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MENAdrought Synthesis of Drought Vulnerability in Lebanon

Final Report

Photo: Jano Hatem / IWMI

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Final Report

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Front cover photograph: Women harvesting vegetables. (Jano Hatem / IWMI)

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Executive Summary

Purpose

This report summarizes MENAdrought findings on the underlying causes of vulnerability to drought impacts in Lebanon. It serves as a link between the impact assessment and policy planning process.

The objective of the vulnerability studies has been to identify who or what is at risk from drought, what causes that risk, and the effects of how actors manage that risk. This can inform drought management planning so that interventions target underlying causes of vulnerability for the identified communities and systems.

The problem context

Lebanon is water-rich compared to other Middle East and North Africa (MENA) nations, which historically has led government officials to place low priority on drought risk management. However, the intense droughts of 1998-2001, 2008, and 2013-2014 had widespread socio-economic impacts, which spurred increased official interest in drought.

Drought frequency has increased in the Levant region over the last century (Kelley *et al.* 2015), and climate change has significantly increased the intensity of recent droughts in Lebanon (Bergaoui *et al.*, 2015). Climate model projections suggest that global warming will likely drive decreased precipitation and snowpack in Lebanon, as well as shortened snow seasons (Karmalkar *et al.*, 2010; MoEW, 2010). Changed snow dynamics will affect hydrological responses in Lebanon's major surface and groundwater basins (Fayad *et al.*, 2017) and alter temporal patterns of water availability.

Increased drought and water scarcity in the future are likely to deepen rural indebtedness and structural socio-economic challenges as well as increase Lebanon's dependence on food imports and the depletion of foreign exchange reserves.

Defining vulnerability

Vulnerability to drought impacts is a socio-environmental phenomenon. Drought risk management practitioners typically explore this dynamic interaction through a conceptual assessment of vulnerability that can shift depending on the time-scale under assessment:

> Short term: Vulnerability = potential impact - coping capacity
> Long term: Vulnerability = potential impact - adaptive capacity

In this formulation, potential impact has two components: exposure and sensitivity. Exposure refers to the presence of people, assets, ecosystems, etc. in areas affected by drought. Sensitivity refers to the climatological thresholds that trigger negative effects. Coping capacity is the ability of communities, people, or systems to withstand drought without irreversible changes in state and functions whereas adaptive capacity is the ability for systems, people, and communities to change form and function under new conditions.

Research methods

We used participatory research methods across multiple vulnerability assessment approaches per the typology developed through a recent review (King-Okumu 2019). The reason for reliance on participatory methods is twofold. Firstly, use of these methods can help establish and facilitate social relations and associations that drive increased application of the knowledge in wider technical and political processes. Secondly, we were unable to apply spatial and statistical approaches due to the lack, or inaccessibility, of relevant datasets.

This research included multiple workshops with the Drought Technical Committee, an inter-disciplinary team coordinated by the Ministry of Energy and Water (MOEW). It also included four focus group meetings and interviews

with smallholders in the Hermel area focused on exploring drought impacts on rural society, particularly food security, livelihoods, and gender-specific effects.

Synthesis of findings related to drought history, hazard mapping, and impacts

Our assessment of drought history over the past two decades identified three nationally significant droughts in 2014, 2008, and 2001 as well as several years with interspersed, creeping, and late-onset droughts.

We developed a drought hazard map (climatological risk) that shows where drought is most frequent and severe. Areas of highest hazard include Tyre in Southern Lebanon, Bint Jbeil in Nabatieh, and Rechaya in the Bekaa. Lower hazard areas include Marjeyoun in Nabatieh, Baalbeck and Hermel in Bekaa, North Lebanon, and areas of Mount Lebanon north of Beirut. Akkar, areas of Mount Lebanon south of Beirut, areas of Bekaa from Zahle south, and other districts of southern Lebanon have intermediate hazard.

We provide stakeholder characterization of drought impacts and describe the impacts that government officials prioritise to address nationally as well as regionally in the Litani and El Kelb basins through drought management planning exercises. These are impacts primarily related to the agriculture and water supply sectors.

Core findings related to drought exposure

We describe the exposure of the agriculture and water sectors as well as specific communities and smallholder livelihoods to drought impacts. Bekaa and Baalbeck-Hermel are the most exposed areas in terms of agricultural activities and environmental risk factors, and smallholder farms are the most exposed to impacts in these areas.

Common irrigation practices increase farmers' exposure to impacts, and poor municipal water supply infrastructure increases the water sectors' exposure. Syrian refugees have affected agricultural labour markets and increased demand from water infrastructure, which has increased their exposure to drought impacts. Female-led households, children, and refugees are particularly exposed to drought impacts because of their disproportionate participation in the agriculture sector as well as higher involvement in seasonal aspects most affected by drought.

Core findings related to drought sensitivity

Several factors increase the drought sensitivity of the agriculture sector: irrigation practices and weak regulatory frameworks around them being inadequate during emergent drought conditions and with recurrent, prolonged droughts; land management including peri-urban/villages expansion that has led soil degradation, the loss of arable lands, and the buffer effect of stabilizing overall production and income; financial, market access, and market organization issues related to unpredictable cropping calendars; and farmers' access to information and guiding support.

Water sector aspects of sensitivity have overlapping themes related to weak regulatory and planning frameworks, as well as enforcement of them. Major sensitivity factors connect to inadequate storage and aging distribution infrastructure to ensure stable quality freshwater supply. Political instability and the refugee influx from Syria have exacerbated these aspects of sensitivity because they have stressed natural resources and associated infrastructure, affected trade and pastoral migration routes, and led to price volatility of core agricultural inputs such as fuel.

Rural communities' primary sensitivity to drought impacts stem from their exceedingly high debt burden, poor access to credit and financial risk mechanisms, and rapidly increasing input costs. As a result, smallholder systems are rapidly losing economic viability, which contributes to the rise of negative coping mechanisms.

Core findings related to coping and adaptive capacity

We provide a conceptual typology of drought management mechanisms including post-impact interventions, pre-impact programs for mitigation, and development of policies and preparedness plans. These, in sequence, range from coping to adaptation mechanisms. At present, central government coping mechanisms are limited to small-scale financial interventions; weak policy and planning frameworks increase sensitivity and preclude effective coping and adaptation.

Farmers and some local authorities undertake a range of coping measures and some have relatively effective coping and adaptive capacity. In the water sector, coping mechanisms are limited and hampered by poor infrastructure, as well as poor regulatory and monitoring systems.

Smallholders undertake a series of coping measures to try and retain profitability in drought years: increasing exploitation of natural resources and cutting costs while trying to take action to retain productivity. When this is inadequate, they use negative coping mechanisms that reduce long-term profitability or lead to migration, contribute to food insecurity, or entail social regression.

Water sector coping mechanisms – primarily the expansion of groundwater pumping – are made less effective because of other drought impacts like water quality degradation that increase the cost of that response; likewise, private sector responses to drought such as illegal tapping of pipelines, increase the challenges for water establishments during times of drought and afterwards as they exacerbate long-term challenges.

Regionally, there is strong variation in needs to improve coping and adaptation, largely driven in drought exposure differences. Officials described several overlapping coping and adaptive capacity improvements needed in the El Kelb and Litani basins: groundwater management, planning, infrastructure improvement, and demand management.

Core conclusions for drought management planning and future research for development

Early work in the MENAdrought program identified stakeholder needs to improve drought risk management. These include the themes of policy-settings, financial systems, institutional coordination, drought management plans and institutional capacity to deliver them, extension services and cropping calendar planning, water management regimes, and underpinning science and information, governance, and policy implementation support.

Government officials subsequently prioritized several discrete components related to policy development, policy implementation support and governance, underpinning information, and infrastructure investment. We mapped and identified aspects of vulnerability for the agriculture and water sectors against these government-prioritized management needs as well as MENAdrought activities to date.

This highlighted that several government-prioritized management needs relate to numerous aspects of vulnerability, as do MENAdrought activities. They also highlighted gaps between aspects of vulnerability and government priorities: for the water supply sector, these align very well with stakeholder-identified needs, though for the agriculture sector they were weighted far more towards explicitly natural resource issues rather than wider socio-environmental systems.

Finally, considering these cross-cutting interventions, and government priority gaps in relation to vulnerability, we identify future research for development opportunities connected to drought impacts and vulnerabilities, drought monitoring, water management, information products and systems, policy and governance mechanisms, financial risk mechanisms, and irrigation improvement.

Photo: Jano Hatem / IWMI

منطقة الشرق الاوسط وشمال افريقيا للجفاف : تقرير تأليفي حول مخاطر التعرض للجفاف والحساسية في لبنان

التقرير النهائي

مقدم إلى: مكتب الشرق الأوسط التابع للوكالة الأمريكية للتنمية الدولية

الإعداد: المعهد الدولي لإدارة المياه (IWMI)

المؤلفون: ستيفن فراغايسي ، مكرم بلحاج فرج ، موسى ماكيي ، غيي جوبينز، عباس فياض ، منى فقيه ، لوسي لورنسون وراشيل ماكدونيل.

صورة الغلاف الأمامي: نساء يحصدن الخضروات. (جانو حاتم / المعهد الدولي لإدارة المياه IWMI)

المصمم: ماريو بحر، غرايس ويندز للاعلانات

شكر وتقدير: يود المؤلفون أن يعربوا عن تقديرهم لمايكل هايز وكودي نوتسون وتيريزا جيد ومارك سفوبودا من جامعة نبراسكا لينكولن والمركز الوطني للتخفيف من آثار الجفاف لدعمهم وتوجيههم فيما يتعلق بهذا العمل.

ملخص تنفيذي

الهدف

يلخص هذا التقرير نتائج مشروع منطقة الشرق الاوسط وشمال افريقيا للجفاف فيما يتعلق بالأسباب الكامنة وراء خطر التعرض لآثار الجفاف والحساسية في لبنان. وهو بمثابة حلقة وصل بين تقييم الأثار وعملية تخطيط السياسات.

الهدف من دراسات أخطار التعرض للجفاف والحساسية هو تحديد ماهية أخطار الجفاف وأسبابه، وتأثيرات كيفية إدارة المتدخلين لهذا الخطر. حيث يمكن الاسترشاد بها لتخطيط إدارة الجفاف لكي تستهدف التدخلات ضد العوامل الكامنة وراء الحساسية على المجتمعات والقطاعات المختلفة.

إشكالية

يعتبر لبنان غنيا بالمياه مقارنة بدول الشرق الأوسط الاخرى، الأمر الذي دفع المسؤولين الحكوميين تاريخياً إلى إعطاء أولوية منخفضة لإدارة أخطار الجفاف. ومع ذلك، كان للجفاف الشديد الذي حدث في السنوات ١٩٩٨-٢٠٠١ و٢٠١٣-٢٠١٤ آثار اجتماعية واقتصادية واسعة النطاق، مما أدى إلى زيادة الاهتمام الرسمي بالجفاف.

ازداد تواتر الجفاف في منطقة المشرق العربي خلال القرن الماضي (Kelley et al., 2015)، وضاعف تغير المناخ من شدة حالات الجفاف الأخيرة في لبنان بشكل كبير (Bergaoui et al., 2015). حيث تشير توقعات نموذج المناخ إلى أنه من المحتمل ان يؤدي الاحتباس الحراري إلى انخفاض هطول الأمطار وتساقط الثلوج في لبنان، فضلاً عن تقلص مواسم الثلوج (MoEW, 2010 ;Karmalkar et al., 2010). وستؤثر ديناميكيات الثلج المتغيرة على الاستجابات الهيدرولوجية في أحواض المياه السطحية والجوفية الرئيسية في لبنان (Fayad et al., 2017) وتغير الأنماط الزمنية لتوافر المياه.

من المرجح أن تؤدي زيادة الجفاف وشح المياه في المستقبل إلى تعميق المديونية الريفية والتحديات الاجتماعية والاقتصادية الهيكلية، فضلاً عن زيادة اعتماد لبنان على الواردات الغذائية واستنزاف احتياطيات النقد الأجنبي.

تعريف أخطار التعرض للجفاف والحساسية

يعتبر التعرض والحساسية لآثار الجفاف ظاهرة اجتماعية بيئية. ويستكشف ممارسو إدارة أخطار الجفاف عادةً هذا التفاعل الديناميكي من خلال تقييم مفاهيمي لخطر التعرض والحساسية الذي يمكن أن يتغير اعتمادًا على النطاق الزمني قيد التقييم:

المدى القصير: خطر التعرض = التأثير المحتمل - القدرة على التعامل

المدى الطويل: خطر التعرض = التأثير المحتمل - القدرة على التكيف

في هذه الصيغة، يتكون التأثير المحتمل من مكونين: التعرض والقابلية للإصابة. ويشير التعرض إلى وجود الأشخاص والممتلكات والنظم البيئية الى اخره في المناطق المتأثرة بالجفاف. تشير القابلية للإصابة إلى العتبات المناخية التي تؤدي إلى تأثيرات سلبية.

ان القدرة على التعامل هي قدرة المجتمعات والأشخاص والأنظمة على تحمل الجفاف دون تغييرات لا رجعة فيها في الحالة والوظائف بينما القدرة على التكيف تعني قدرة الأنظمة والأفراد والمجتمعات على تغيير الشكل والوظيفة في ظل ظروف جديدة

اساليب البحث

استخدمنا اساليب البحث التشاركية عبر مناهج تقييم خطر التعرض والحساسية المتعددة حسب التصنيف الذي تم تطويره من خلال مراجعة حديثة (King-Okumu, 2019). ان الاعتماد على الأساليب التشاركية يرجع الى سببين هما: أولاً، يمكن أن يساعد استخدام هذه الأساليب في إنشاء وتسهيل العلاقات الاجتماعية والجمعيات التي تؤدي إلى زيادة تطبيق المعرفة في عمليات فنية وسياسية أوسع. وثانيًا لم نتمكن من تطبيق الأساليب المكانية والإحصائية بسبب نقص مجموعات البيانات ذات الصلة.

تضمن هذا البحث ورشات عمل متعددة مع اللجنة الفنية للجفاف، والتي تتكون من فريق متعدد التخصصات بتنسيق من وزارة الطاقة والمياه (MOEW). كما تضمنت أربع اجتماعات لمجموعات النقاش المركز ومقابلات مع أصحاب الحيازات الصغيرة في منطقة الهرمل ركزت فيها على استكشاف آثار الجفاف على المجتمع الريفي، لا سيما الأمن الغذائي وسبل العيش والآثار الخاصة بالجنسين.

