought or long-term climate change conditions lead to a decline in agricultural productivity and result in migration, the factors leading to poor socioeconomic conditions in rural areas are broader than climate drivers themselves. Migration decisions appear to be taken when strategies to cope with economic hardship have been unsuccessful (Wodon et al. 2014).

Further, previous fieldwork in Baalbeck-Hermel (Fragaszy et al. 2022b) suggested that migration was not typically undertaken by the most vulnerable within a community, but by those with at least slightly greater resources. Migration is resource-intensive and, without familial or other personal networks in the destination area, risky (Wodon et al. 2014).

5. Recommendations

There is a complex interaction between drought hazard and the series of drought-related impacts that affect fragility and migration decisions. The case studies conducted in Rechaya and Zarqa revealed that droughts, water scarcity and associated climatic changes heavily impact agricultural production and hence the livelihoods of agrarian communities, especially in rural areas.

However, the impacts of drought are obscured and mediated by a range of factors, especially water management, water and energy resource costs, and the socioeconomic circumstances within households and communities. These factors interact within complex social-ecological systems and steer economic decisions, of which migration is one. The interaction of some of these intermediating factors may also impact social cohesion and increase economic hardships and fragility.

This study demonstrates that the combined impacts of increasing costs and reducing incomes can lead to shifts away from agriculture entirely. Whether that leads to migration is a function of both push and pull factors. For example, in areas like Hashmiyeh in the Zarqa Governorate, where government services and other employment opportunities exist, migration is less likely. Where agricultural and rural development is a priority component of the political economy, out-migration—and emigration, which is more induced by push factors than pull factors—is less likely to occur.

Therefore, the summary recommendations of this study shown in Table 1 address all aspects within the effect chain—drought management, sustainable agricultural development and resilience, water management and socioeconomic resilience—through an economic and social policy lens. Table 1 outlines key recommendations that could promote resilience to drought impacts. These recommendations are synthesized from the findings of our case studies that we consider appropriate even for locations elsewhere in the region. The recommendations are grouped thematically and prioritized according to our judgment of the extent to which they address the underlying challenges we found in this study. However, it should be noted that the priority, sequencing and design of activities in the two case-study countries as well as the wider Levant should be refined through stakeholder consultations and localized analysis for policy and sustainable investment.

More detailed recommendations based on findings and policies from Lebanon and Jordan can be found in Annexes D and E, respectively.

Table 1. *Key recommendations to promote resilience to drought impacts on the basis of findings from case studies in Rechaya district in Lebanon, and Zarqa Governorate in Jordan.*

Objective	Recommendation	Recommended action	Priority
Drought management and recovery	Support and improve drought monitoring and early warning systems.	Facilitate dissemination of risk information to relevant stakeholders including farmers.	Primary
		Combine monitoring and drought announcement with clearly defined management steps; reduce uncertainty regarding agency roles.	Primary
		Coordinate and utilize the capacities of farmers and local organizations for monitoring and enforcement.	Secondary
		Increase coverage of monitoring data.	Secondary
	Develop and implement a drought risk reduction and recovery plan.	Establish a legislative framework for drought risk reduction that includes coordination at the national, subnational and local levels.	Primary
		Pair drought declaration with financial relief programs; create incentives to develop and provide clear applications for drought monitoring information.	Primary
		Encourage local participation in decision-making.	Secondary
Sustainable agricultural development and resilience	Enhance agricultural extension services and empower agricultural cooperatives for climate-smart practices.	Invest in and support professionalization of agricultural cooperatives through capacity building and training.	Primary
		Invest in expanding agricultural extension services at local rural scales, including access to veterinary services for pastoralists.	Primary
		Mainstream climate-smart irrigation and production practices through extension services.	Primary
		Establish coordination efforts or formalize public consultations with cooperatives.	Secondary

Objective	Recommendation	Recommended action	Priority
	Support marketing and domestic market access and infrastructure.	Monitor and regulate market prices for locally produced agricultural goods and prevent sudden price drops and meltdowns.	Primary
		Invest in infrastructure of postharvest operations including grading, packaging, refrigerated transport and storage of local produce, and enhance the capacities of cooperatives in executing these operations.	Secondary
		Build capacities of smallholder farmers for entry into and competition in domestic markets.	Tertiary
	Support development and marketing of drought- and heat-tolerant seed and crop varieties.	Support and finance local production of drought-tolerant varieties.	Primary
		Set up reduced-interest loans or small grants programs to facilitate the adoption and upscaling of drought-tolerant varieties.	Secondary
		Ease the entry of locally produced varieties into local markets and support their promotion.	Tertiary
Water management	Support equitable water demand management.	Improve government-based water accounting systems, support integrated, participatory and evidence-based national and basin-level water monitoring and planning.	Primary
		Provide economic incentives for climate-smart irrigation and water conservation practices. These can be in the form of special subsidies, tax breaks or restructured water tariffs for farmers.	Primary
		Coordinate groundwater management across agencies, citizens and farmers for the enforcement of regulations.	Secondary
	Increase local water capture and storage.	Mainstream and finance rainwater harvesting initiatives for municipalities, creating shared communal rainwater reserves or discrete sources for municipal water consumption.	Primary
		Support municipalities in increasing local water storage capacities such as additional tanks, pools and reservoirs.	Secondary
	Scale up integration of renewable energy into water operations.	Support integration of renewable energy into operation of water infrastructure; facilitate small-scale investments in solar-powered water pumping systems for farms and households.	Primary
	Improve wastewater management and mainstream safe wastewater use.	Develop or improve wastewater treatment facilities that encourage use of wastewater.	Primary
Socioeconomic resilience	Support diversification of skills and off-farm income opportunities.	Support diversification of rural economies and development of small businesses for rural job creation.	Primary
		Invest in establishment and staffing of schools and educational services in rural areas.	Secondary
		Provide opportunities for vocational training, especially for women and youth, to ease entry into local job markets, for example, within small-scale industry and agricultural services.	Secondary
		Expand the scope of rural economic empowerment initiatives and small- scale production, with a focus on women's economic empowerment.	Secondary

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Annex A. Overview of Field Work and Social-ecological Context in Rechaya, Lebanon

Table A1. *Focus group discussions and surveys conducted in Rechaya, Lebanon, on Day 1, April 28, 2022.*

	Village	Meeting place	Number of participants
1	Tannoura	Municipality	7
2	Ain Hirsha	Municipality	1
3	Beit Lehia	House of Mukhtar	2
4	Bakkifa	Residence of cooperative member	4
5	Kaoukaba	Municipality	6
Total number of surveys on Day 1			20

Table A2. *Focus group discussions and surveys conducted in Rechaya on Day 2, April 29, 2022.*

	Local authority	Meeting place	Number of surveys
1	Dahr El Ahmar	Municipality	3
2	Aaqabe	House (Lejnit ahel el dayaa)	5
Total number of surveys on Day 1			8

Table A3. *Officials interviewed as part of the local authority stakeholder group in Rechaya, Lebanon.*