الموجز التجميعي للاستنتاجات المتعلقة بتاريخ الجفاف، ورسم خرائط المخاطر، والتأثيرات

حدد تقييمنا لتاريخ الجفاف على مدى العقدين الماضيين ثلاث حالات جفاف كبيرة على الصعيد الوطني في السنوات ٢٠٠١ و٢٠٠٨ و٢٠١٤ بالإضافة إلى السنوات العديدة التي حدثت فيها فترات جفاف متداخلة وزاحفة او متأخرة. لقد طورنا خريطة لمخاطر الجفاف (المخاطر المناخية) توضح الأماكن التي يكون فيها الجفاف أكثر تواترًا وشدة. وتشمل المناطق الأكثر عرضة للخطر صور في جنوب لبنان وبنت جبيل في النبطية وراشيا في البقاع. في حين تشمل المناطق ذات المخاطر المنخفضة مرجعيون في النبطية وبعلبك والهرمل في البقاع و شمال لبنان ومناطق جبل لبنان شمال بيروت. اما عكار ومناطق جبل لبنان بجنوب بيروت ومناطق البقاع من جنوب زحلة ومناطق أخرى في جنوب لبنان معرضة لخطر متوسط. ونقدم للمتدخلين توصيفًا لتأثيرات الجفاف ووصفا للآثار التي يعطيها المسؤولون الحكوميون الأولوية لتتم معالجتها على المستوى الوطني والإقليمي في حوضي نهر الليطاني ونهر الكلب من خلال عمليات التخطيط لإدارة الجفاف. وترتبط هذه التأثيرات في المقام الأول بقطاعي الزراعة وإمدادات المياه.

النتائج الأساسية المتعلقة بالتعرض للجفاف

نقوم هنا بوصف تعرض قطاعي الزراعة والمياه وكذلك مجتمعات محددة وسبل عيش أصحاب الحيازات الصغيرة لتأثيرات الجفاف. يعتبر البقاع وبعلبك الهرمل أكثر المناطق تعرضاً من حيث الأنشطة الزراعية وعوامل الخطر البيئية، حيث تعد مزارع أصحاب الحيازات الصغيرة الأكثر تعرضاً للتأثيرات في هذه المناطق.

تزيد ممارسات الري الشائعة من تعرض المزارعين للآثار، كما تزيد البنية التحتية غير الكافية لإمدادات المياه البلدية من تعرض قطاع المياه لتأثيرات الجفاف. وأثر اللاجئون السوريون على أسواق العمل الزراعي وزاد الطلب على البنية التحتية للمياه، مما زاد من خطر تعرضهم لآثار الجفاف. وتتعرض الأسر التي تقودها النساء والأطفال واللاجئون بشكل خاص لتأثيرات الجفاف بسبب مشاركتهم غير المتكافئة في قطاع الزراعة وكذلك زيادة مشاركتهم في الجوانب الموسمية الأكثر تضررًا من الجفاف.

النتائج الأساسية المتعلقة بالحساسية للجفاف

هناك عدة عوامل تزيد من حساسية القطاع الزراعي للجفاف منها: ممارسات الري والأطر التنظيمية الضعيفة المحيطة بها و التي تعتبر غير ملائمة أثناء ظروف الجفاف الطارئة و فترات الجفاف المتكررة والممتدة؛ و إدارة الأراضي بما في ذلك التوسع في المناطق شبه الحضرية / القرى الذي أدى إلى تدهور التربة وفقدان الأراضي الصالحة للزراعة والتأثير على لاستقرار الإنتاج والدخل الكلي ؛ و المسائل المالية والوصول إلى الأسواق وتنظيم السوق المتعلق بتقويمات المحاصيل ؛ وحصول المزارعين على المعلومات والدعم الإرشادي.

تشمل جوانب الحساسية لقطاع المياه مواضيع متداخلة تتعلق بضعف الأطر التنظيمية والتخطيطية، فضلاً عن تطبيقها. وترتبط عوامل الحساسية الرئيسية بالتخزين غير الكفء والبنية التحتية القديمة للتوزيع لضمان إمدادات مياه عذبة ذات جودة ثابتة. ولقد أدى عدم الاستقرار السياسي وتدفق اللاجئين من سوريا إلى تفاقم هذه العوامل لأنها سببت ضغطا على الموارد الطبيعية والبنية التحتية المرتبطة بها وأثرت على التجارة وطرق الهجرة الرعوية كما أدت إلى تقلب أسعار المدخلات الزراعية الأساسية مثل الوقود.

ان حساسية المجتمعات الريفية الأساسية لتأثيرات الجفاف تنبع من عبء الديون المرتفع للغاية وصعوبة الوصول إلى الائتمان والى آليات إدارة المخاطر المالية، والزيادة السريعة في التكاليف. و نتيجة لذلك، تفقد أنظمة أصحاب الحيازات الصغيرة بسرعة قدرتها الاقتصادية على الاستمرار، مما يساهم في ظهور آليات التعامل السلبية.

النتائج الأساسية المتعلقة بالقدرة عل التعامل والقدرة على التكيف

نقدم هنا تصنيفًا مفاهيميًا لآليات إدارة الجفاف بما في ذلك (تدخلات ما بعد التأثير، وبرامج ما قبل التأثير للتخفيف، وتطوير السياسات وخطط التأهب. وتتراوح هذه الاليات، بالترتيب، من آليات التعامل إلى آليات التكيف. وتقتصر آليات التعامل الحكومية المركزية في الوقت الحاضر على التدخلات المالية المحدودة؛ و تعمل أطر السياسات والتخطيط الضعيفة على زيادة الحساسية وتحول دون التعامل والتكيف الفعالين.

يضطلع المزارعون وبعض السلطات المحلية بمجموعة من تدابير التعامل، حيث يتمتع بعضها بفعالية نسبية في التعامل والتكيف. في قطاع المياه، تعتبر آليات التعامل محدودة وتواجه عقبات بسبب ضعف البنية التحتية، بالإضافة الى ضعف أنظمة الرقابة والتنظيم.

يتخذ أصحاب الحيازات الصغيرة سلسلة من تدابير التعامل لمحاولة الاحتفاظ بالمردودية في سنوات الجفاف وهي كالاتي: زيادة استغلال الموارد الطبيعية وخفض التكاليف مع محاولة اتخاذ إجراءات للحفاظ على الإنتاجية. وعندما يكون هذا غير كافٍ، فإنهم يستخدمون آليات التعامل السلبية التي تقلل المردودية على المدى الطويل أو تؤدي إلى الهجرة أو تساهم في انعدام الأمن الغذائي أو تؤدي إلى الانتكاس الاجتماعي.

أصبحت آليات التعامل في قطاع المياه، وهي تشمل في المقام الأول التوسع في ضخ المياه الجوفية - أقل فاعلية بسبب تأثيرات الجفاف الأخرى مثل تدهور جودة المياه الذي يزيد من تكلفة تلك الاستجابة، و على غرار ذلك، فإن استجابات القطاع الخاص للجفاف، مثل الاستغلال غير القانوني لخطوط الأنابيب ، تزيد من التحديات التي تواجه مؤسسات المياه في أوقات الجفاف وبعده لأنها تؤدي إلى تفاقم التحديات طويلة الأجل.

على المستوى المحلي، هناك تباين قوي في الاحتياجات لتعزيز قدرات التعامل والتكيف، ويعزى ذلك لحد كبير الى الاختلافات في التعرض للجفاف. وقام المسؤولون بتقديم تصنيف للعديد من الإصلاحات المتداخلة و الضرورية فيما يتعلق بالقدرة على التعامل والتكيف الضرورية في حوضي نهر الكلب والليطاني وهي كالاتي: إدارة المياه الجوفية والتخطيط وتحسين البنية التحتية وإدارة الطلب.

الاستنتاجات الأساسية لتخطيط إدارة الجفاف والبحث المستقبلي من أجل التنمية

حدد العمل في برنامج منطقة الشرق الاوسط وشمال افريقيا للجفاف MENAdrought احتياجات المتدخلين لتحسين إدارة أخطار الجفاف. وتشمل هذه المواضيع وضع السياسات والنظم المالية والتنسيق المؤسساتي وخطط إدارة الجفاف، والقدرة المؤسساتية على تقديمها وخدمات الإرشاد وتخطيط تقويم المحاصيل، وأنظمة إدارة المياه ودعم العلوم والمعلومات ، ودعم الحوكمة وتنفيذ السياسات.

أعطى المسؤولون الحكوميون بعد ذلك الأولوية للعديد من المكونات المنفصلة المتعلقة بتطوير السياسات ودعم تنفيذ الحوكمة والمعلومات الأساسية والاستثمار في البنية التحتية. وقمنا برسم خرائط وتحديد جوانب خطر التعرض في قطاعي الزراعة والمياه مقابل احتياجات الإدارة ذات الأولوية من قبل الحكومة.

وقد سلط ذلك الضوء على أن العديد من احتياجات الإدارة ذات الأولوية من قبل الحكومة تتعلق بجوانب عديدة لخطر التعرض والحساسية، كما أبرزنا الفجوات بين جوانب خطر التعرض والحساسية و الأولويات الحكومية: فبالنسبة لقطاع إمدادات المياه، فهو يتماشى بشكل كبير مع الاحتياجات التي يحددها المتدخلون، على الرغم من أنه بالنسبة لقطاع الزراعة، قد تم ترجيحها بشكل أكبر نحو قضايا الموارد الطبيعية بشكل صريح بدلاً من النظم الاجتماعية والبيئية الموسعة.

أخيرًا وبالنظر إلى هذه التدخلات الشاملة، والفجوات في أولويات الحكومة فيما يتعلق بخطر التعرض والحساسية، فإننا نحدد مجال الأبحاث المستقبلية للمواضيع التالية: فرص التنمية المرتبطة بآثار الجفاف وخطر التعرض والحساسية ومراقبة الجفاف وإدارة المياه ومنتجات أنظمة المعلومات وآليات السياسة والحوكمة واليات المخاطر المالية وتحسين الري.

Photo: Jano Hatem / IWMI

Synthèse du projet de la région du Moyen-Orient et d'Afrique du Nord (MENAdrought) sur la vulnérabilité à la sécheresse au Liban

Rapport Final

Soumis au: Bureau du Moyen-Orient de l'USAID

Préparé par: l'Institut International de Gestion de l'Eau (IWMI)

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Photo de couverture: Des femmes récoltant des légumes. (Jano Hatem/ IWMI).

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IWMI International Water Management Institute

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Résumé

But

Ce rapport restitue les résultats principaux du projet de la région du Moyen Orient et l'Afrique du Nord de la sécheresse (MENAdrought) relatifs aux causes sous-jacentes de la vulnérabilité aux impacts de la sécheresse au Liban. Il sert de lien entre l'évaluation d'impact et le processus de planification politique.

L'étude de vulnérabilité vise à identifier *Qui* ou *Ce qui* est menacé par la sécheresse, les causes du risque et les effets des manières dont les intervenants gèrent ce risque. Cela peut ainsi éclairer la planification de la gestion de la sécheresse afin que les interventions ciblent les causes sous-jacentes de la vulnérabilité des communautés et des systèmes identifiés.

Le contexte du problème

Le Liban est un pays riche en eau, comparativement à d'autres pays du Moyen-Orient et d'Afrique du Nord (MENA), ce qui a historiquement conduit les responsables politiques à accorder une faible priorité à la gestion des risques de la sécheresse. Cependant, les sécheresses intenses de 1998-2001, 2008 et de 2013-2014 ont eu des impacts socio-économiques étendus, ce qui a incité les autorités à accorder un intérêt plus accru à la sécheresse.

La fréquence du phénomène de la sécheresse a augmenté dans la région du Levant au cours du siècle dernier (Kelley *et al.*, 2015). Cependant, le changement climatique a considérablement accru l'intensité des sécheresses récentes au Liban (Bergaoui *et al.*, 2015). Les projections des modèles climatiques suggèrent que le réchauffement climatique entraînera très probablement une diminution des précipitations, du manteau neigeux au Liban, ainsi que le raccourcissement des saisons de neige (Karmalkar *et al.*, 2010 ; MoEW, 2010). La modification de la dynamique affecterait les réponses hydrologiques dans les principaux bassins hydrologiques de surface et souterrains (Fayad *et al.*, 2017) et modifiera les équilibres temporels de la disponibilité en ressources des eaux.

Au futur, il est susceptible que la sécheresse accrue et la pénurie d'eau vont contribuer davantage à approfondir l'endettement rural et les défis socio-économiques structurels, ainsi qu'accroître la dépendance du Liban vis-à-vis des importations en produits alimentaires et la déplétion des réserves de change.

Définir la vulnérabilité

La vulnérabilité aux impacts de la sécheresse est un phénomène socio-environnemental. Les praticiens de la gestion des risques de sécheresse explorent généralement cette interaction dynamique à travers une évaluation conceptuelle de la vulnérabilité qui peut varier en fonction de l'échelle de temps en cours d'évaluation:

> Court terme : Vulnérabilité = impact potentiel – capacité de réponse pour faire face à la sécheresse
> Long terme : Vulnérabilité = impact potentiel - capacité d'adaptation

Dans cette formulation, l'impact potentiel englobe deux composantes : l'exposition et la sensibilité. L'exposition fait référence à la présence de personnes, des biens, d'écosystèmes, etc., dans des zones touchées par la sécheresse. La sensibilité se réfère aux seuils climatologiques qui déclenchent des effets négatifs. La capacité de combat est la capacité des communautés, des personnes ou des systèmes à faire face à la sécheresse sans changements irréversibles d'état et de fonctions, tandis que la capacité d'adaptation est la capacité des systèmes, des personnes et des communautés à changer de forme et de fonctionner sous des conditions nouvelles.

Méthodes de recherche

Nous avons utilisé des méthodes de recherche participative à travers plusieurs approches d'évaluation de la vulnérabilité selon la typologie développée dans le cadre d'une étude récente de King-Okumu (2019). Le recours aux

méthodes participatives repose sur une double raison. Premièrement, l'utilisation de ces méthodes peut aider à établir les relations sociales et les associations qui conduisent à une application accrue des connaissances dans des processus techniques et politiques plus larges. Deuxièmement, nous n'avons pas été en mesure d'appliquer des approches spatiales et statistiques en raison du manque ou de l'inaccessibilité des données nécessaires.

Nos travaux de recherche participative se basaient sur les ateliers de travail avec le Comité Technique de la Sécheresse, une équipe interdisciplinaire coordonnée par le Ministère de l'Énergie et de l'Eau (MOEW). Ils incluaient également quatre réunions de groupes de discussion et des entretiens avec la petite paysannerie de la région d'Hermel, axés sur l'exploration des impacts de la sécheresse sur la société rurale, en particulier la sécurité alimentaire, les moyens de subsistance et les effets propres à chaque genre.

Synthèse des résultats relatifs à l'historique de la sécheresse, à la cartographie des risques et aux impacts

Notre évaluation de l'histoire de la sécheresse au cours des deux dernières décennies a permis de recenser trois périodes de sécheresses au niveau nationale, notamment les années 2014, 2008 et 2001, ainsi que plusieurs années caractérisées par des sécheresses intercalées, rampante, et tardives.

Nous avons développé une carte des risques de sécheresse (risques climatologiques) qui montre les zones de sécheresse les plus fréquentes et les plus sévères. Les zones les plus à risque sont les suivantes: Tyr dans le sud du Liban, Bint Jbeil à Nabatieh et Rachaya dans la Bekaa. Les zones à moindre risque comprennent Marjayoun à Nabatieh, Baalbeck et Hermel dans la Bekaa, le nord du Liban, et des zones du mont Liban au nord de Beyrouth. L'Akkar, les régions du Mont Liban au sud de Beyrouth, les régions de la Bekaa à partir de Zahlé au sud et d'autres districts du sud du Liban présentent un risque intermédiaire.

Nous proposons une caractérisation des points de vue des acteurs sur les impacts de la sécheresse et décrivons les impacts traiter a priori par les responsables du gouvernement aux niveaux national et régional dans les bassins hydrologiques du Litani et d'El Kelb à travers des exercices sur la planification de la gestion de la sécheresse. Il s'agit d'impacts principalement liés aux secteurs de l'agriculture et de l'approvisionnement en eau.

Conclusions principales relatives à l'exposition à la sécheresse

Nous décrivons l'exposition des secteurs de l'agriculture et de l'eau ainsi que des communautés spécifiques et des moyens de subsistance de la petite paysannerie aux impacts de la sécheresse. La Bekaa et Baalbek-Hermel sont parmi les zones les plus exposées en termes d'activités agricoles et des facteurs de risque environnementaux. En effet, les petits exploitants agricoles représentent la catégorie la plus vulnérable aux impacts de la sècheresse dans ces zones.

Les pratiques courantes d'irrigation augmentent l'exposition des agriculteurs aux impacts vue la déplétion des ressources en eaux, les mauvaises conditions d'approvisionnement en eaux par les municipalités aide à augmenter le risque d'exposition du secteur. Les réfugiés Syriens ont touché les marchés du travail agricole et ont causé l'augmentation de la demande en services hydrauliques, ce qui a accru leur exposition aux effets de la sécheresse. Les femmes, les enfants et les réfugiés en général sont particulièrement exposés aux impacts de la sécheresse en raison de leur participation disproportionnée au secteur agricole ainsi qu'une plus grande implication dans les aspects saisonniers les plus touchés par la sécheresse.

Conclusions principales relatives à la sensibilité à la sécheresse

Plusieurs facteurs augmentent la sensibilité à la sécheresse du secteur agricole : les pratiques d'irrigation, les cadres réglementaires inadaptés en période de sécheresse émergente, récurrentes, ou prolongées ; la gestion des terres, y compris l'expansion périurbaine des villages qui a entraîné la dégradation des sols, la perte en terres arables et de l'effet tampon de la stabilisation de la production et des revenus ruraux ; les problèmes financiers, d'accès au marché et de son organisation liés à des calendriers imprévisibles des cultures; et l'accès des agriculteurs à l'information et à l'assistance.

Les aspects de la sensibilité du secteur de l'eau présentent des thèmes communs liés à la faiblesse des cadres réglementaires et de planification, ainsi qu'à leur application. Les principaux facteurs de sensibilité sont liés à une mobilisation inadéquate et à une infrastructure de distribution vieillissante pour assurer un approvisionnement stable des ressources en eau douce de qualité. L'instabilité politique et l'afflux de réfugiés en provenance de Syrie ont exacerbé ces aspects de sensibilité car ils ont mis à rude épreuve les ressources naturelles et les infrastructures associées, affecté les routes commerciales et pastorales et conduit à la volatilité des prix des principaux intrants agricoles tels que le carburant.

La principale sensibilité des communautés rurales aux effets de la sécheresse provient de leur endettement excessivement élevé, de leur accès limité au crédit et aux mécanismes de gestion des risques financiers, ainsi que de l'augmentation rapide des coûts en intrants. Par conséquent, les systèmes de petits exploitants perdent rapidement leur viabilité économique, ce qui contribue au recours à des practices nuisibles à long terme.

Conclusions principales relatives à la capacité de combat/réponse et à la capacité d'adaptation

Nous proposons une typologie conceptuelle des mécanismes de gestion de la sécheresse, y compris les interventions post-impact, les programmes d'atténuation d'avant impact et l'élaboration des politiques et des plans de préparation. Ceux-ci, passent, successivement, des mécanismes de combat/réaction aux mécanismes d'adaptation. À l'heure actuelle, les mécanismes de réaction du gouvernement central se limitent à des interventions financières à petite échelle ; des cadres politiques et de planification faible augmentant ainsi la sensibilité et empêchant une réponse et une adaptation efficaces.

Les agriculteurs et certaines autorités locales mènent une série de mesures de réponse dont certains ont des capacités de réaction et d'adaptation relativement efficaces. Pour le secteur de l'eau, les mécanismes d'adaptation sont limités et entravés par la limite des infrastructures, ainsi que par des systèmes de réglementation et de surveillance insuffisants.

Les petits exploitants s'engagent souvent dans une série de mesures de réponse pour conserver leur rentabilité pendant les années de sécheresse : accroître l'exploitation des ressources naturelles et réduire les coûts tout en essayant de prendre des mesures pour maintenir la productivité. Lorsque cela est insuffisant, ils utilisent des mécanismes de réaction qui réduisent la rentabilité à long terme ou conduisent à la migration, contribuent à l'insécurité alimentaire ou entraînent une régression sociale.

Dans le secteur de l'eau, les mécanismes d'adaptation sont limités et entravés par la limitation des infrastructures, ainsi que par des systèmes de réglementation et de surveillance insuffisants. Ces mécanismes concernent principalement l'expansion du pompage des eaux souterraines engendrant la dégradation de la qualité de l'eau ; de même, les réponses du secteur privé à la sécheresse, telles que l'exploitation illégale des canalisations, augmentent les défis pour les établissements d'approvisionnement en eau pendant et après les périodes de sécheresse, car elles exacerbent les défis à long terme.

Au niveau régional, il existe une forte variation des besoins d'amélioration de la réponse et de l'adaptation, due, en grande partie, aux différences d'exposition à la sécheresse. Les responsables libanais ont décrit plusieurs types d'amélioration de capacité de réponse et d'adaptation communes qui ont été requises dans les bassins d'El Kelb et du Litani : gestion des eaux souterraines, planification, amélioration des infrastructures et gestion de la demande.

Conclusions fondamentales sur la planification et la gestion de la sécheresse et possibilités de travaux de recherche pour le développement au futur

Les premiers travaux du projet de la région du Moyen Orient et de l'Afrique du Nord sur la sécheresse (MENAdrought) ont identifié les besoins des acteurs pour améliorer la gestion des risques due à la sécheresse. Il s'agit notamment des thèmes relatifs à l'élaboration des politiques, des systèmes financiers, de la coordination institutionnelle, des plans de gestion de la sécheresse et de la capacité institutionnelle pour leur mise en œuvre, des services de vulgarisation et de la planification du calendrier des cultures, des systèmes de pilotage et de gestion de l'eau et des sciences de l'information correspondantes, de la gouvernance et du soutien à la mise en œuvre des politiques.

Les responsables gouvernementaux ont ensuite priorisé plusieurs éléments distincts relativement à l'élaboration des politiques, au soutien à la mise en œuvre des politiques et à la gouvernance, aux informations sous-jacentes et aux investissements dans les infrastructures. Nous avons cartographié et identifié les aspects de la vulnérabilité des secteurs de l'agriculture et de l'eau par rapport à ces besoins en matière de gestion prioritaire ainsi qu'aux activités de lutte contre la sécheresse de la MENA à ce jour.

Cela a mis en évidence que plusieurs besoins de gestion prioritaires sont liés à de nombreux aspects de la vulnérabilité, tout comme pour les activités de réponse contre la sécheresse dans la région MENA. Ils ont également souligné les écarts entre les aspects de la vulnérabilité et les priorités du gouvernement : pour le secteur de l'approvisionnement en eau, les priorités du gouvernement s'alignent très bien avec les besoins identifiés par les acteurs, bien qu'ils aient été axés, pour le secteur de l'agriculture, beaucoup plus sur les questions explicitement liées aux ressources naturelles que sur des systèmes socio-environnementaux plus larges.

Enfin, compte tenu de ces interventions transversales et des écarts prioritaires du gouvernement en matière de vulnérabilité, nous identifions les travaux de recherches futurs et les opportunités de développement relatifs aux volets impacts et vulnérabilités à la sécheresse, la surveillance de la sécheresse, la gestion de l'eau, les systèmes d'information, les mécanismes politiques et de gouvernance, les mécanismes de gestion du risque financier, et l'amélioration de l'irrigation.

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1. Introduction

Drought has significant impacts on hydrological, agricultural, ecological, and socio-economic systems in Lebanon (Fragaszy *et al.* 2020). With limited water delivery and storage infrastructure – about 6% of total resources used effectively, which is less than 10% of the MENA average (MoEW, 2010) – as well as spring- and groundwater-dependent agricultural systems, Lebanon will face increasing hydrological, agricultural, and socio-economic drought risk under conditions of climate change (CNRS 2015; Haddad *et al.* 2014).

The MENAdrought project works through the Integrated Drought Management Program's (IDMP) "three pillars" approach to improve overall drought management. The three pillars are:

1. drought monitoring and early warning;
2. impact and vulnerability assessments; and
3. mitigation, preparedness, and response planning (WMO and GWP, 2014).

This report focuses on MENAdrought and the predecessor MENA-RDMS projects' activities and findings related to the vulnerability[1] assessment in Lebanon. The purpose of the evaluations has been to understand the root causes of drought impacts and underlying causes of vulnerability across geographic regions, economic sectors, communities, and the environment. This information is a key input to drought risk management planning in Lebanon.

The most relevant activities to date include the following:

- 2016-2017: stakeholder needs assessment (Fragaszy *et al.* 2020; Jedd *et al.* 2020) to engage key stakeholders and produce information on current and desired drought monitoring and management practices as well as impacts and sources of vulnerability. Following the country-wide evaluations, key stakeholders attended workshops and provided feedback on results and guidance on key topics to prioritize in subsequent impact and vulnerability studies.
- 2018-2019: drought impact and vulnerability studies focused on the agriculture and water supply sectors. In particular, they included detailed data review and participatory research approaches to asses drought impacts, sources of vulnerability, and priorities for government intervention to address both.
- 2020 - present:
    a. baseline assessment to identify gaps in the first attempt to embed drought risk management using data-driven systems and a participatory approach.
    b. Composite Drought Index (CDI) improvements including the completion of drought history (2000-present) and drought hazard mapping.
    c. case study participatory research primarily amongst smallholder rainfed, irrigated, and livestock farmers in Hermel. These took a micro-level livelihoods approach (UNDRR, 2009), and they focused on the following aspects of drought vulnerability: debt and access to finance, food security, gender effects, and livelihoods issues including in relation to market supply chains.

[1] The UN's Sendai Framework for Disaster Risk Reduction defines vulnerability as: the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

1.1 Vulnerability as a concept

Before discussing findings, it is necessary to clarify key terms and concepts so that the project findings, and their implications for future work, can be articulated within a clear framework.

Vulnerability[2] to drought impacts is a socio-environmental phenomenon. Drought risk management practitioners typically explore this dynamic interaction within socio-environmental systems (SES). We can use a conceptual definition of vulnerability that shifts depending on the time-scale under assessment:

Short term: Vulnerability = potential impact - coping capacity
Long term: Vulnerability = potential impact - adaptive capacity

Potential impact

In this formulation, potential impact has two SES components: exposure and sensitivity. Exposure relates to the presence of people, assets, ecosystems, etc. in drought-affected areas. Sensitivity relates to the climatological thresholds that trigger negative effects.

Sensitivity is a highly variable characteristic within a given system. In contrast, exposure is typically more straightforward. This is because sensitivity is affected by numerous interactive processes (both human-driven and other), whereas exposure is a fixed feature in a given place and point in time. For example, the sensitivity of two barley crops in the same location can differ significantly depending on land management practices, pest occurrence, highly localised soil characteristics, or many other reasons. Likewise, the sensitivity of water supply systems can vary depending on the age and characteristics of the storage and distribution infrastructure, management regimes, water demand, or many other reasons. But the exposed assets (the crops or the water for municipal systems) would be the same in both cases.

Therefore, within each region, economic, sector, community, etc., sensitivity is highly variable as a feature of numerous sub-systems, whereas exposure varies between regions, economic sectors, communities, etc.

Coping and adaptive capacity

Coping capacity is the ability of communities, people, or systems to withstand drought without irreversible changes in state and functions. In contrast, adaptive capacity is the ability for systems, people, communities, etc., "to change form and function markedly under new conditions" (Riebsame 1991). Coping and adapting are very different things, but in many cases, the underlying characteristics that enable them are the same, and they largely revolve around the resources and options available to people, and the related SES factors.

For example, drought insurance may help people cope with or adapt to drought by reducing financial risks associated with drought impacts. However, while coping would entail a general continuity of practices over time, adaptation would entail a change in practices over time. Likewise, drought management policy that subsidizes feed provision for livestock during drought may help pastoralists cope with drought but will not, on its own, encourage changing practices. The line between these two concepts is porous, but differentiating between them is particularly useful when consideration of climate change enters the picture and water scarcity becomes more of a chronic issue.

[2] The UNISDR definition of vulnerability is: "The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards".