	Local authority
1	Aaqabe
2	Aaiha
3	Ain Aarab
4	Ain Hirsha
5	Bakkifa
6	Beit Lahia
7	Bire
8	Dahr El Ahmar
9	Deir El Aachayer
10	Kaoukaba
11	Kfar Danis
12	Kfar Mechki
13	Kfar Quouq
14	Majdel Balhis
15	Mdoukha
16	Houche El Qnaabe
17	Rechaya
18	Tannoura
19	Yanta

The Rechaya district in the southeast of the Bekaa Governorate in Lebanon covers 545 km2, about 5.2% of the country's total area (Figure A1). The district capital, Rechaya Al Wadi, is about 100 km southeast of Beirut at an elevation of 1,250 masl. Administratively, the district is divided into 26 municipalities organized into two Unions of Municipalities: the Union of Municipalities of Jabal Al Sheikh and the Union of Municipalities of Independence Citadel, established in 2012. However, there are some villages in the district without a municipality or whose municipal status is disputed. Rechaya has a mostly mountainous area, and is home to Lebanon's second highest peak, Mount Hermon/Jabal Al Sheikh (2,800 masl). The district also has flat plains in the Bekaa, where wheat and other crops are cultivated. Other than these features, pastures, rangelands and barren lands cover most of the district (MoE Lebanon 2016).

In terms of population, Rechaya is one of the smallest districts in the country, with 0.7% of all residents, about 33,800. It has a Druze majority, with pockets of Christian-majority villages in the southwest and Sunni-majority villages in the northwest bordering West Bekaa. The average household size is around 3.4, and 82.4% of the households are headed by a man (CAS 2020). The services sector is the largest employer, employing 90.4% of women and 68.1% of men. However, compared with the national level, employment in agriculture in Rechaya is greater by 6.4 percentage points for working men (CAS 2020). In 2019, it had an unemployment rate of 12.7%, greater than the national average of 11.4%, in which women make up a larger proportion than men (CAS 2020).

Agriculture is still the main economic activity and has outsized socioeconomic influence. Rechaya district produces high quality olives and olive oil, grape molasses and honey which are sought after locally. Several villages specialize in producing honey, especially the capital, Rechaya Al Wadi. The agricultural profile of the district is characterized by rainfed crops such as olives, vineyards, cereals and grains, alongside fruit crops (MoE Lebanon 2016). Wheat, barley and other cereals are grown as rainfed winter crops with yields dependent primarily on precipitation. Legumes are among the seasonal crops grown in the wet season, making it the second most important crop in the district. But vast open expanses are the district's dominant feature, used primarily as rangelands for grazing goats and sheep, the former being more common (MoE Lebanon 2016). Milk production remains the purpose of cattle rearing. Finally, protected agriculture in the district is limited to around 3 hectares, and includes mostly tomatoes, cucumbers and leafy vegetables. Rechaya district has the least industry out of the four districts in the Bekaa, with most industrial activity focused on the agri-food sector, including oil-pressing and molasses factories. Other industries in the district include small tourism and artisanal crafts.

Water resources in Rechaya are limited in comparison with neighboring West Bekaa and Zahle. Despite an abundance of springs, especially at the foothills of Jabal Al Sheikh, the water needs of residents and farmers are not being met. In the absence of government-supplied water service provision (through the Bekaa Water Establishment) or irrigation schemes, many municipalities rely increasingly on digging public or private wells to tap into groundwater resources (MoE Lebanon 2016). For about 60.9% of the households, non-piped water supply is the main source of drinking water (CAS 2020).

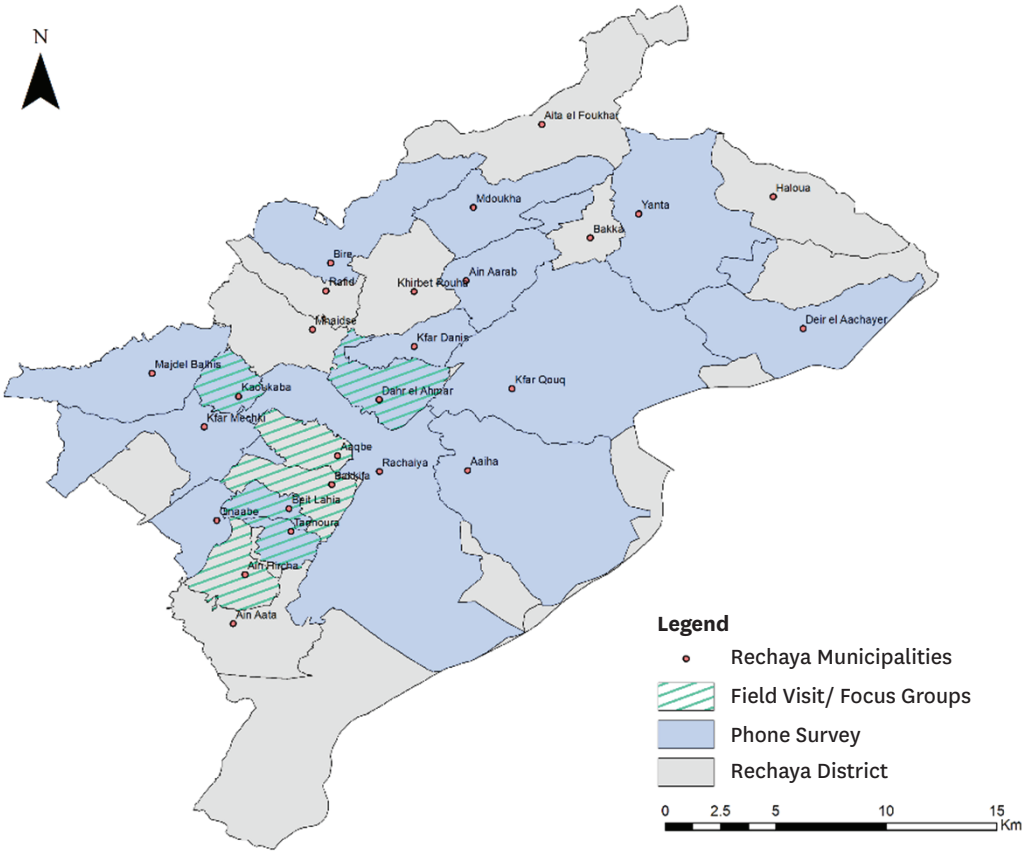

Figure A1. *Map of surveyed localities in Rechaya, Lebanon.*

Annex B. Overview of Field Work and Social-ecological Context in Zarqa Governorate, Jordan

Table B1. *Field visit schedule in Zarqa and Amman, Jordan.*

Date	Location	Meetings
May 10, 2022	Hallabat	12-member focus group of farmers, pastoralists and residents; local government officials
May 11, 2022	Hashimyeh	11-member focus group of farmers, pastoralists and residents; local government officials
May 12, 2022	Ministry of Agriculture, Amman	Office of the Director of Agreements and International Cooperation Directorate
	National Center for Research and Development, Amman	Specialist in biotechnology
May 14, 2022	Bani Hashem Al Sukhnah	7-member focus group of farmers, pastoralists and residents; local government officials

The Zarqa River is the second main tributary of the Jordan River after the Yarmouk. The Zarqa River Basin (ZRB) is among the most significant surface water basins in Jordan and hosts one of the country's major cities, Zarqa (Figure B1). The Zarqa Governorate is located 70 km northeast of Amman. Its boundaries extend to the Mafraq Governorate to the north, Saudi Arabia to the east, and the Balqa and Jerash governorates to the west. It is connected with the national capital, other governorates and neighboring Arab countries by a network of excellent international and major roads that facilitate the movement of goods and commercial trading. Zarqa has a population of 1,364,878 inhabitants, with a high population density of 286.7 inhabitants per square kilometer (MoI Jordan 2022.).