1.2 Drought impacts are driven by vulnerability and responses

The realisation of drought impacts results from a climatological hazard, SES responses to them, and underlying vulnerability, as illustrated by Van Loon *et al.* (2016) in Figure 1 reproduced below:

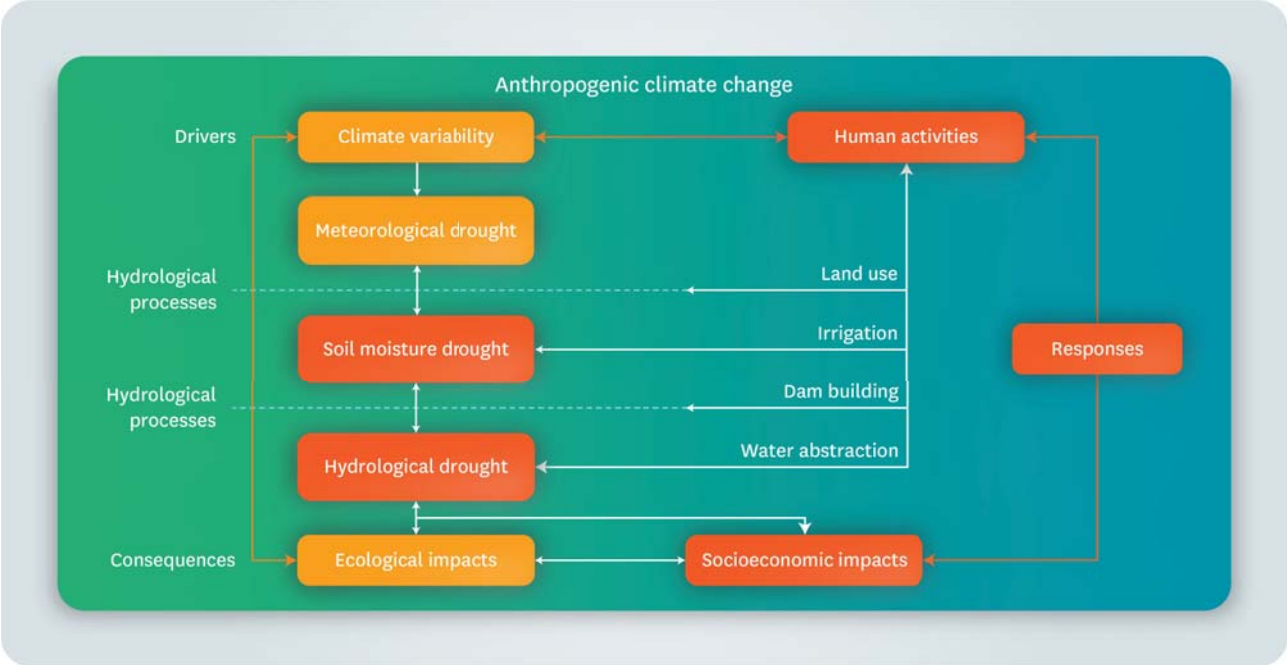

Figure 1. *Drought propagation - effects, responses, and impacts*

People and environmental systems respond to initial drought impacts, which causes secondary effects in the same systems and beyond. For example, the biophysical response to drought in barley crops can be reduced yield, which results in decreases in food and production, and income for farmers. If the farmer were to irrigate the crop to avoid reductions in yields, the second-order effect would be increased water abstraction (with associated reduction in water availability for other uses) rather than declines in food production. Irrigation would thus be a coping strategy for the farmer, and his/her ability to undertake irrigation would be the coping capacity to reduce vulnerability.

Coping strategies (and adaptation strategies) can cause negative effects within a given system, or for other systems. For example, irrigation of the barley crop might accelerate soil degradation via salinization thereby reducing the land's future productive capacity. The conceptual diagram in Figure 2 illustrates these potential negative feedback loops between drought impacts on various parts of the SES, responses to them and second-order impacts, and the ultimate effect in increasing vulnerability.

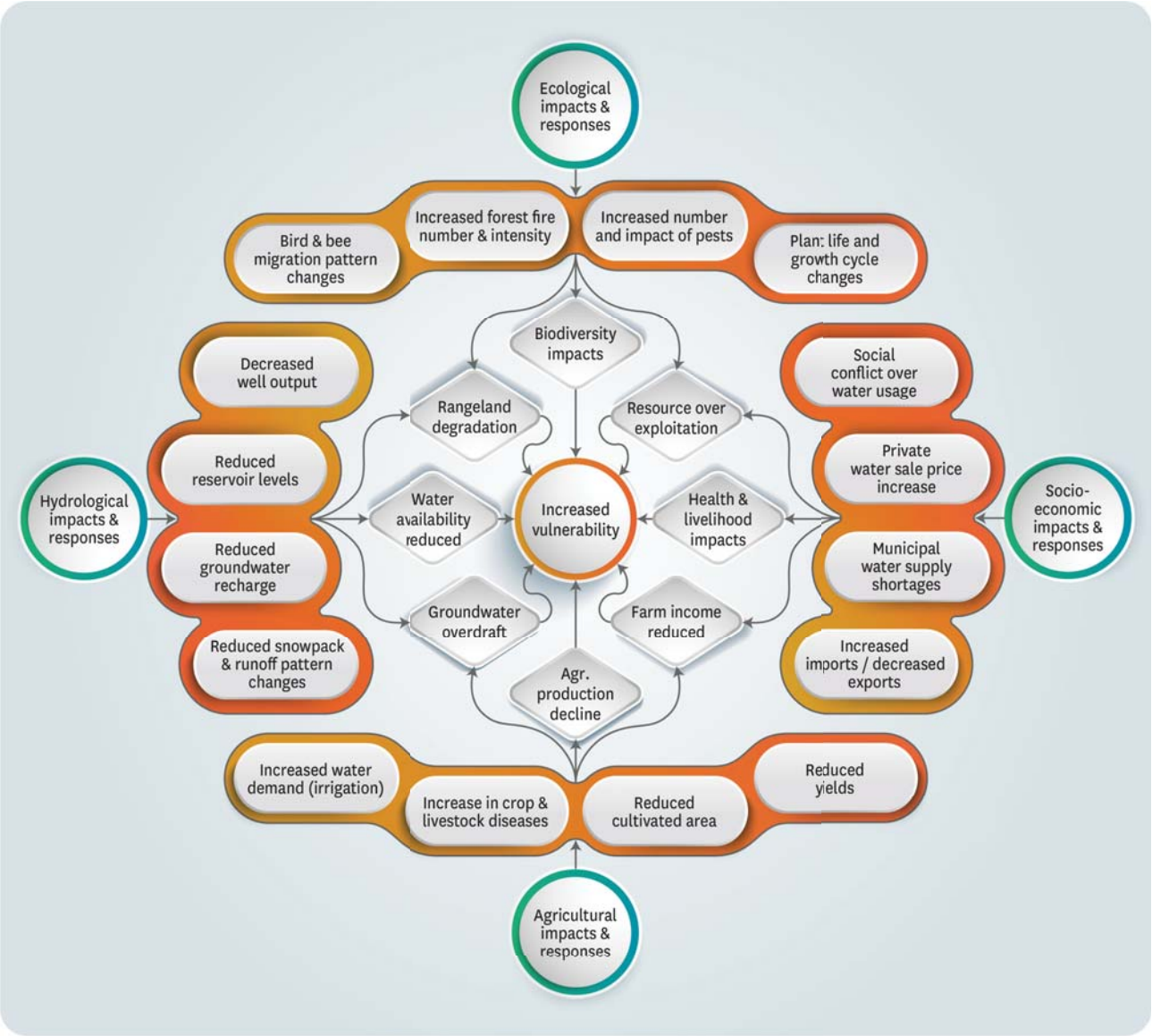

Figure 2. *Drought impacts and potential negative feedbacks on vulnerability*

The vulnerability assessment, then, provides a framework for identifying SES causes of impacts. It bridges the gap between impact assessment and policy formulation by directing attention to the underlying causes of vulnerability rather than to its result or negative impacts that follow the drought hazard event (Knutson *et al.*, 1998). The objective is to identify who or what is at risk, what causes risk, and the effects of how risk is managed. The purpose is to inform drought management planning so that interventions target underlying causes of vulnerability for the identified communities and systems.

1.3 Assessing drought vulnerability

Since vulnerability is context-, location-, and SES-specific, its assessment can and should be multidimensional (Sivakumar et al. 2014). Drought vulnerability assessments fall into several broad categories (King-Okumu 2019):

1. Community-based resilience and livelihoods assessment (focuses on people, their assets and ability to recover from drought)

2. Ecosystem based agro-ecological (focuses on ecosystems, their productivity and responses to climate extremes);

3. Water balance accounting and basin management (focuses on water availability, and relation to demands from different sectors of the economy);

4. Macro-economic assessment (focuses on implications for national economic development planning);

5. Institutional analysis (focuses on stakeholder dynamics, communication, and power relations); and

6. Inclusive approach (focuses on design of the consultation).

These approaches use different methods, focus on different SES, and produce very different types of information about drought vulnerability components (exposure, sensitivity, and coping capacity). Our work incorporated several of these approaches, though not all to their fullest extent.

For example, our ecosystem-based agro-ecological assessment linked directly with development of the CDI. It did not explicitly assess crop response to drought; rather, we evaluated past drought effects on agricultural production as a function of their severity (per the CDI, its components, and ground precipitation measurements). This certainly relates to drought vulnerability, but we would need to develop additional methods to support robust scenario modelling or forecasting of drought impacts. This would be a feasible next step given the base of information that we have developed.

Assessing drought vulnerability from multiple angles has provided a wide-ranging perspective on communities at risk, underlying causes of risk, and potential interventions to reduce risks. Table 1 below shows a summary of the projects method(s) in relation to each of these approaches, the general types of information produced, specific content on vulnerability components, and comments on its role in understanding drought vulnerability. In addition to the primary research, we reviewed relevant literature, which is detailed in Section Six but not included in Table 1.

The rest of the report is structured as follows:

- Section two provides findings on drought history, hazard, and impacts.
- Section three provides findings on drought exposure
- Section four provides findings on drought sensitivity
- Section five provides findings on drought coping and adaptive capacity
- Section six concludes the report by linking drought management planning to aspects of vulnerability and relatedresearch for development needs
- The appendices contain extensive technical information that supports the information presented in the body of the report.

Table 1. *Summary table of vulnerability assessment approaches taken, methods used, and information produced*

Approach	Method	Type of results produced	Exposure info	Sensitivity	Coping / adaptive capacity	Comment
Community-based resilience and livelihoods assessment	1. Participatory research; 2. Focused drought vulnerability survey	1. Regional-, sector-, or community-specific information on drought impacts and vulnerability; stakeholder-prioritised needs to improve drought monitoring and management (focused on livelihoods); 2. Quantitative and qualitative data focused on access to finance, debt, market chains, gender, and food security.	1. From description of primary impact types and locations; 2. Key focus on vertical exposure within sectors (from producers to consumers via market chains).	1. From description of drought management needs as well as drought patterns/ typology; 2. Key focus on agro-ecological and socio-economic aspects of sensitivity.	1. From description of drought monitoring and management needs; 2. Key focus on coping capacity and strategies, including identification of positive and negative strategies and factors in their use.	1. Findings stimulated stakeholder feedback (especially government officials) on priority impacts and themes of vulnerability to assess in MENAdrought activities. 2. Findings help characterise national impact evaluations and identify specific levels of market chains / governance to target for interventions.
Ecosystem based agro-ecological	1. CDI-based drought history assessment; 2. CDI-based drought hazard mapping; 3. Assessment of irrigation and crop water use	1. Time-series of drought severity; 2. Hazard hot spots (frequency of drought events). 3. Evaluation of irrigation application in relation to estimated crop water use	1 & 2 Information is hazard-focused; can be coupled with impact data to assess exposure, sensitivity, and adaptive capacity between areas, sectors, etc. 3. Describes macro-level over-irrigation in relation to crop water requirements	1 & 2 As for exposure 3. Information is relevant to water availability and quality aspects of drought sensitivity	1 & 2 As for exposure 3. Identifies pathways for increasing the crop water use efficiency and associated potential to expand irrigation as a coping and adaptation mechanism	1 & 2 We have produced the critical climatological information on which to base spatialized vulnerability mapping and scenario modelling; other components produce relevant data on exposure, sensitivity, and adaptive capacity. 3. This can inform agricultural investment considerations including related to extension services.
Water balance accounting and basin management	1. Participatory research; 2. Water accounting +	1. Information on water management including sector monitoring, impacts and responses including case examples; 2. Water accounting for predominantly agricultural basin to identify land cover classes and their relation to surface water / groundwater flows and uses	1. Types and location of water resources most affected, and flow-on effects; 2. Changes in discharges between drought and normal years	1. Hydrology and water sector characteristics and context that contribute to impacts; 2. Data limitations constrained analysis of sensitivity	1. Identification of water sector coping mechanisms, needs for their improvement, and desired adaptation measures; 2. As for sensitivity.	Assessments focused on the water balance aimed to evaluate links between water management, urban supply, and agricultural production regimes. Vulnerability-specific components focused on infrastructure, management planning, monitoring, and capacity for coordination and collaboration.
Macro-economic assessment	This would not be possible in Lebanon without extensive primary data collection and collation.	This would provide information on drought effects on agriculture (focus on rainfed systems), forest fires, health, and government expenditure.	This would focus on relative exposure of various sub-sectors.	This would be of limited value in and of itself, but this data helps to inform assessment of sensitivity through other approaches.	This would support examination of how coping mechanisms (e.g. feed subsidies) affect sub-sectors.	This information would be particularly useful to highlight the costs of drought impacts and determine sectors of relative importance to focus on for macroeconomic reasons. It would inform analysis of sensitivity and coping mechanisms evaluated through other approaches and methods. Also, it would improve understanding of food security and food demand/supply balance.
Institutional analysis	Participatory research including stakeholder mapping;	Coordination and collaboration gaps, and other stakeholder-prioritised needs to improve drought management (focused on institutions)	Limited – some information on how gaps link to exposed sectors in particular.	Governance, coordination, and action-oriented aspects of sensitivity.	As for sensitivity.	Institutional analysis was a core component in structuring drought technical committee arrangements.
Inclusive approach	Structure of needs assessment;	Range of participant types in each country to feed into needs assessment – central government agencies and local representatives; farmers' union and collectives; civil society organizations, chambers of agriculture and commerce; academics and researchers, finance sector, and international institutions.	Broadened the types of exposure surfaced by participants and considered in work program.	As for exposure.	As for exposure;	The broad needs assessment surfaced key issues of relevance for different stakeholder types, which fed into program development that focused on government planning components.

2. Drought history, hazard, and impacts

In this section, we use the MENAdrought CDI to evaluate drought history and spatial aspects of drought hazard in the 2001-2020 period[3] . Then we discuss identified and priority impacts for government stakeholders to address.

This examination of impacts is intended to stay at the macro-level; subsequent sections also include discussion of drought impacts, particularly for the agriculture sector and smallholder communities, but in the context of specific aspects of exposure, sensitivity, and coping mechanisms.

2.1 Drought history

Results show three significant nationwide droughts in the period: 2001, 2008, and 2014. The latter, 2014, had the most severe drought. Beginning in early winter, it affected large areas of the country, and the CDI class reached "exceptional drought" - defined as having a return period of 20-50 years - in many places. Media reports of drought impacts were common, and the drought served to increase public awareness, including that of officials, regarding the issue of increasing water scarcity in Lebanon. This was the "reference drought" that most stakeholders referred to when describing drought impacts, vulnerability, and management needs (Fragaszy *et al.*, 2020; Jedd *et al.* 2020).

Additionally, there were several years of regional or otherwise widespread but slow onset droughts that increased in severity from late winter to spring: 2004, 2010, and 2013. Slow onset droughts are particularly difficult to characterize at the national level and can therefore pose risks to communities if there is inadequate information available to support management efforts.

The years 2005-2007, 2009, 2012, and 2016-2018 had locally relevant droughts that can lead to overall moderately dry years at the national level. These droughts are unlikely to have significant impacts beyond the local area, though they do contribute to land degradation and desertification in Lebanon.

Finally, the remaining years exhibited mostly normal to extremely wet conditions. Figure B1 in Appendix B shows the CDI outputs on which this summary information is based. We also provide characterization of drought history results compared to other studies in Appendix B.

2.2 Drought hazard

Below we show the drought hazard results for Lebanon by district. The map presented in Figure 3 identifies districts that, compared to the national average, have higher or lower climatological exposure to drought risk. In other words, it shows the places where drought is climatologically more frequent and intense compared to those where it tends to be less frequent and intense.

Areas of highest hazard include Tyre in Southern Lebanon, Bint Jbeil in Nabatieh, and Rechaya in the Bekaa. Lower hazard areas include Marjeyoun in Nabatieh, Baalbeck and Hermel in Bekaa, North Lebanon, and areas of Mount Lebanon north of Beirut. Akkar, areas of Mount Lebanon south of Beirut, areas of Bekaa from Zahle south, and other districts of southern Lebanon have intermediate hazard.

This regional picture generally aligns with stakeholder descriptions of areas that are most vulnerable to drought impacts. Indeed, Lebanese stakeholders prioritised the Bekaa and southern coastal plains for drought vulnerability research given their perception that it had high climatological hazard risk as well as high exposure and poor adaptive capacity of the agriculture and water sector, respectively.

[3] We use the "hydrological year" that spans from September to August, and we denote years using the final season. For example, a dry year in 2001 includes the period of September 2000 to August 2001.

This information is highly relevant as we consider the variable drought risk exposure of different communities, sectors, and regions. Drought hazard is the highest in rainfed olives-based systems and irrigated fruit orchards (citrus and banana) in Southern plainsthat are vulnerable to desertification.

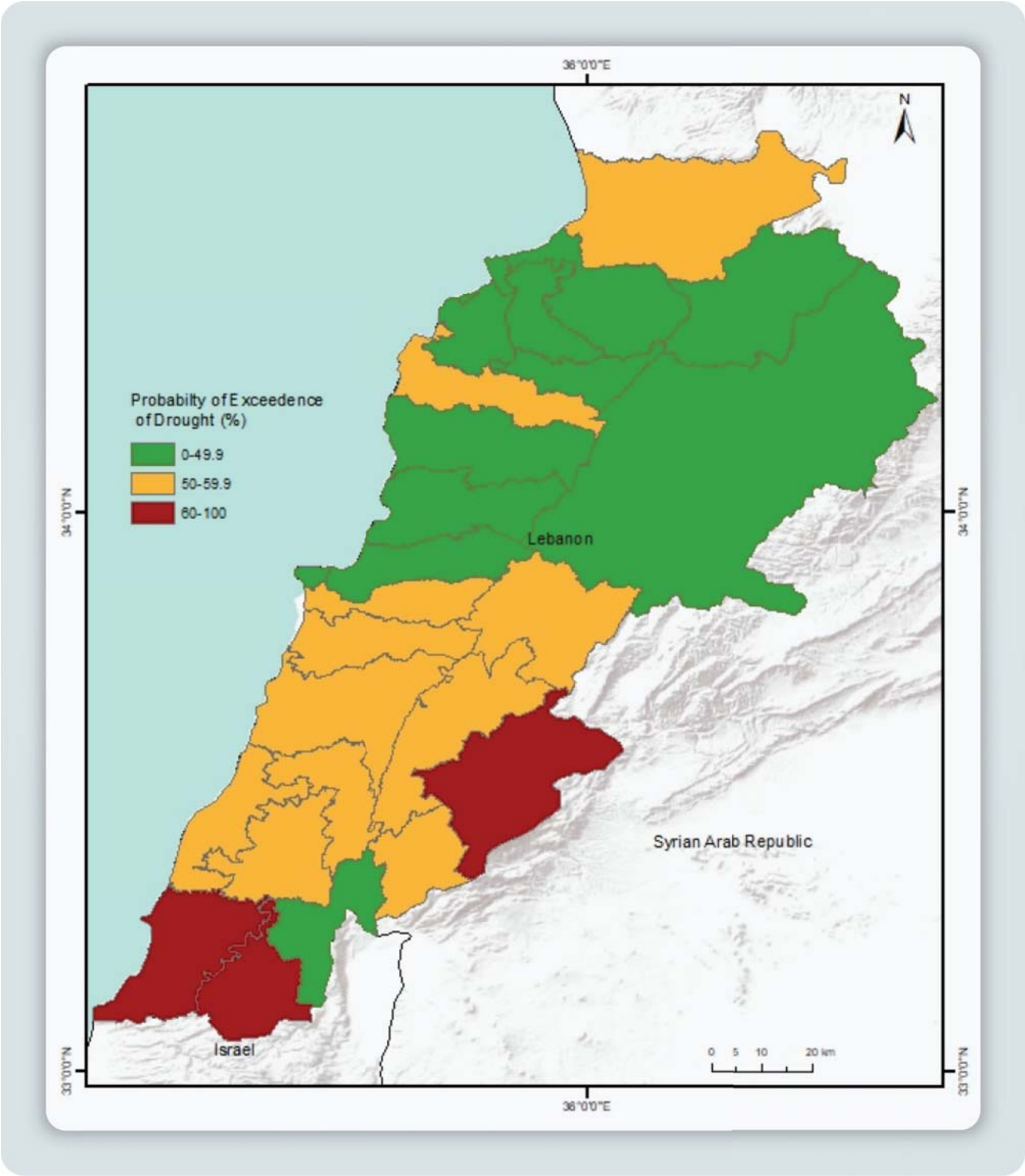

Figure 3. *Drought hazard map for Lebanon*

2.3 Drought impacts

National level

We identified no reports that systematically estimate drought impacts on the Lebanese economy. A review of available data (see Appendix B for more detail) led us to conclude that extant national and sub-national statistics are not conducive to statistical assessments of drought impacts because of the following combination of factors:

- Agricultural cultivation, yield, and production statistics were only collected regularly from 2000-2007, and those do not have adequate spatial disaggregation;
- Spring and streamflow gauging stations do not have long records and there are significant data gaps;
- No central government spending is specifically tagged as drought-related;
- Producer-directed agricultural subsidies are relatively minor and primarily for agricultural inputs and credit facilitation rather than purchases that are highly responsive to drought, such as fodder (World Bank, 2010; FAO, 2020)
- Geopolitical disruptions such as the 2006 war and the Syrian civil war from 2011 onwards have major effects on the population and economy;
- Statistics on the number and extent of forest fires are not regularly collected.

In short, we were unable to quantify drought impacts through typical statistical approaches without substantive additional data collection. This in itself is a critical finding: hydrological, agricultural, and socio-economic monitoring data currently produced and collated at the national and sub-national level is only able to support cursory drought impacts assessment.

Nonetheless, media reports illustrate drought's significant impacts. For instance, reliefweb.int[4] reported that in the Bekaa, Lebanon's agricultural heartland, a typical farmer's profit dropped by half from the previous year (decreasing to around $6,000 in 2014 from $14,000 in 2013). This was due to direct losses as well as shifts to less profitable crops in anticipation of reduced irrigation water availability. Also, irrigation networks were completely shut off in parts of the Litani and Hasabani basins – major production areas – and municipal water supply shortages led to increasing public and political attention on drought and water management issues.

While we cannot extrapolate from these examples, they do give an indication of the likely magnitude of impacts, and Table B1 in Appendix B identifies the breadth of types of impacts. Given these data limitations, and the project objective for the drought impact and vulnerability studies to inform drought risk management planning, we used participatory approaches to 1) evaluate the relative importance of drought impacts nationally and in the Kelb and Litani river basins, and 2) to characterise cascades of drought impacts within sectors to identify potential points for policy and management interventions.

In Appendix B, we provide an overview and detailed tables (B2-5) on stakeholder perceptions of the magnitude of drought impacts nationally and regionally as well as how they have changed from the past and are likely to change in the future.

National and regional (Kelb and Litani basins) priority impacts to address

Stakeholders consider that the priority impacts to address most connect to the water supply and agriculture sectors. This is due to increased costs and reduced outputs. Social impacts to address reflect political stability and social harmony objectives, especially concerning refugee resettlement. Environmental impacts are most relevant to freshwater resources including water quality.

Tables 2 and 3 below show specific national priority drought impacts to address. Therefore, subsequent MENAdrought vulnerability evaluation and drought management planning efforts focused on these impacts.

[4] https://reliefweb.int/report/lebanon/lebanon-s-drought-needs-long-term-solutions

Table 2. *Priority national drought impacts*

Economy	Society	Environment
Increased irrigation costs	Water user conflicts	The lower water level in reservoirs, lakes, and ponds
Cost of new/supplemental water resource development	Political conflicts over border control and/or closure to the movement of goods and people	Reduced flow from springs and streams
Loss from crop production	Management conflicts related to lack of accurate water use metering and consistent supply	Water quality effects
Disrupted food supply and increased import	Institutional constraints on water use	Disruption of water supplies
The loss to the tourism industry		Damage to fish habitat due to coastal pollution
Revenue loss from the reduced tax base		Air quality effects

Regional priority impacts differed slightly or were more specific. For instance, in both basins, decreased crop and fruit production from rainfed systems was a priority. Table 3 shows basin-level drought impact priority themes.

Table 3. *Priority basin-level drought impacts*

El Kelb	Litani
Increased water scarcity	Increased cost to replace lost water
Reduced surface water flow	Increased water scarcity
Drought-related impacts on snow season	Decreased water quality
Forested lands/forest health degradation	Decreased water storage/reduced exploitable water supply
Increased water storage and supply cost	Reductions in agricultural production (especially rainfed)
Increased cost to replace lost water	

2.4 Section summary

Our assessment of drought history over the past two decades identified three nationally significant droughts in 2014, 2008, and 2001 as well as several years with interspersed, creeping, and late-onset droughts.

We developed a drought hazard (climatological risk) map that shows where drought is most frequent and severe. Areas of highest hazard include Tyre in Southern Lebanon, Bint Jbeil in Nabatieh, and Rechaya in the Bekaa. Lower hazard areas include Marjeyoun in Nabatieh, Baalbeck and Hermel in Bekaa, North Lebanon, and areas of Mount Lebanon north of Beirut. Akkar, areas of Mount Lebanon south of Beirut, areas of Bekaa from Zahle south, and other districts of southern Lebanon have intermediate hazard.

We provide stakeholder characterization of drought impacts and describe the impacts that government officials prioritise to address nationally as well as regionally in the Litani and El Kelb basins through drought management planning exercises. These are impacts primarily related to the agriculture and water supply sectors.

3. Vulnerability – exposure

In this section, we describe aspects of drought exposure determined through participatory research conducted with government stakeholders and smallholder farmers as well as evaluation of crop water use and irrigation. We provide a national overview, then focus on the agriculture and water supply sectors, and finally livelihood and community aspects of drought exposure including a focus on refugees, women, and children.

3.1 National overview

We used surveys of government stakeholders to assess the drought vulnerability of the Lebanese economy, society, and ecosystems generally, as well as the following specific sectors: agriculture, water, energy, tourism, and public health. We also used workshops to explore factors in the vulnerability of the agriculture and water supply sectors.

By sector, the studies found that agriculture and water supply are the most vulnerable due to exposure of producers (farmers/water establishments) and consumers (population/industries) to a range of water availability and quality impacts.

In regard to ecosystems, loss of snowpack and biodiversity; forest fires; and land degradation were prominent issues. In relation to societal vulnerability, migration and health issues were very important. Economic aspects of vulnerability stem from increased energy demands and water resource scarcity. Full results are shown in Table C1 in Appendix C.

Stakeholders consider the inland Bekaa region, which is primarily semi-arid, to be the most vulnerable region overall. This is because, with 45% of all nationally cultivated land, it is the main agricultural area and thus highly exposed. Stakeholders also consider that climate extremes – that is, reduced precipitation and large diurnal temperature fluxes – are more common in Bekaa, as borne out in the hazard mapping shown in Section 2.2. In contrast, coastal regions face high population growth leading to increased water demand and subsequent pressure on water supplies, which is the primary aspect of vulnerability.

Stakeholders report that the agriculture sector's vulnerability to drought stems from many inter-connected sources. Environmental aspects of vulnerability are most prominent in the rainfed sub-sector and relate to rainfall deficit, pests (insects), extreme temperature fluxes, repeated heatwaves, early spring high temperatures, and water quality problems.

Stakeholders describe irrigation from spring and surface water systems as most vulnerable to drought and so request seasonal drought and water availability forecasting to anticipate volumes required to maintain yield productivity as this is a major concern.

They described fruit orchards, pine nuts and seasonal cultivations as the crops most affected by drought. Meanwhile, livestock herders and farmers in mountainous areas are usually the most vulnerable groups. In addition to direct production losses, farmers emphasized that crop quality degradation was equally important because of its effect on market prices.

Litani and Orontes basins

The total utilized agriculture area covers 231,000 ha in Lebanon (70% of the potential arable area), with about 41% located in the Bekaa Valley districts of Baalbeck-Hermel and Bekaa (Agricultural Census, 2010). Irrigated land varies between about 89,000 and 118,000 ha, and the average farm holding is about 1.36 ha, with irrigated farms slightly smaller on average (1.23 ha).

The large majority of irrigation occurs in the Litani and Orontes basins (Kibaroglu and Jaubert, 2016). The 2010-2014 mean annual flow rate of the Litani River was 331 MCM/yr while the Orontes was 334 MCM/yr in the same period (IWMI 2021). Aquifer recharge in the Orontes varies from 88.3 MCM/yr and 210 MCM (Bekaaa Water Establishment and USAID-LRBMS, 2011).