The ZRB has an average annual precipitation of around 400 mm in its western part and around 150 mm in its far east. It is characterized as a semi-humid to arid agroclimatic zone and is mainly covered by shrub vegetation (BRP-NCRD 2011). The ZRB is divided into two main regions. The first is the western part, comprising the catchment area of Sayl Amman, the southern branch of the Zarqa River, and all the small subwatersheds in the northwest of the basin. The second is the Wadi Dhulail, containing the eastern branch of the Zarqa River and the Qaa Khanna areas. The catchment area is situated in the Zarqa and Mafraq Governorates (BRP-NCRD 2011).

Considerable environmental damage can be noticed in the city of Zarqa. High population growth has caused its urban areas to spread, leading to land degradation and soil erosion. Water quality has deteriorated because 80% of the industrial and solid waste disposal areas are located around Sayl Amman-Zarqa where 20% of the whole population of Jordan resides in a dense urban setting (BRP-NCRD 2011). The Zarqa River, which is the main water resource for agriculture along its banks, is currently polluted due to the overflow from the wastewater pumping station upstream, leaks from the sewer lines passing through the riverbed, and industrial activities along the river. Heavy urbanization and utilization of water from the ZRB has resulted in a reduction of the base flow from 5 m^3/s to less than 1 m^3/s and the discharge of springs from an average of 317 million cubic meters (MCM) before 1985 to less than 130 MCM since 2000 (Shammout et al. 2021).

Climate change is expected to impact agriculture and rangelands alike in the ZRB. With an anticipated 1-4°C increase in temperatures and a reduction in rainfall, surface water and groundwater availability are expected to decrease. Unmanaged withdrawals have depleted groundwater resources. Most of the area has dried out, which disturbs the fragile moisture balance in the deeper soil layers. In the western part of the ZRB, water resources of the basin mostly serve the drinking water purposes of urban areas and the irrigation needs of agriculture, which have left the basin highly depleted.

A large part of the land in the basin is classified as badia rangeland, receiving less than 150 mm of annual rainfall. These rangelands, mainly in the eastern part of the basin, have deteriorated largely due to the harsh environmental conditions and human misuse. Overgrazing, logging, using rangelands for cereal crops and establishing land claims are the main factors contributing to the misuse of rangelands in this part of the ZRB (BRP-NCRD 2011). This has led to changes in land use in the basin. Over the past few decades, livestock owners here have shifted to commercial activities. For instance, livestock numbers in Jordan dropped from 2.6 million in 1998 to 2 million in 2002. A number of reasons are responsible for these changes, including government subsidy cuts, lack of veterinary services and an increase in prices of live animals in the export market (BRP-NCRD 2011).

These factors have led to an increase in demand for agricultural land, especially in the western parts of the *badia* along the Sayl Amman-Zarqa river branch. Between 1989 and 2017, agricultural area in this part of the basin increased by 9.97% and open rangelands decreased by 12.34%, albeit partly due to changes in rainfall patterns and shifts in seasonality (Shammout et al. 2021). These problems of water and land degradation now threaten agropastoral livelihoods. People in this area depend disproportionately on natural resources and also have fewer alternative livelihood options compared to other socioeconomic groups. Livestock activities do not currently constitute the main source of income in these areas (BRP-NCRD 2011).

Hashmiyeh

Hashmiyeh is a village 10 km north of Zarqa city. It lacks most governmental departments, sufficient medical services and qualified infrastructure. Over 90% of the households are headed by men, with women having negligible incomes. Income sources vary; they include livestock raising, factory work, and trade and civil service jobs. Many households keep 5-10 heads of sheep or goats for domestic use and trade. A study on poverty in Jordan classified Hashmiyeh as a poverty pocket with 30% of its inhabitants falling below the poverty line (IUCN 2014).

Hallabat

Hallabat is located 25 km northeast of Zarqa city. Its villages have a total population of around 7,000 inhabitants, mainly from the Bani-Sakhr tribe. These have been facing hardships since abandoning their mobile lifestyle as Bedouins in the 1950s. However, their main income continues to come from livestock. Unemployment has increased in recent years due to the deterioration of pastures. Many families own 7-17 heads of sheep and use milk products for home consumption while selling young lambs to meet other financial needs (IUCN 2014).

Bani Hashe

Located 21 km north of Zarqa city, Bani Hashem consists of four communities with a total population of 15,000, mostly of Bedouin origin. The area was characterized by rich plant cover and abundant water resources, which encouraged Bedouin tribes to settle there since the 1850s. Due to population growth and urbanization, natural resources were overexploited. In 1954, a malaria outbreak drove the inhabitants away from water resources. They started selling their lands and abandoned agriculture and pastoralism and shifted to employment in the civil service. Now Bani Hashem is a desertification hotspot due to climate change, droughts and human social activities which include overgrazing and quarrying. Income sources for the local people include jobs in the military and the civil service. About 20% of the households depend completely on livestock raising (IUCN 2014)