The Upper Litani Basin (ULB) covers 45,700 ha, and non-cereals are grown over 35,500 ha. Jaafar and King-Okumu (2016) estimate total water withdrawals (surface and groundwater) to be 415 MCM/yr considering the efficiencies of

the different irrigation systems. With this estimation, non-cereals water consumption in the ULB is about 250 MCM. This is equivalent to 704 mm/yr of irrigation application, though estimated crop evapotranspiration does not exceed 415 mm/yr given crop types. In contrast supplementary irrigated wheat covers 10,200 ha (mainly wheat) in the region and irrigation does not exceed 150 mm/yr. The most recent estimates of groundwater withdrawal – which are highly uncertain – are in the order of 150 MCM/yr with about 80% for irrigation (USAID-LRBMS 2011). Still, the Bekaa Water Establishment (BWE), found a deficiency of 50MCM in a dry year (Jaafer and King-Okumu, 2016).

The Upper Orontes Basin (UOB) covers 13,800 ha, where non-cereals grow over 12,400 ha. Non-cereals consume in total 80 MCM, which is equivalent to 645 mm/yr of irrigation application while crop evapotranspiration does not exceed 364 mm/yr on average. About 1,400 ha are grown in supplementary irrigated wheat (Kibaroglu and Jaubert, 2016). Figure C1 in Appendix C shows these areas.

This information indicates high over-irrigation rates, which is explored more fully in Section 4.1.

3.2 Exposure in the water supply sector

Municipal water supply limitations mean that most Lebanese rely on private wells, rainwater storage or purchased water from the private sector for at least part of the year, typically towards the end of summer. During droughts, the need for alternate water sources starts earlier and is more frequent in the year. Humanitarian relief organizations, which primarily rely on water purchases and tankers due to the inability to install municipal infrastructure in refugee areas, stated that during 2014, costs for water purchases increased dramatically due to increased demand (approximately 50% higher) and concomitant higher prices in the private sector (Fragaszy *et al.*, 2020). Anecdotes from stakeholder suggest that because of limited water availability and much hotter and more humid weather, water-borne disease burden increased dramatically compared to typical summers.

Stakeholders focused on the lack of surface water storage and groundwater drawdown as core features of exposure in the water supply sector. Surface water flows are highly seasonal, and storage capacity is very low – about 6% of total resources, which is less than 10% of the MENA average (MoEW, 2010).

Groundwater utilization, first from the approximately 5,050 springs in Lebanon and subsequently from the approximately 20,000 legal and estimated 50,000-60,000 illegal wells, has underpinned economic development and improved water availability throughout Lebanon (MoEW and UNDP, 2014). However, groundwater table drawdown is a significant problem in the coastal and interior plains areas, and the Litani basin aquifer has experienced a drawdown of approximately 20m since the 1970s (ibid).

Groundwater resources are similarly impacted through recharge processes and over-abstraction as a management response. These declines result in higher pumping costs for users, primarily in the agricultural sector but also within municipal services. The tourism and health sectors are also impacted as water quality degradation, which is linked to drawdown and drought, leads to increased waterborne disease burden.

Poor water infrastructure is a major aspect of exposure: the MoEW (2010) estimated that more than 50% of transmission and distribution networks are past their useful life and also have very high leakage rates. This is especially relevant in coastal areas more reliant on surface water. Likewise, the lack of wastewater treatment and re-use infrastructure further exposes the sector to drought risk.

Also, the major population increase due to Syrian refugees has put enormous additional strain on this infrastructure and the institutions that deliver water services. The Syrian refugee population in Lebanon is the highest per capita concentration of refugees globally (one in four), and the fourth largest refugee population worldwide. The Lebanese government currently estimates that the country is hosting 15 million Syrian refugees who have arrived since 2011; around 70% of whom were registered with UNHCR by the end of September 2018. About 69% of Syrian families live below the poverty line, with 51% of the refugee community falling below the survival minimum expenditure basket (UNHCR *et al.*, 2018).

3.3. Livelihoods and community aspects of exposure

One-fifth of the country's 200,000 farm households depend entirely on their farm income. These, and other smallholder farming systems, are typically limited in area due to land fragmentation from inheritance and absence of land consolidation. These farms are outcompeted by more industrialised farm systems and have seen their profitability erode as more capital-intensive modes of farming have proliferated. They are not well integrated into market structures, and their economic precariousness means they are particularly sensitive to drought impacts.

Indeed, droughts impact their farm productivity disproportionately due to their lack of coping mechanisms, which has consequent negative effects on their livelihood and food security. In Appendix C we provide additional detail on agricultural class hierarchies in the case study area of Hermel.

Farm labour

The availability of cheap refugee labour has ambivalent impacts on drought exposure. Refugee labourers are often willing to work in poorer working conditions for lower pay. In the short term, this has created windfalls for larger agricultural producers that have no doubt reduced the impact of recent droughts. However, , refugee labour has also reduced farm labourer income, further exposing households in the sector to drought impacts. Households in the sector experience some of the highest poverty rates, with 20 percent of these households categorised as extremely poor (World Bank, 2010: 3).

Refugees, women, and children

Many refugees have been absorbed into the informal economy, particularly within the agricultural sector (Hamade, 2016). They are particularly exposed to drought risks because majority-refugee areas do not have adequate access to municipal water supplies or sanitation (i.e., wastewater treatment). Drought worsens the health situation in workers' camps.

More generally, increased water scarcity, and the decreased economic viability of rural livelihoods and the agricultural sector at large, have increased the potential risks associated with drought. As tension around joblessness, underemployment, and resource access increases, public perceptions worsen. This can lead to decreased tolerance toward Syrian refugees.

Over half of refugees are under 18, and about 20% of families are female-headed households (UNHCR *et al.*, 2018). Female-headed households are more likely to experience poor food consumption and lower dietary diversity. These populations are disproportionately affected by drought events.

Women and children are also disproportionately exposed to drought impacts. The UN-ILO estimates that 16 percent of employed women work in agriculture, as opposed to 11 percent of employed men (ILO, 2018, cited in ILO and FAO, 2020). Women represent 40 percent of the agricultural labour force and most work on family farms, though many also undertake seasonal labour such as harvesting where they are typically paid significantly less than their male counterparts.

This is similar in the food processing and agri-business industries. Most women work part time as they are responsible for other household and childrearing duties. As such, the lack of maternity cover and other protective working standards would imply that drought-related pressure on the sector are likely to disproportionately affect women employed in the sector.

Decreased profitability of farming during droughts increases casualisation of the labour force, lowers wages, and increases child labour participation. This leads to children not attending school, doing hard labour, and being exposed to toxic agricultural inputs. On top of chronic food insecurity, these have long-term effects on the physical and mental development of children. However, no Lebanon-specific studies have assessed the impacts of drought events on these underlying vulnerabilities.

3.4 Section summary

We describe the exposure of the agriculture and water sectors as well as specific communities and smallholder livelihoods to drought impacts. Exposure is related to the location of economic activities and populations; as such,

the Bekaa and Baalbeck-Hermel are the most exposed areas in terms of agricultural activities and environmental risk factors, and smallholder farms are the most exposed to impacts in these areas.

Common irrigation practices increase farmers' exposure to impacts, and poor municipal water supply infrastructure increases the water sectors' exposure. Syrian refugees have affected agricultural labour markets and increased demand from water infrastructure, which has increased their exposure to drought impacts. Female-led households, children, and refugees are particularly exposed to drought impacts because of their disproportionate participation in the agriculture sector as well as higher involvement in seasonal aspects most affected by drought.

4. Vulnerability – sensitivity

In this section, we report aspects of drought sensitivity described by government stakeholders and smallholder farmers as well as evaluation of crop water use and irrigation. We focus on the agriculture and water supply sectors and then discuss community and livelihood aspects of vulnerability including aspects related to political instability.

4.1 Sensitivity in the agriculture sector

Agriculture sector sensitivity to drought impacts stems from multiple sources, including the following:

- Water availability and quality challenges stem from irrigation practices, weak regulation (and non-enforcement of it) on irrigation water use, and practices that degrade water quality and infrastructure;
- Land management and urban development have increased sensitivity due to desertification through overgrazing rangelands, degradation of soil health, and construction practices that increase erosion linked to droughts;
- Poor access to credit and financial risk mechanisms as well as market access issues, which are related to political instability; and
- Poor access to information/extension and support on drought, water availability, market needs, and coping mechanisms.

Water use and irrigation

Crop water availability during drought periods is further reduced by the predominance of inefficient irrigation practices. Sprinkler and farrow systems dominate the landscape (over 75% of the area), while drip systems cover 22% of the area, almost entirely with non-pressure compensating emitters. Drip irrigation is most common for stone fruits and vegetables, while sprinkler irrigation is largely used to produce potatoes, wheat, tobacco, lettuce, and onions.

Flood irrigation remains commonplace. Stakeholders mentioned numerous barriers to uptake of improved irrigation techniques:

- lack of awareness, extensions services, and guidance about new technologies
- lack of cooperative arrangements to use them;
- lack of incentives because irrigation water pricing is determined by area cultivated rather than by volume used, and in some areas, irrigation scheduling is related to time shares rather than volume shares;
- Unreliable water supply leads farmers to over-irrigate since they do not know whether water will continue to be available;
- inability to utilize modern systems because of water quality problems, especially siltation (Amery, 2002); and
- lack of capital and/or reliable electricity supply for drip systems.

Drip irrigation is increasingly important in the coastal strip where most agriculture is rain-fed (olive orchards) and well-supplied, and citrus and bananas are a common crop. They require large volumes of water and are impacted by salinity, making them particularly sensitive during droughts. Increasing localized saline intrusion is exacerbated during droughts due to increased abstraction.

New technologies and practices have been implemented unevenly in Lebanon. For instance, as water treatment capacity increases, there is interest in using treated wastewater for irrigation. Some organizations have issued guidelines, but there are no regulations or guidelines from the central government about its use; still, farmers continue to try and access treated wastewater and even untreated wastewater including through directly tapping pipes.

Case studies of irrigation in the Bekaa – potatoes and apples

In the Bekaa, where potatoes are the most prominent field crop, farmers characterize drought as insufficient rainfall during the September-March period and decreased soil moisture in the arable soil layer. We assessed irrigation practices through a typical example provided wherein an average commercial potato farmer who would usually have 100 dunams of potatoes yearly would reduce cultivated area to only 50 dunams in a dry year to reduce irrigation requirements.

Irrigation operations generally consist of operating 2 sprinklers per dunam (dispersing each 1.5 m3/hr, 16 x 16m spacing). We estimated crop water requirements to average around 500-600 mm. Farmers typically apply at least two times actual evapotranspiration, with average yields of 30 t/ha. This is at least 25% below optimum potential considering the irrigation system and environmental conditions. With irrigation costs around 250 USD[5]/du (25% of the total variable costs), and potatoes sold at 250-400 USD/ton, over-irrigation and related drops in productivity represent a major drain on income.

We also evaluated a model apple orchard's irrigation practices. The irrigation system consists of a drip system with two emitters for 8 liters/hr per tree. Irrigation scheduling consists of durations varying from 2 to 7 hours/day in the irrigation season extending from April to September. Total irrigation water applied over the period is 2,197 mm, while crop water requirements do not exceed 820 mm. With an irrigation system efficiency of 65%, the total application should not exceed 1,100 mm. In this case, evapotranspiration-based irrigation scheduling in the model farm generally leads to irrigating 2 times the actual evapotranspiration.

Due to the lack of knowledge of crop water requirements and the usage of a non-pressurized system, over-irrigation in the model farm is estimated to be 3.2 times the net requirements. For a net grown area of 150 ha over 200 ha, the total volume of over-irrigation could reach 2.3 MCM/yr, or enough to irrigate an additional 250-300 ha.

Overgrazing and desertification

The areas most vulnerable to desertification in Lebanon are the semi-arid northeast and southern Lebanon, and this stems in part from the frequency and intensity of drought conditions coupled with over-grazing and poor soil management practices in those areas (Ministry of the Environment, 2003). Unfortunately, officials know little about drought impacts from 2013-2014 in those areas, especially northeast Lebanon, where pastoralism is dominant, because data collection was curtailed due to security concerns.

However, stakeholders said that livestock exports have increased significantly in the past several years, indicating that increasing numbers of pastoralists have relocated permanently to the region. Traditionally Syrian and Lebanese pastoralists have straddled the anti-Lebanon range as grazing conditions change seasonally. Pastures have suffered major degradation in recent years as overgrazing has increased significantly. Pastoralists often plant barley for animal feed, even on marginal lands or with inadequate watering. During periods of drought, they are increasingly dependent on chopped maize from Syria, as farmers across the border try to obtain better prices than those in Lebanon. When cross-border fodder flows were interrupted or prices rose slightly during droughts (due to the high-water requirements of maize crops), herders and farmers with livestock were pushed to borrow to buy fodder and to cover increased veterinary service needs.

Overall, disruption of this migratory pattern and livestock concentration on the Lebanese side may have severe long-term impacts if over-grazing continues at such intensity and/or coincides with significant drought periods.

Poor access to information and guiding support on drought and water availability

Government agencies do not share data and information well amongst each other. Moreover, government agencies have sporadic engagement with various social groups and in some areas, particularly in remote areas with security

[5] Note this was USD equivalent prior to the financial crash and devaluation of the Lebanese Pound.

issues resulting from the conflict in Syria. In combination, this results in limited public outreach, including extension services, which increases sensitivity to drought impacts.

Civil society and private sector stakeholders are unable to access vital information from public agencies. For instance, irrigators said they cannot obtain information on how much water is available from the relevant agencies and are frequently not given advance notice if irrigation supplies will be cut. One state agency was not informed in advance that its water supply would be cut off entirely. This low level of communication leads to poor outcomes: farmers are highly risk averse in planting choices and profligate when irrigating because they can't know when water will stop being available.

Addressing these issues will require improved extension capacity and information dissemination skills. Extension agents are spread thin and currently rely on agricultural inputs suppliers and key individual farmers to understand conditions on the ground. They hope to provide more direct communication channels which would allow farmers to get information from extension agents and then feed information back to the centre, thus ensuring that information provided is useful and relates to their needs. For instance, farmers want early season drought monitoring information to be provided alongside guidance on crop type and timing of planting; likewise, they want drought monitoring later in the season to link with guidance on irrigation scheduling. Enabling local validation of drought monitoring outputs is a potential avenue to build this engagement.

We note that LARILEB, a smartphone app that provides agriculture-relevant weather and climatology information to over 50,000 users, is a very positive step and a working example of how agencies are attempting to address some of these issues.

4.2 Sensitivity in the water supply sector

The study identified numerous drivers of sensitivity in the water supply sector (Table 4). These challenges pre-date the Syrian war. The massive influx of refugees increased them significantly, and now the interlinked political, financial, and pandemic crises are exacerbating them further.