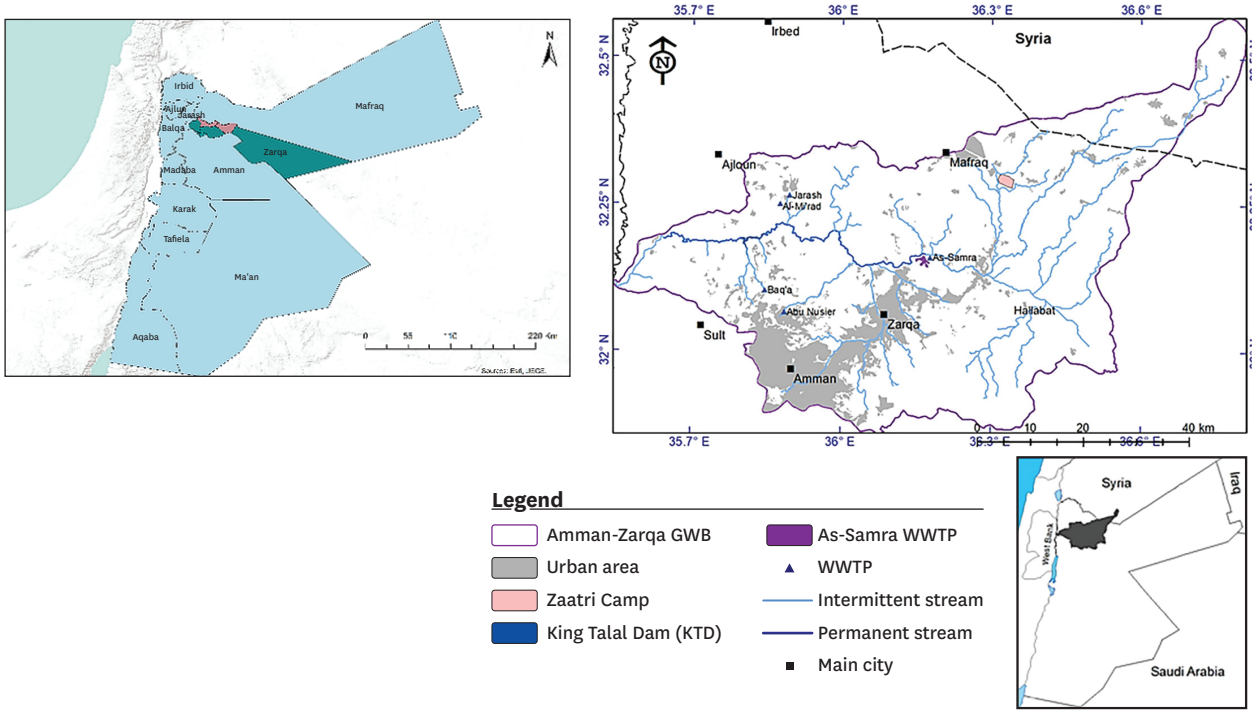

Figure B1. *(clockwise from top left) Map of the Zarqa Governorate in Jordan; Detail map of the Zarqa river basin; The Zarqa river basin in Jordan and Syria. (Source: Shammout et al. 2018)*

Annex C. FCM Metrics

Table C1. *Fuzzy cognitive mapping themes and centrality values for Rechaya, Lebanon.*

Node	Category*	Degree centrality	Betweenness centrality	Eigenvector centrality
Absence of water management plans	I	4	0	0.506500905
Borrowing money/accumulation of debt	O	2	6	0.042383743
Change in planting schedules	O	1	0	0.002901053
Climate change-driven changes in precipitation, temperature and seasonality	C	3	0	0.014729032
Competition in labor market	N	1	0	0.006268196
Cost of agriculture	I	7	42.75	0.599659838
Cost of fuel	I	10	34.5	1
Cost of water	I	8	91.75	0.967035913
Costs of materials for agriculture	I	1	0	0.118109928
Crop diversification	O	1	0	0.002901053
Cultural traditions	N	1	0	0.051004751
Decline in agricultural production	O	3	8	0.068979154
Decline in agricultural income or profits	O	5	12	0.223288473
Difficulty accessing food, or changing diets	O	1	0	0.019927164
Droughts and natural water scarcity	C	2	0	0.112198845
Educational opportunities	N	2	0	0.072158656
Emigration or outward migration	O	4	0	0.107401197
Employment opportunities	N	2	0	0.072158656
Expenditure greater than outcome	I	4	31	0.101172866
High cost of living	I	4	70	0.431430046
Influx of foreign migrants	N	2	0	0.031824468
Investment in renewable energy	O	2	0	0.297280512
Lack of transparency in water distribution	I	3	0.916666667	0.21960162
Land fragmentation	N	2	2	0.075077199
Limited income	N	1	0	0.019927164
Distrust in Regional Water Establishment and government	O	4	3.416666667	0.302946988
Power shortage	I	4	1.5	0.509332756
Pressure on services	I	4	17	0.155308865
Selling land or assets	O	3	26	0.122219028
Shift away from agriculture	O	8	22.75	0.258957912
Shift to rainfed agriculture	O	3	0	0.4877494
Shift to subsistence farming	O	2	0	0.162089171
Social cohesion	N	4	9.25	0.142014958
Tensions over water access	O	5	12.25	0.229159397
Travel to springs for potable water	I	3	6.916666667	0.356894258
Volatility of market prices for agricultural goods	I	1	0	0.043979243
Water availability	C	5	32	0.500669326
Water supply from municipal or private wells	I	6	18	0.800920329
Water supply from water tankers	I	2	0	0.311758669
Weak agricultural infrastructure	I	2	0	0.315071474
Weak or absent public water service provision	I	6	0	0.582840289
Worsening socioeconomic conditions	I	4	10	0.114015041

**Note:* C = Climatic driver; N = Non-climatic driver; I = Intermediating factor; O = Outcome.

Table C2. *Fuzzy cognitive mapping themes and centrality values for Zarqa Governorate, Jordan.*

Node	Category*	Degree centrality	Betweenness centrality	Eigenvector centrality
Cost of agriculture	I	10	103.8	1
Shift away from agriculture	O	10	93.26667	0.66042
Cost of water	I	9	156.1333	0.770602
Decline in agricultural revenue or profits	O	9	90.2	0.662975
Decline in agricultural production	O	8	57.86667	0.283528
Cost of fuel	I	7	40	0.657646
Decline in rangeland productivity	O	6	9.5	0.185907
Invest or remain in agriculture	I	6	0	0.095698
Water availability	C	5	88.06667	0.238177
Worsening socioeconomic conditions	O	5	24	0.204797
Climate change-driven changes in precipitation, temperatures and seasonality	C	5	0	0.253589
Government irrigation and subsidy programs	N	5	0	0.571459
High cost of living	I	4	109	0.325055
Expenditure greater than income	I	4	64	0.086254
Contamination of groundwater and surface water	O	4	10	0.078899
Competition in labor market	O	4	6	0.004179
Difficulty accessing food, or changing diets	O	4	0	0.019217
Droughts and natural water scarcity	C	4	0	0.176016
Emigration or outward migration	O	4	0	0.280442
Selling land or assets	O	3	35	0.136458
Borrowing money/accumulation of debt	O	3	31	0.076146
Pressure on services	I	3	18	0.090902
Cost of fodder and consumables	I	3	14	0.32251
Disappearance of small farms	O	3	8.733333	0.382133
Cost of well digging and operation	I	3	7.066667	0.305377
Land fragmentation	N	3	6	0.163223
Mistrust in quality of agricultural produce of the region	O	3	6	0.172678
Employment opportunities	N	3	3	0.196574
Settlement of Bedouin communities	O	3	1.5	0.146366
Migration into Zarqa	O	3	1	0.036067
Increase in pests and invasive species	O	3	0.5	0.142355
Cost of transporting water from source or to herds	I	3	0	0.478093
Drop in water table	O	3	0	0.122769
Government social service programs	N	3	0	0.076241
Social cohesion	N	3	0	0.000187
Rationing of household water supply in Zarqa	O	2	29	0.049416
Reliance on fuel	I	2	21	0.134705
Use of government-operated wells for exporting water or pumping to cities	I	2	12	0.012807
Inadequate government subsidies and restrictions	N	2	8	0.066576
Limited income	N	2	8	0.017667
Increase in salinity of soils	O	2	6	0.058075
Social tensions	O	2	4	0.00086
Salt water intrusion	O	2	3.866667	0.079995
Cost of maintenance of fruit trees	I	2	2	0.246817
Remaining in Zarqa	O	2	0.5	0.021056
Centralization of government	N	2	0	0.015629
Competition from imported goods	I	2	0	0.16453
Contamination of Sayl Zarqa	O	2	0	0.049533
Cooperation between farmers and pastoralists	O	2	0	4.59E-05
Cost of living in Amman	I	2	0	0.011247

Node	Category*	Degree centrality	Betweenness centrality	Eigenvector centrality
Cost of transporting fodder to herds	I	2	0	0.326371
Cultural traditions	N	2	0	0.148871
Educational opportunities	N	2	0	0.185244
Honor code between clans	I	2	0	4.59E-05
Influx of foreign migrants	O	2	0	0.01872
Quarrying and polluting industrial activity	N	2	0	0.052137
Shift to rainfed agriculture	O	2	0	0.186378
Skills limited to agriculture	N	2	0	0.057545
Absence of wastewater networks and treatment facilities	I	1	0	0.015534
Cattle disease	O	1	0	0.055823
Cost of food	I	1	0	0.003784
Cost of renewable energy	N	1	0	0.026522
Crop diversification	O	1	0	0.049929
Decline in food quality	I	1	0	0.003784
Inadequate food safety regulations	I	1	0	0.003784
Inadequate market regulation for agricultural products	I	1	0	0.130532
Investment in rural tourism	O	1	0	0.130029
Land degradation	O	1	0	0.036603
Loose regulation of migrant labor	I	1	0	0.000823
Migrant work ethic	I	1	0	0.000823
Population growth	N	1	0	0.032137
Shift to subsistence farming	O	1	0	0.130532
Taxation and water tariffs	I	1	0	0.151722
Use of synthetic agrochemicals	I	1	0	0.011434
Wage or pension stagnation	O	1	0	0.003478

**Note:* C = Climatic driver; N = Non-climatic driver; I = Intermediating factor; O = Outcome

Annex D. Recommendations Based on the Rechaya Case Study

Table D1. *Recommendations on drought management and recovery based on the case study in Rechaya, Lebanon.*

Recommendation	Recommended action	Priority	Related findings	Rationale	Existing policy instruments
Support and improve drought monitoring and early warning systems.	Facilitate dissemination of risk information to relevant stakeholders, including farmers.	Primary	Farmers are capable of adopting coping strategies to respond to water scarcity and drought conditions. However, these are often adopted after an unsuccessful season and after losses have been incurred.	The Lebanese Agricultural Research Institute (LARI) has created weather forecasting facilities and developed a nationwide drought Early Warning System (EWS) for growers. These services necessitate daily monitoring, recording and forecasting. LARI's experts analyze the gathered weather data and develop information services before dissemination to farmers and the public. LARI has developed a text messaging service and a mobile application to disseminate forecasts and warnings (Verner et al. 2018). Likewise, MoEW has led the development of an EWS supported by the MENAdrought project. That tool is an integral component of the draft Drought Action Plan.	* A Drought Action Plan developed as part of the MENAdrought Project (Fragaszy et al. 2022b; Jobbins et al. 2022) * Disaster Risk Response Framework * LARI's Early Warning System * A sustainable natural resource management platform (SuNaR) and early warning system developed by the Lebanese National Council for Scientific Research (CNRS-L) * Access to Information Law No. 28 of 2017 as amended in 2021 (GoL 2021) * National Agriculture Strategy 2020 (MoA Lebanon 2020) * National Water Sector Strategy Update 2020 (MoEW Lebanon 2020)
	Combine monitoring and drought announcement with clearly defined management steps; reduce uncertainty regarding role of agencies.	Primary			
	Coordinate and utilize the capacities of farmers and local organizations for monitoring and regulatory enforcement.	Secondary			
	Increase coverage of monitoring data.	Secondary			
Develop and implement a drought risk reduction and recovery plan.	Establish legislative and/or policy frameworks for drought risk reduction that include coordination at the national, subnational and local levels.	Primary	Losses from drought and prolonged dry periods and costs of supplementary water pumping and supply decrease revenues, which in turn impacts farm and household income.	The draft national Drought Action Plan has been developed by the Drought Technical Committee, an interministerial group led by MoEW. It includes recommended governance and decision-making frameworks for drought response, as well as drought preparedness, mitigation and response actions. Its implementation will require development of sector-specific components, such as exploration of innovative financial mechanisms like crop insurance and drought contingency funds to insure economic resilience of smallholder farmer households.	
	Pair drought declaration with financial relief programs; create incentives to develop and provide clear applications for drought monitoring information.	Primary			
	Encourage local participation in decision-making and revision of drought management and recovery strategies.	Secondary			

Table D2. *Recommendations on sustainable development and resilience based on the case study in Rechaya, Lebanon.*

Recommendation	Recommended action	Priority	Related findings	Rationale	Existing policy instruments
Empower agricultural cooperatives for climate-smart practices and their role in agricultural development and coordination of extension services.	Support the expansion and professionalization of agricultural cooperatives through capacity building and training.	Primary	Cooperatives have also been shown to support farmers in staying in their rural homes and reducing the rural exodus (ILO 2018)	The regulatory framework of cooperatives in Lebanon includes the Decree Law 17199 and its amendments forming the General Directorate for Cooperatives, which manages registration and permitting of cooperatives and monitors their activities. The Lebanese Federation of Cooperatives, established through Decree 10659 of 1968, is the representative body of all registered cooperatives and coordinates relations with the government. The National Union for Cooperative Credit is mandated by law to regulate disbursement of credit to cooperatives. Pillar 3 of the National Agriculture Strategy (NAS) 2020 is to promote and organize cooperative work in value chains. Pillar 5 aims to enhance the effectiveness of MoA's extension services and affiliated institutions and develop staff capacities.	* National Agriculture Strategy 2020 (MoA Lebanon 2020)
	Invest in revitalizing and expanding agricultural extension services at local rural scales.	Primary			
	Enhance coordination efforts between governance bodies and cooperative or public formal consultations.	Secondary			
Improve agricultural infrastructure, including access roads, water networks and market access.	Monitor and regulate market prices for locally produced agricultural goods and prevent sudden and major price drops.	Primary	Farmers and pastoralists often face difficulties in accessing fields and transporting water to them, which increases costs of fuel and decreases profitability.	The NAS 2020 details several programs to restore the livelihoods and productive capacities of farmers and producers, support the adoption of good agricultural practices, and support the adoption of innovative and modern technologies. Pillar 3 of NAS 2020 aims to enhance the efficiency and competitiveness of agri-food value chains through modernization of value-chain infrastructure, postharvest systems, and wholesale and local markets. Pillar 4 encourages the adoption of innovative technical solutions for climate change adaptation.	* National Agriculture Strategy 2020 (MoA Lebanon 2020)
	Invest in infrastructure of postharvest operations including grading, packaging and refrigerated transport and storage of local produce and enhance the capacities of cooperatives in executing these operations.	Secondary			
	Building capacities of smallholder farmers to enter and compete in domestic markets.	Tertiary			
Support the development and marketing of drought- and heat-tolerant seed and crop varieties.	Support and finance local research and production of drought-tolerant varieties.	Primary	Droughts and water-scarce conditions have direct impacts on crop production.		
	Set up reduced-interest loans or small grants programs to facilitate the adoption and up-scaling of drought-tolerant varieties.	Secondary			
	Ease the entry of locally produced varieties into local markets and support their promotion.	Tertiary			

Table D3. *Recommendations on water management based on the case study in Rechaya, Lebanon.*