Table 4. *Water supply sector sensitivity to drought impacts*

Infrastructure	Water resources	Regulatory enforcement	Supply/demand	Management planning
Low storage capacity: 6% of total resources mobilized- lowest in the MENA region	Shifts in hydrological regimes (snow and precipitation seasonality) due to climate change	Surface and groundwater contamination laws unenforced	Inability to store winter/ spring floods for summer peak demands	Poor coordination between governmental organizations and agencies
Degraded supply and distribution networks and high proportion of non-revenue water	Poor water quality (pollution and saline intrusion in coastal areas)	Well licensing and surface water and groundwater pumping laws unenforced	Rising demand, shrinking supply with current storage capacity	Lack of water and drought legislation
Limited wastewater treatment capacity	Limited availability (linked to infrastructure)	Illegal access to networks	Low wastewater treatment and reuse	No or weak basin scale management planning
Delayed progress in programmes to improve water storage, including hill lakes and dams, due to wars	Poor metering and understanding of water production/consumption	Illegal wells	Poor pricing mechanisms and incentives	

Rapidly increasing demand for water has negatively affected the water resources themselves, as well as the infrastructure and institutional capacity to deliver them. The sudden influx of refugees rendered water management plans obsolete; likewise, it strained sanitation systems and social coping mechanisms. Political and financial crises have stalled decision-making and investment planning. This has led to growing tensions between large refugee and host communities. For instance, in Arsal, conflicts have emerged surrounding wastewater mismanagement, as untreated wastewater is often discharged directly to land and water. This has significant soil, water, agricultural, and health impacts.

Aspects of water sector vulnerability to drought are examined in more depth in Section 5.5, where we relate them specifically to coping and adaptation mechanisms as well as identified drought management needs.

4.3 Livelihood and community sensitivity

Rural social conditions

Smallholders rely on family employment, but talented young people increasingly see a bleak future in agriculture and so migrate to cities or emigrate. There are very few vocational training opportunities for youth such as Agricultural Technical Schools because only 1% of the state budget is allocated to the Ministry of Agriculture (MoA).

Medium-sized and large farms rely on external employment (both Lebanese and foreign). In the Baalbeck-Hermel area, more than 100,000 Syrian refugees have arrived, and they now constitute 40% of the total agriculture-sector workforce. Approximately 90% of this Syrian workforce is informally employed. An additional 21,000 Syrians work in the food processing sector.

These refugees are low-skilled, and men are paid an average of $17/day (40% less than their Lebanese counterparts). Women and children are paid $7 and $4/day, respectively. It should be noted that these figures date from before the 2020 financial crisis.

Women and drought sensitivity

On small and medium-sized landholdings, and in times of crisis and natural hazards affecting rural livelihoods, men migrate and leave farming and household chores to women. Women from small farming households often work as pickers on larger farms, at half-pay of male workers, to make ends meet. The case of refugee women is serious because labour brokers tend to disrupt inter-family partition and rotation of work.

Furthermore, the roles that women are assigned – typically manual weeding and picking in fields or packaging in factories – tend to be non-contractual and paid on a daily basis. During drought, there is more use of chemicals such as pesticides, fertilizers, etc, which can be damaging to health. Moreover, within the informal work economy, there is no healthcare or social protection benefits. Apart from this precarious agricultural employment, social barriers limit women's access to better paid jobs, and they tend to be limited to personal care positions.

Whether as laborers or growers (the latter group representing a very low proportion overall), women have far less control than men on productive resources, such as land and markets, and the division of labor. Likewise, they have low representation in cooperatives, associations, and rural decision-making bodies. This is a consequence of social and cultural norms as well as women's limited access to education and past involvement in class-based struggles.

Debt and access to finance

The 2006 war caused considerable damage to rural infrastructure. The 2008 food crisis saw major increases in food and agricultural input prices. Major drought impacts in 2014 and more recent hyper-inflation due to Lebanon's political-financial crisis have caused considerable damage to the productive capacity of small and medium-sized farmers and led to the emergence of a rural debt crisis.

Since 2011, the consequences of droughts and cost of inputs increasing by more than 400% (FAO, 2021) have increased farmers' indebtedness and led to increased poverty in rural communities. Reductions in input usage are already having a tangible impact on food production. These issues interact, amplify each other, and affect the upstream and downstream contributions of the sector along agricultural value chains.

Every farmer who participated in interviews and focus group discussions was heavily indebted. These debts were accumulated for a variety of reasons, but the impact of drought conditions on production was a central concern for all respondents.

This situation is familiar to most, if not all, farmers in the country. Following droughts, farmers have to raise capital to invest in operations or service debts. Depending on where they are situated in the class structure, they may take vastly different approaches.

Large farmers are typically able to access state support including through the Investment Development Authority of Lebanon (ADIL) and Kafalat loan guarantee program as described in Appendix D.

Medium and smallholder farmers have few options to access finance. Commercial banks impose many conditions, restrictions, and requirements for loans. Farmers complain about high interest rates that can exceed 15% as well as having no recourse to reschedule payments during droughts.

None of the farmers interviewed had received any financial assistance from government sources, either in the form of loans or direct assistance. Although the National Union for Cooperative Credit is an important venue for affordable farm credit, stakeholders complained of membership problems and the need to properly account for currency devaluation that affects share prices.

These farmers also used informal private loans from family and friends, or informal moneylenders. The average interest rate quoted by participants for loans from informal moneylenders serving Hermel was about 8%. However, with the current financial crisis affecting the country, and more people falling into poverty and debt, it is not known how much drought-affected communities are likely to have to pay to borrow from private lenders.

Supermarkets and local producers also provided a lifeline when droughts and other crises threatened their livelihoods. Local retailers offered very small amounts of credit - for labneh, lentils, flour, and eggs - that provided vital buffers against the effects of joblessness and insecurity.

Overall, the most important financial relationship medium and small farmers have is with wholesale input suppliers.

Wholesale input suppliers

For inputs such as seed, fertilizer, and pesticides, input suppliers were considered the most accessible and reliable source of short-term borrowing. Unplanned seasonal drought-related expenditures (large irrigation needs) can result in farmers needing credit and financial consolidation with input suppliers and wholesalers (who prefer to be paid in USD). Despite this, many small and medium-sized farm owners use this option. For farmers facing cashflow problems and income delays due to droughts, wholesalers represent a vital (though unregulated) source of capital.

Wholesalers provide informal loans to farmers with the understanding that the loans will be repaid once their produce is harvested and sold to the wholesaler. When the impacts of drought on yield and quality have been significant, wholesalers may reschedule or defer repayment to the next season. This is a common way in which droughts can burden farmers with inter-seasonal debt. In addition, wholesalers influence the pricing of crops to offset any risk from market fluctuations or other defaults. Wholesalers influence farmers' choice of crops that may leave farmers more sensitive to drought in subsequent seasons. Also, wholesalers act as commissioners when providing credit facilities at high interest rates and often push farmers into chronic debt (see also FAO and ILO, 2020).

Farmers perceive their relationships with input suppliers as the greatest source of anxiety in terms of the impacts of drought on their ability to repay loans or credit facilities. As one farmer summarized, "if the debt to suppliers is not paid during the season, the supplier will not sell to us the next season."

Financial risk mechanisms

Farmers are particularly sensitive to drought impacts due to their lack of financial risk mechanisms and reliance on export markets. Smallholder farmers most frequently rely on loans from local agricultural input suppliers. During drought periods, these creditors commonly increase input prices (when demand for inputs is higher) at least partially to offset the increased loan repayment defaults, thus having ripple effects through the whole sector.

In Appendix D, we provide an overview of national and/or sub-national disaster risk finance mechanisms that could be viable for Lebanon as drought coping mechanisms in the future.

Financial integration of women

Nationally, female entrepreneurs participate in only 3% of bank investment credit services and receive an infinitesimal proportion of agricultural investment. As their income does not allow them to meet their family needs, credit alternatives are limited to the 33% of women able to hold accounts (individually or in groups).

These women benefit from short-term support (World Bank, 2018). However, local inheritance laws, sectarian personal status laws, and other customary practices are tangible in the inequitable distribution of household assets and property. The lack of safeguards can prevent the poorest households from accessing the resources needed to mitigate the effects of drought on livelihoods and food security. The only credit facilities interviewees had access to, in addition to informal loans from family and friends, were very limited lines of credit opened with local grocers, usually for no more than one month.

However, there are encouraging signs of improvement. In 2017, around 33% of women ages 15 and older reported having used a mobile money service or having an account at a bank or other financial institution in the past year. This reflects improving access to credit facilities to provide short-term mitigation and ongoing viability of agricultural projects during drought years (World Bank, 2018).

Market access

The closure of overland trade routes with Syria has significantly increased the sensitivity of pastoralists, as already described, as well as farmers. It has affected the competitiveness of Lebanese agricultural exports because of the additional costs of sea-route exports to its traditional export markets.

4.4 Section summary

In this section, we highlighted several factors that increase the drought sensitivity of the agriculture sector. We have discussed the inadequacy of irrigation practices and weak regulatory frameworks around them during emergent drought conditions and with recurrent, prolonged droughts. We have considered land management including peri-urban/village expansion that has led to the loss of arable lands and the buffer effect of stabilizing overall production and income. We have noted financial, market access, and market organization issues related to unpredictable cropping calendars. Finally, we have considered farmers' access to information and guiding support.

Water sector aspects of sensitivity have overlapping themes related to weak regulatory and planning frameworks, as well as enforcement of them. Major sensitivity factors connect to inadequate storage and aging distribution infrastructure to ensure stable quality freshwater supply. Political instability and the refugee influx from Syria have exacerbated these aspects of sensitivity because they have stressed natural resources and associated infrastructure, affected trade and pastoral migration routes, and led to price volatility of core agricultural inputs such as fuel.

Rural communities' primary sensitivity to drought impacts stem from their exceedingly high debt burden, poor access to credit and financial risk mechanisms, and rapidly increasing input costs. As a result, smallholder systems are rapidly losing economic viability, which contributes to the rise of negative coping mechanisms.

5. Vulnerability – Coping and adaptive capacity

In this section, we start with a conceptual overview of drought management typologies and then describe the status quo of drought management in Lebanon. We then discuss identified stakeholder needs for improved drought management as well as prioritised themes to strengthen adaptive capacity.

5.1 Conceptual descriptions of drought management

Drought management ultimately falls to both the public and private sectors. Historical examples illustrate that multi-stakeholder and public-private sector engagements have been critical to help nations shift from predominantly crisis management response frameworks to risk reduction and management frameworks[6].

Drought policy and management broadly fall into three categories: post-impact interventions for emergency relief (coping); pre-impact programs for risk reduction (often adaptation); and development of preparedness plans and policies (related to coping and adaptation; Wilhite *et al.* 2007). Summary examples of actions in these categories, their broad policy intent, and challenges with each are shown in Table 5 below (McDonnell *et al.* 2019).

[6] in reference to Brazil, see Bretan & Engle, 2017; Mexico, see Aguilar-Barajas *et al.*, 2016, Ortega-Gaucin *et al.*, 2018.

Table 5. *Drought policy intervention types (Source McDonnell et al. 2019 after Wilhite et al. 2007)*

Policy type	Examples	Policy intent	Challenges
Post-impact interventions	Water and feed provision for livestock; debt forgiveness for farmers; rural job-creation programs; water rationing and pricing regimes; expansion of groundwater pumping.	Relief measures for those affected by drought; reduce long-term impacts of drought event.	Implementation without reducing incentives for risk reduction measures; timeliness of interventions.
Pre-impact programs for mitigation	Drought early warning systems; surface water storage; irrigation efficiency; water demand management; water pricing regimes.	Reduce underlying vulnerability to avoid or reduce impacts.	Can lead to path-dependency on unsustainable resource use (eg., groundwater over-abstraction).
Development of preparedness plans and policies	Organizational frameworks; institutional arrangements; operational plans and triggering technical definitions.	Facilitate and expedite coordination, collaboration, and action.	Requires strong institutional capacity and coordination to implement effectively.

5.2 Status quo of governmental drought management and coping mechanisms

Overview

Lebanon has no national policies or plans specific to drought, this includes: definitions, legal mechanisms for declaration, management plans, coordination mechanisms, or coordinated inter-agency drought response activities. In legal and technical senses, officials cannot identify or declare the onset of drought conditions.

Therefore, people, businesses, and institutions including government agencies intervene according to their individual work programs, mandates and through their own frameworks. There is not a guiding national strategy for drought management, and efforts are not coordinated.

Drought is managed on a case-by-case basis using a post-impact and *ad hoc* crisis response. For instance, in response to the 2014 drought, the Public Works Parliamentary Committee developed short-term and long-term mitigation options. Short-term options included calling for a national state-of-emergency to address the crisis; importing water from nearby countries (e.g., Turkey); drafting regulations for restricting water use and/or guidelines to reduce water consumption; reducing irrigation; enforcing water laws on illegal abstraction from wells; water trucking; and fines for specific high water-use activities such as car washing. Mid- to long-term mitigation options included, among other themes, the building of dams to increase surface water storage. However, government and civil society stakeholders reported that by the end of the hydrological year in August, almost none of the proposed mitigation measures had been applied.

Governmental coping mechanisms for the agriculture sector

Despite the lack of formal drought declaration mechanisms, government agencies have a few tools available to mitigate drought impacts on agriculture. The most direct is a cash pay-out from the Higher Relief Fund, which is administered by the army and run by an inter-ministerial committee to provide relief following natural disasters.

However, this Fund was set up after the 2006 war with Israel and was structured to deal with war damage primarily, and so it is seen as an inflexible mechanism to deal with flood, drought and forest fire impacts. Soldiers are the primary assessors and as a result, there are major survey gaps because they are not trained to understand drought impacts on crops, and only a limited number of MoA and MoEW officials can accompany them. Pay-outs have, in some cases, taken more than a year.

The state can influence the rescheduling of private credit through Kefalat, a privately owned firm that issues and guarantees agricultural loans. When local banks (which are often the applicant to Kefalat on behalf of the ultimate client) request rescheduling of credit, Kefalat can request the central bank to permit rescheduling or extension of additional credit as needed. This was done on a large scale following major war and fire damage in 2006 and as of 2016 on a smaller scale due to the closure of the border with Syria and subsequent drop in agricultural exports.

Other than these mechanisms, central government activities promote reduction in exposure and sensitivity. The Green Plan's subsidies and technical assistance for small-scale water storage creation, MoA's subsidies for drip irrigation systems and livestock vaccination programs, and LARI's subsidy for soil analyses all fall within this category. Likewise, the reforestation campaign run by MoA has drought risk reduction and overall water management as a core feature. Livestock management interventions are focused on avoidance of rangeland and forest degradation rather

than fodder subsidies or provision, and so they aim to reduce sensitivity to impacts rather than simply ameliorating impacts once the occur.