Recommendation	Recommended action	Priority	Related findings	Rationale	Existing policy instruments
Support equitable water demand management, groundwater monitoring and water-efficient agriculture	Improve staffing and capacities of Regional Water Establishments (RWEs) for enforcement of regulations, water-use monitoring, maintenance and communication with municipalities, agricultural cooperatives and farmers.	Primary	There is a gap in communication between municipalities and RWEs, and an overlap of responsibilities, which contributes to weak institutional efficacy. This can be attributed to a shortage of employees who are able to cover the various responsibilities RWEs undertake. This has weakened the RWEs' capacity to manage and oversee water use and well operation violations (El Amine et al. 2018). Our findings indicated that this gap in communication and coordination is seen as a lack of transparency and support, leading to distrust in regional and national water governance. This can lead to tension or conflict between the public and governance bodies. This has been documented across the Bekaa (UNICEF Lebanon and IFI 2022).	Formal agreements between RWEs and municipalities to make them work together on collecting tariffs, managing water sources or renewing the network can be beneficial to all parties involved. Such agreements can be an adaptation to Water Law No. 192 (GoL 2020).	* Water Law No. 192 (GoL 2020) * National Water Sector Strategy Update (MoEW Lebanon 2020) * National Agriculture Strategy (MoA Lebanon 2020)
	Increase oversight and coordination between MoEW, RWEs and local authorities for well drilling authorization and monitoring of illegal well drilling and operation.	Primary		Illegal tapping into distribution networks is a major risk to management and overall water sector integrity. Adopting metering systems is necessary to control consumption and set tariffs based on consumption. This will allow monitoring of the water quantity used, as well as sustaining groundwater since payment would be done based on volume consumed. Water Law No. 192 of 2020 regulates the extraction and use of water resources and protects them from depletion. It can be used at a policy lever for monitoring and demand management.	
	Reduce uncontrolled exploitation of groundwater resources by incorporating bulk metering or district metering into existing and new water supply networks and distribution points.	Primary		This currently falls within the mandate of the MoEW. This ministry can be supported in the authorization process by introducing an intermediary body between the permit applicant and MoEW. The RWEs are well poised for this intermediary role, given their mandates and access to regional and local data and information that can be used in assessment of applications. The RWEs would be able to investigate drilling plans and assess whether a proposed well could be substituted with proximal sources, or those that otherwise meet the needs of the applicant. If the relevant RWE deems the need cannot be met by existing sources or alternatives, then the application can be raised to MoEW for further study. This two-step process is an opportunity to decentralize the permit-seeking and well authorization process. Its success would reduce haphazard or illegal well drilling which impacts water availability and equitability, limits corruption and strengthens the role of RWEs in safeguarding water resources in their jurisdiction. This can be developed as a policy under Water Law No. 192.	
	Provide economic incentives for climate-smart irrigation and water conservation practices. These can be in the form of special subsidies or small-grant programs.	Primary	Farmers cope with water-scarce conditions by cultivating less land and shifting to rainfed or subsistence farming. This limits their productivity and income. The majority of farmers we interviewed used inefficient irrigation practices and have high costs of operation and low profitability during water-scarce conditions. This limits their capacity to upgrade to climate-smart and water-efficient irrigation means or technology.	NAS 2020 has set up programs within Pillars 4 and 5 that encourage adoption of climate-smart agriculture and cutting edge irrigation techniques. They can be used as a policy lever to couple agricultural credit and financing for incentives for guided climate-smart and water-efficient practices. Pillar 4 focuses on climate change adaptation and sustainable use of irrigation water and other natural resources.	

Recommendation	Recommended action	Priority	Related findings	Rationale	Existing policy instruments
Increase local water capture and storage.	Mainstream and finance rainwater harvesting initiatives for municipalities, creating shared communal rainwater reserves or discrete sources for municipal water consumption.	Primary	Reliance on groundwater abstraction for municipal, household and irrigation uses decreases water availability, increases vulnerability of water resources to the impacts of droughts and prolonged dry periods and threatens water security at all three levels.	The National Guideline for Rainwater Harvesting Systems (Al-Housseiny 2016) offers detailed guidelines and technical and commercial information on how to size and implement rainwater harvesting systems in rural and urban settings, mainly for domestic applications and external uses which could extend to irrigation. It cites Building Law 646 (dated 11/12/2004) and Building Law Implementation Decree 15873, Environment Protection Law 444 (GoL 2002) and Potable Water Standard Decree 1039 (dated 2/8/1999) as general codes and standards for harvesting systems. The National Water Sector Strategy Update also supports rainwater harvesting and storage, incorporating the National Guidelines.	* National Guideline for Rainwater Harvesting Systems (Al-Housseiny 2016) * Building Law 646 dated 11/12/2004 and Building Law Implementation Decree 15873 (Mourad 2018) * Environment Protection Law 444 (GoL 2002) * National Water Sector Strategy (MoEW Lebanon 2020)
	Support municipalities in increasing local water storage capacities such as additional tanks, pools and reservoirs.	Secondary			
Invest and scale up the use of renewable energy in water supply and distribution.	Support integration of renewable energy into operation of water infrastructure and facilitate small-scale investments in solar-powered water pumping systems for farms and households.	Primary	Water supply at the municipal and farm levels is often interrupted due to fuel shortages and power outages. This is often supplemented with costly private water supply from tankers which places financial burdens on low-income households and farmers.	The potential for integration of renewable energy into the water sector in Lebanon is constrained by the absence of an enabling legal framework, the lack of financial incentives and performance-driven assessments (Farajalla et al. 2022). The National Water Sector Strategy (NWSS) and MoEW's Policy Statement on Electricity Sector's Sustainable Growth (MoEW Lebanon 2022) do not currently integrate renewable energy into the operations of water facilities. However, this has been recommended by water-energy nexus studies (MoEW Lebanon 2022). The MoEW has also shown support and launched international bidding for private sector solar and wind energy initiatives.	* National Water Sector Strategy 2020 (MoEW Lebanon 2020) * Policy Statement on Electricity Sector's Sustainable Growth (MoEW Lebanon 2022)
Improve wastewater management and mainstream safe wastewater use practices.	Develop, rehabilitate or expand the operating capacities of wastewater treatment facilities that allow safe use of wastewater.	Primary	Reliance on groundwater abstraction for municipal, household and irrigation uses decreases water availability, increases vulnerability of water resources to the impacts of droughts and prolonged dry periods and threatens water security at all three levels. Wastewater treatment and use provides opportunities to augment water supply while reducing the risk of contamination of groundwater aquifers.	The licensing of small wastewater treatment plants (WWTPs) is regulated through Resolution No. 3/1 of 2005. The NWSS promotes the expansion of wastewater collection and treatment capacities and encourages the reuse of treated wastewater. Environment Protection Law No. 444 establishes quality standards for wastewater discharge and directs coordination between MoEW and the Ministry of Environment in upholding these standards in natural resource management.	* National Water Sector Strategy 2020 * Water Law No. 192 (GoL 2020) * Environment Protection Law No. 444 (GoL 2002).
	Empower local and regional cooperatives or water users' associations to practice oversight over treatment plants and quality assessments.	Secondary			

Table D4. *Recommendations on socioeconomic resilience based on the case study in Rechaya, Lebanon.*

Recommendation	Recommended action	Priority	Related findings	Rationale	Existing policy instruments
Support diversification of skills and off-farm income opportunities.	Support diversification of rural economies and development of small businesses for rural job creation.	Primary	* Migration decisions (whether internal migration or emigration) are most influenced by weak or absent educational and off-farm job opportunities in rural areas. * Farmer households with limited agricultural income often lack the skills or financial ability to find opportunities locally or elsewhere. * In Rechaya, those seeking necessity-driven enterprise face difficulty in accessing financing, and have relatively limited entrepreneurial skills or links and market networks (Maddah 2022).	No single formal policy framework manages rural economies; however, Maddah (2022) recommends adoption of an Entrepreneurship Action Plan modeled to international rural development policies and plans.	* N/A
	Invest in establishment and staffing of schools and educational services in rural areas.	Secondary			
	Provide opportunities for vocational training, especially to women and youth, to ease entry into local job markets, for example, within small-scale industry and agricultural services.	Secondary			
	Expand the scope of rural economic empowerment initiatives and small-scale production, especially those targeted at women's economic empowerment.	Secondary			

Annex E. Recommendations Based on the Zarqa Case Study

Table E1. *Recommendations on drought management and recovery based on the case study in Zarqa Governorate, Jordan.*

Recommendation	Recommended action	Priority	Related findings	Rationale	Existing policy instruments
Support and improve drought monitoring and early warning systems.	Facilitate dissemination of risk information to relevant stakeholders, including farmers.	Primary	Farmers are capable of adopting coping strategies to respond to water scarcity and drought conditions; however, these are often adopted after an unsuccessful season and after losses have been incurred.	Stakeholders report that the government needs clear mechanisms to declare drought. This would allow monitoring information to be disseminated to relevant users once the thresholds have been reached, which can be the basis for drought intervention policies. As it stands, the government avoids drought declaration because they view it as having severe financial implications (e.g., feed subsidy and compensation for yield reduction). Clarifying the mechanisms of drought declaration would reduce the uncertainty regarding agency roles and reliance on foreign donors (Fragaszy et al. 2022a; Jedd et al. 2021).	* Drought Action Plan (MWI Jordan 2022) * Jobbins et al. (2022) * Water Sector Policy for Drought Management (MWI Jordan 2018) * National Climate Change Adaptation Plan of Jordan (MoE Jordan 2021)
	Combine monitoring and drought announcement with clearly defined management steps; reduce uncertainty regarding role of agencies.	Primary			
	Coordinate and utilize the capacities of farmers and local organizations for monitoring and enforcement.	Secondary			
	Increase coverage of monitoring data.	Secondary			
Develop and implement a drought risk reduction and recovery plan.	Establish legislative frameworks for drought risk reduction that include coordination at the national, subnational and local levels.	Primary	Losses from drought and prolonged dry periods and costs of supplementary water pumping and supply decrease revenues, which in turn impact farm and household income.	Existing drought response lacks coordination and integration between stakeholders at different levels and remains under the umbrella of water management. The development of the Drought Action Plan (MWI Jordan 2022) and the National Climate Change Adaptation Plan represent opportunities to shift from crisis management (UNICEF Jordan and Economist Impact 2022). Formalizing the Drought Action Plan would help to meet the need for clear definitions and management steps for drought. Jordan's Economic Green Growth National Action Plan 2021-2025 (MoE Jordan and MoA Jordan 2020; MoE Jordan and MWI Jordan 2020) aims to enhance cooperation and coordination amongst different ministries and agencies. This includes hosting regular, inclusive sector-level donor and development partner consultations, more frequent public-private-civil society dialogues on key policies and investments, and conducting more public outreach and awareness programs on government successes and lessons learned.	
	Pair drought declaration with financial relief programs; create incentives to provide a clear application for drought monitoring information.	Primary			
	Encourage local participation in decision-making.	Secondary			

Table E2. *Recommendations on sustainable agricultural development and resilience based on the case study in Zarqa Governorate, Jordan.*

Recommendation	Recommended action	Priority	Related findings	Rationale	Existing policy instruments
Enhance agricultural extension services and empower agricultural cooperatives for climate-smart practices.	Invest in and support professionalization of agricultural cooperatives through capacity building and training.	Primary	Farmers reported a significant decrease in activity by the extension services center. This includes reductions in specialized staff and experts, quality of information and conduct of periodic meetings with farmers. They described the current work of extension services as "monitoring while it should be mentoring instead" (Al Naber et al. 2019. Pastoralists often require timely access to veterinary services, especially during dry periods. The absence of such services was reported as a significant threat (Fragaszy et al. 2022a).	The Green Growth National Action Plan for the agriculture sector (MoE Jordan and MoA Jordan 2020) sets explicit goals for the improvement of extension services. This alongside policies of the National Water Strategy (MWI Jordan 2016a) can be used as a framework to integrate drought-responsive services.	* Green Growth National Action Plan 2021-2025 for the agriculture sector (MoE Jordan and MoA Jordan 2020) * Water Reallocation Policy – Items 34 and 35 (MWI Jordan 2016b). * Groundwater Sustainability Policy – Items 17, 18 and 19 (MWI Jordan 2016c)
	Invest in expanding agricultural extension services at local rural scales, including access to veterinary services for pastoralists.	Primary			
	Mainstream climate-smart irrigation and production practices through extension services.	Primary			
	Establish coordination efforts or public formal consultations with cooperatives.	Secondary			
Support marketing and domestic market access and infrastructure.	Monitor and regulate market prices for locally produced agricultural goods and prevent sudden price drops and meltdowns.	Primary	Volatile market prices and difficulties in adapting to market demands and fluctuations prevent smallholder farmers from generating revenue that allows them to sustain their livelihoods. Also, information for market coordination is weak and is most degraded under drought conditions in relation to tracking of price volatility. During droughts, the ongoing costs of fodder and water purchases and veterinary services, even if subsidized, become unsustainable for smallholders (Fragaszy et al. 2022a).	Government policies consider marketing only as a supplementary service for production despite its importance in determining economic returns. Policy focus on developing production has often resulted in oversupply of some products and wasting of large quantities of produce due to an imbalance between local supply and demand. The marketing infrastructure is weak, and the few existing wholesale markets outside of Amman do not represent real markets (IUCN ROWA 2019).	* National Strategy for Agricultural Development (MoA Jordan 2016)
	Invest in infrastructure of postharvest operations including grading, packaging, refrigerated transport and storage of local produce and enhance the capacities of cooperatives in executing these operations	Secondary			
	Building capacities of smallholder farmers to enter and compete in domestic markets.	Tertiary			
Support the development and marketing of drought- and heat-tolerant seed and crop varieties.	Support and finance the local production of drought-tolerant varieties	Primary	Droughts and water-scarce conditions have direct impacts on crop production.	The National Strategy for Agricultural Development (MoA Jordan 2016) focuses on promoting sustainable agricultural development and improving food security in the highlands through improving rural people's access to technology and resources, ensuring optimum use of resources such as soil and water, improving access to financial services and marketing support.	* National Strategy for Agricultural Development (MoA Jordan 2016)
	Set up reduced-interest loans or small-grants programs to facilitate adoption and upscaling of drought-tolerant varieties.	Secondary			
	Ease the entry of locally produced varieties into local markets and support their promotion.	Tertiary			

Table E3. *Recommendations on water management based on the case study in Zarqa Governorate, Jordan.*

Recommendation	Recommended action	Priority	Related findings	Rationale	Existing policy instruments
Support equitable water demand management.	Improve government-based water accounting systems and support integrated, participatory and evidence- based national and basin-level water monitoring and planning.	Primary	* Decline in water availability due to natural and anthropogenic causes. * High cost of water contributing to lower agricultural revenues. * Unclearly structured water tariffs or fines create conflict and mistrust between farmers and government. * Water pricing as a tool for improved water productivity is obstructed by limited jurisdiction or influence on regulating water on-farm or otherwise influencing on-farm behavior and technology update (Al Naber et al. 2019)	* Controlling illegal wells is viewed as key to effective water management. But groundwater governance is not effective even though a regulatory framework is in place. Participants wanted more active coordination between ministries (Fragaszy et al. 2022a). * Improving the subsidy and tariff system should be gradual and part of comprehensive reform. As such, it will require significant time to be implemented (UNICEF Jordan and Economist Impact 2022). * Agricultural and municipal water and wastewater tariffs could include price incentives for water conservation and setting the price levels to recover the cost of operation and maintenance and the costs of ongoing necessary capital improvements in water supply systems.	* Green Growth National Action Plan 2021-2025 – Water Sector (MoE Jordan and MWI Jordan 2020) * Groundwater Abstraction Policy – Items 11 and 12 (MWI Jordan 2016c; Salman et al. 2018) * Water Reallocation Policy – Item 18 (MWI Jordan 2016b). * Irrigation Water Allocation and Use Policy (MWI Jordan 2008a) * Irrigation Equipment and System Design Policy of 2008 (MWI Jordan 2008b) * Water Demand Management Policy (MWI Jordan 2016d)
	Provide economic incentives for climate-smart irrigation and water conservation practices. These can be in the form of special subsidies, tax breaks or restructured water tariffs for farmers.	Primary			
	Coordinate groundwater management across agencies, citizens and farmers for enforcement for regulations.	Secondary			
Increase local water capture and storage.	Mainstream and finance rainwater harvesting initiatives for municipalities, creating shared communal rainwater reserves or discrete sources for municipal water consumption.	Primary	* Decline in water availability due to natural and anthropogenic causes. * High cost of water contributing to lower agricultural revenues.	Through the Green Growth National Action Plan 2021-2025, the Government of Jordan is expected to set up a financing facility to support projects that augment rural and urban water supply (MoE Jordan and MWI Jordan 2020). The facility will work in collaboration with MWI, MoA and municipal governments to identify and develop projects (UNICEF Jordan and Economist Impact 2022).	* Green Growth National Action Plan 2021-2025 for the water sector (MoE Jordan and MWI Jordan 2020)
	Support municipalities in increasing local water storage capacities such as additional tanks, pools and reservoirs.	Secondary			
Scale up integration of renewable energy into water operations.	Support integration of renewable energy into operation of water infrastructure. Facilitate small-scale investments in solar-powered water pumping systems for farms and households.	Primary	High cost of renewables slows the energy transition and lengthens and increases reliance on expensive fuel for irrigation and transport.	Both the Green Growth National Action Plan and the National Water Strategy (MWI Jordan 2016a) can be used as policy levers to expand access to renewable energy sources in water operations, including financing for such developments.	* Green Growth National Action Plan 2021-2025 for the water sector (MoE Jordan and MWI Jordan 2020). * Energy Efficiency and Renewable Energy Policy for the Water Sector 2020-2030 - Goals 2 and 3 (MWI Jordan 2021)
Improve wastewater management and mainstream safe wastewater use.	Develop or improve wastewater treatment facilities that encourage use of wastewater.	Primary	Contamination of the Sayl Zarqa and polluting industrial activity in the surrounding areas negatively impact both production and marketing of produce from Zarqa as well as human health.	The National Water Strategy (MWI Jordan 2016a) includes several policies and action plans supporting the expansion of safe use of treated wastewater, notably by building new wastewater treatment plants and exploring productive and cost-effective uses of treated effluent in agriculture, industry and municipal contexts.	* National Water Strategy (MWI Jordan 2016a) * Water Substitution and Reuse Policy (MWI Jordan 2016e) * Decentralized Wastewater Management Policy (MWI Jordan 2016f) * National Climate Change Adaptation Plan of Jordan (MoE Jordan 2021) – use of non-conventional water sources
	Monitor WWTP effluent, especially around the Sayl Zarqa river (treated wastewater for irrigation in the Jordan Valley and its production need continuous monitoring and reinforcement).	Primary			

Table E4. *Recommendations on socioeconomic resilience based on the case study in Zarqa Governorate, Jordan.*

Recommendation	Recommended action	Priority	Related findings	Rationale	Existing policy instruments
Support diversification of skills and off-farm income opportunities.	Support diversification of rural economies and development of small businesses for rural job creation.	Primary	* The limited skills of the rural population and the lack of educational and vocational opportunities restrict off-farm income opportunities, which in turn limit household incomes. * Influx of foreign labor creates competition in local labor markets, limiting opportunities for off-farm income.	This is a prominent theme in national development objectives and donor funding. The Jordan National Social Protection Strategy 2019-2025 (MSD Jordan 2019) is a policy framework often used for rural development alongside the National Strategy for Microfinance (MoPIC Jordan 2005) and the National Policy Framework for Microfinance (MoPIC Jordan 2017). The latter can be used to support poverty alleviation through increasing the accessibility of microfinance for the country's poor people.	* National Social Protection Strategy 2019-2025 (MSD Jordan 2019) * National Strategy for Microfinance (MoPIC Jordan 2005) * Jordanian National Policy Framework for Microfinance (MoPIC Jordan 2017)
	Invest in establishment and staffing of schools and educational services in rural areas.	Secondary			
	Provide opportunities for vocational training, especially for women and youth, to ease entry into local job markets, for example, within small-scale industry and agricultural services.	Secondary			
	Expand the scope of rural economic empowerment initiatives and small-scale production, with focus on women's economic empowerment.	Secondary			

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Jordan: Ministry of Water and Irrigation
Lebanon: Ministry of Energy and Water

National partners:
Jordan: Department of Statistics; Jordan Meteorological Department; Ministry of Agriculture; Ministry of Health; Ministry of Environment; National Agricultural Research Center; National Center for Security and Crisis Management; and the University of Jordan
Lebanon: American University of Beirut; Beirut and Mount Lebanon Water Establishment; Lebanese Agricultural Research Institute (LARI); Lebanese Meteorological Department-Directorate General of Civil Aviation; Litani River Authority; Ministry of Agriculture; Ministry of Environment; South Lebanon Water Establishment; National Center for Remote Sensing.
Non-governmental organizations: Agency for Technical Cooperation and Development (ACTED) and STAMMOSE

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