5.3 Agricultural coping and adaptation mechanisms

Due to constraints on central government agencies, and because of collective local identities, patronage networks, practices and water governance regimes, farmers' primary responses to drought are highly dependent on their geographical context. Also, responses can be driven by local government because municipal authorities, in some cases, can exercise a great deal of control over water resources during times of drought.

National coping and adaptation mechanisms

Farmers in the plains and coastal areas, the Bekaa, and Akkar all expand groundwater utilization and seek to improve irrigation efficiency, while those in mountainous areas engage in a range of activities that focus on building resilience. For example, during and after the 2014 drought, orchard farmers tried to adopt rainwater retention and harvesting techniques like those used in more arid climates such as bunding or applying soil polymers to help retain moisture.

Farmers seek the ability to form water user associations to improve resource governance. They are currently inadequately provided for in law and only a small number exist formally, primarily in southern Lebanon. Where they exist, they have helped farmers adapt efficient irrigation operations and have promoted strong water usage monitoring mechanisms.

Local variations

As described above, communities' capacity to cope with impacts varies significantly by municipality. For example, during the 2014 drought, local authorities in Qab Elias, the third largest municipality in the Bekaa, limited orchard irrigation to young trees and for keeping trees alive but not for production. The number of irrigations for other fruit and vegetable crops was limited to once per season (Municipality of Qab Elias – Wadi Dalm, 2014). Stakeholders described these interventions as effectively and equitably implemented, though they noted that local respect for the head of the municipality and tight-knit social structure were critical to their implementation, as was municipality's legal control of the main water sources. These factors do not exist to the same extent in all areas and thus drought interventions by municipalities, if they are made at all, are coordinated and implemented almost entirely at the local level to widely varying effect.

Smallholder coping mechanisms

Interviewees stated that when coping with drought, smallholders typically undertake a series of coping measures.

First, they increase use - to the point of over-exploitation - of natural resources (groundwater and springs) for irrigation. They then undertake a series of measures to preserve productivity and cut costs. These can include:

- increasing use of manure to conserve water;
- illegal well drilling;
- illegal connection to the water network;
- minimising costs by illegally employing the poorest workers (refugees);
- reducing use of inputs; and
- abandonment of particular crops (e.g. melon).

Next, they reduce farming investments, and take measures to reduce risk of future losses. This series of actions reduces short-term expenditure and risk exposure. However, it often significantly hampers farmers' ability to recover following the drought event. This reduces long-term profits and leads to chronic impoverishment.

A typical example of this type is the change in cropping patterns due to drought. For example, in Zahle, a typical farmer would have two-thirds of his farm planted with potatoes most years. When the 2014 drought began, farmers replaced the plantings with okra, which requires less water, but it is more labour-intensive and brings in much lower prices. Replacements may also consist of planting perennial tree crops, which could be considered an adaptation mechanism (MoA; FAO).

Interviewees stated, and the literature cited in Section 3.3 and 4.3 above permits information triangulation on these themes, that farmers do not stop at this replacement logic if the coping measures described above are inadequate. The next measures increasingly undermine long-term earning potential, result in the abandonment of farming, or involve illicit trade or what is considered to be social regression. These measures include the renting (or sale) of farming land to large landowners, potentially leading to migration to cities.

The speed of the cascade depends on the initial capital and the coping and adaptability of agricultural practices. When dealing with markets, smallholders are at a significant disadvantage compared to large-scale wine, fruit, and vegetable farms for industry and export.

Food insecurity

The lack of post-independence efforts for rural development has resulted in local food production satisfying only 20% of the domestic demand (UNWFP, 2016). Drought events reduce the access and utilization components of food security, especially among the 20% of rural subsistence households and other smallholders.

Nearly half of the interviewees in the case study area reported experiencing shortages in key food items during periods of financial hardship and therefore worry about the overwhelming effect of drought conditions. The consumption of micronutrient-rich foods was particularly affected.

Interviewees stated that while farmers typically consume meat at least once or twice a week under normal conditions, drought pressure on household expenditures has caused more than two-thirds of farmers to reduce their meat consumption to once or twice a month (see also Government of Lebanon and the United Nations, 2018). In this context, their households replace meat with additional legumes (mainly lentils, chickpeas, and beans). Farmworkers reported using consumption-based coping strategies, such as skipping meals, reducing portion sizes, and sleeping on an empty stomach. Yet, these farmworkers (mainly Syrian refugees) also reported that such disruptions in their household food consumption were regular experiences during their nearly 10 years in the country and that they had also experienced them during other hardships, not only during drought.

Food insecurity is compounded by factors of (geo)political instability, financial crises, and most recently the coronavirus pandemic. The massive influx of Syrian refugees has created a substantial increase in demand for food, including affordable protein sources such as eggs. This has caused the food security situation throughout Lebanon to further deteriorate. Food insecure households have lower per capita expenditures, are more indebted, and spend the majority of their expenses on food, as opposed to medical services or education.

Inadequate food consumption is alarming, combined with high adoption of coping strategies, especially by households in the most fragile areas such as in Akkar, Baalbek-Hermel, and the North. Lebanese women are more vulnerable in terms of food consumption compared to men: national surveys indicate women are more likely to consume insufficient amounts of food, and the prevalence of anaemia in pregnant women has steadily increased from 29.3% in 2001, to 35.2% in 2016 (UNHCR *et al.* 2018)

Compared to their male counterparts, female-headed households are more likely to experience inadequate food consumption in addition to lower dietary diversity.

5.4 Water supply sector coping mechanisms – synthesis example

We developed an integrative example of how drought's social, economic, and environmental impacts, underlying sources of vulnerability, and management responses interact in relation to water sector supply. We tested and refined the conceptual model with workshop stakeholders. The generalized example shown in Figure 4 relates to Water Establishments and municipal water supply.

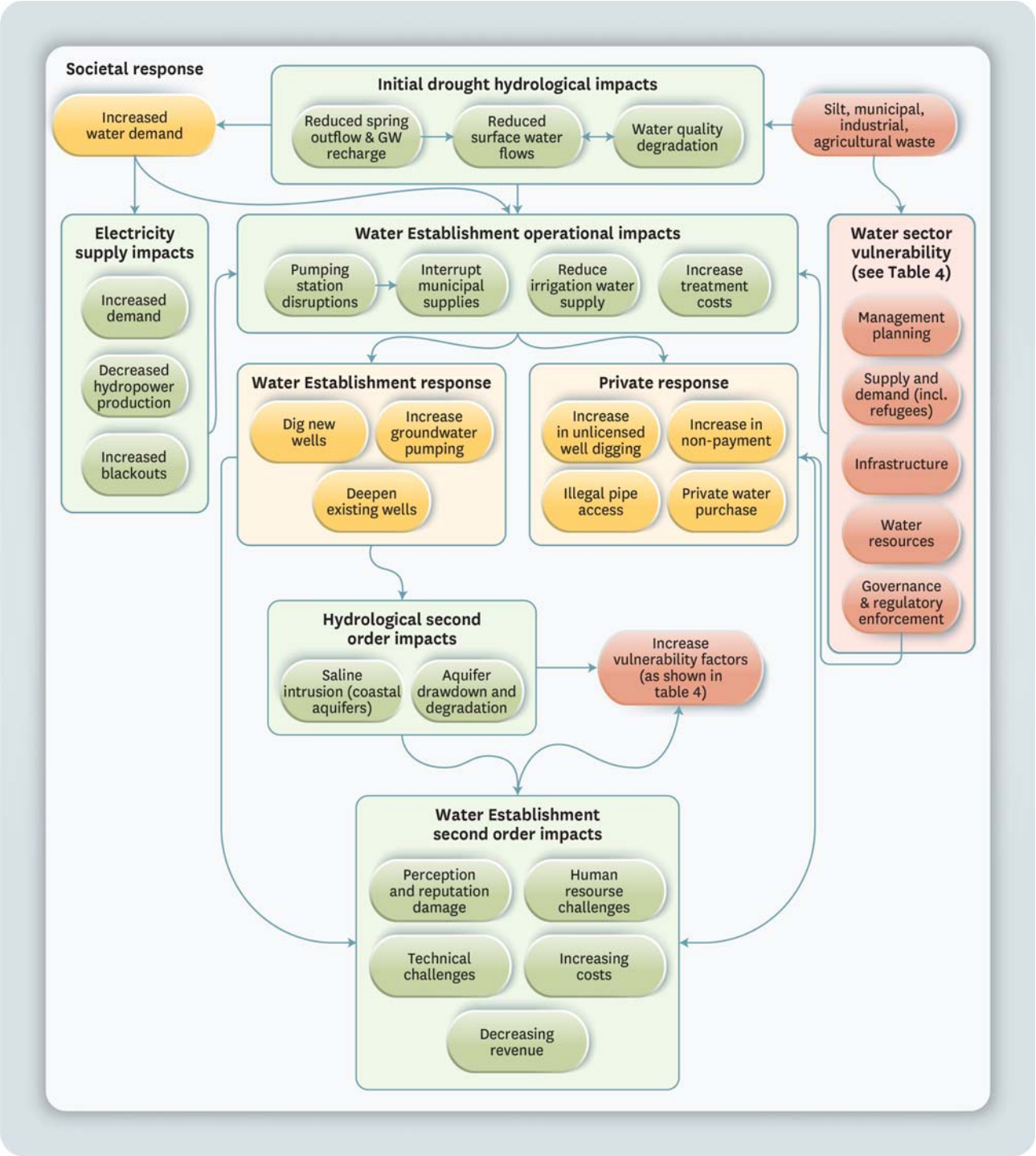

Figure 4. *Case study of drought impact, vulnerability, and management response interactions. Green indicates impacts; yellow indicates coping mechanisms; pink indicates aspects of vulnerability.*

Initial drought impacts on hydrological systems result in reduced water quality and water availability. Societal responses to this scarcity – and other factors such as increased temperature and irrigation requirements that accompany drought – lead to increased demand for water and electricity.

These changes in basic water supply and quality affect water establishments' ability to meet societal demand, particularly due to the factors of vulnerability described in Table 4. For example, high leakage rates and reduced streamflow and reservoir levels result in more frequent and longer municipal supply disruptions. To attempt to meet societal demand, water establishments primarily rely on increased groundwater abstraction; individuals and businesses increasingly turn to private water supply including digging new wells, and there are increased instances of illegal pipe access as well as non-payment for water services.

These responses lead to aquifer degradation via drawdown and, in coastal areas, saline intrusion. They also lead to a range of impacts on water establishments, such as accelerating infrastructure decline and increasing costs of maintaining current levels of supply. These present a range of institutional challenges, and given that water establishments struggled to meet demand even before the substantial influx of refugees to Lebanon, they represent a major set of problems that further increase vulnerability.

5.5 Building adaptive capacity

Building on these findings, we surveyed government stakeholders about priority focus areas for improving coping and adaptive capacity mechanisms in the water and agriculture sectors as well as for wider social stability objectives. Full results are shown in Tables E1-E3 in Appendix E.

Overall, officials focused less on adaptive capacity components than coping mechanisms. However, strengthening human capital, conserving natural capital, and increasing the resilience of built infrastructure to climate extremes were among the highest priority adaptive capacity elements.

In terms of water sector measures, stakeholders emphasized the importance of developing concrete plans to reduce water demand and increase water use efficiency, improve water establishments' capacity for groundwater management including monitoring and control of abstraction, developing watershed management plans, and addressing pollution through wastewater treatment.

Focus areas to address agricultural drought risks highlighted the priority of shifting to more efficient irrigation systems and methods and adopting sustainable agriculture practices such as agricultural water conservation technologies and practices. Focus areas for wider socio-economic sectors included the development of early warning systems and also improved sanitation infrastructure. These themes very closely reflect the findings related to exposure and sensitivity reported in Sections 3 and 4.

At the basin scale, stakeholders prioritised different sets of actions as shown in Table 6 below. In the El Kelb basin (the coastal side of Mount Lebanon), there is more emphasis on water management practices, whereas needs are more diverse in the Litani and include a mix of water conservation and agricultural management themes.

Table 6. *High priorities for drought mitigation and risk management options as recommended by stakeholders for the el Kelb and the Litani river basins.*

El Kelb Basin	Litani Basin
reducing water demand	protecting and managing groundwater
developing watershed management plans	conservation agriculture and integrated pest management techniques
protecting and managing groundwater	reducing water demand and developing watershed management plans
reclaiming wastewater	shift to less water consuming crops and shift to more efficient irrigation systems and practices (techniques)

5.6 Section summary

We provide a conceptual typology of drought management mechanisms including post-impact interventions, pre-impact programs for mitigation, and development of policies and preparedness plans. These, in sequence, range from coping to adaptation mechanisms. At present, central government coping mechanisms are limited to relatively small-scale financial interventions; weak policy and planning frameworks increase sensitivity and preclude effective coping and adaptation.

Farmers and some local authorities undertake a range of coping measures and some have relatively effective coping and adaptive capacity. In the water sector, coping mechanisms are limited and hampered by poor infrastructure, regulatory, and monitoring systems.

Smallholders undertake a series of coping measures to try and retain profitability in drought years: increasing exploitation of natural resources and cutting costs while taking action to retain productivity. When this is inadequate,

they use negative coping mechanisms that reduce long-term profitability, contribute to food insecurity, or entail social regression.

Water sector coping mechanisms – primarily the expansion of groundwater pumping – are made less effective because of other drought impacts like water quality degradation that increase the cost of that response; likewise, private sector responses to drought, such as illegal tapping of pipelines, increase the challenges for water establishments during times of drought and afterwards as they exacerbate long-term challenges.

Regionally, there is strong variation in needs to improve coping and adaptation, largely driven in drought exposure differences. Officials described several overlapping coping and adaptive capacity improvements needed in the El Kelb and Litani basins: groundwater management, planning, infrastructure improvement, and demand management.

6. Informing drought risk management

Here we describe drought management needs which stakeholders have articulated. We explicitly link these to identified aspects of vulnerability. We then provide a brief description of ongoing drought policy planning and how that relates to identified management needs and vulnerability. Lastly, we reflect on findings to date and additional research for development that would help inform and embed drought risk management approaches in Lebanon.

6.1 Drought management planning – stakeholder-identified and government-prioritized needs

Jedd *et al.* (2020) report stakeholder needs to improve drought management that relate to policy-settings, financial systems, institutional coordination, drought management plans and institutional capacity to deliver them, extension services and crop planning, and water management regimes. These are core components of integrated water resource management (IWRM) systems. They also cover underpinning science and information, governance, and policy implementation support. Additional detail is provided in Appendix F.

We used subsequent engagements with government stakeholders to confirm these findings and provide more specificity to guide their own work plans. Government stakeholders narrowed the focus to specific (though still wide-ranging) aspects of policy development, policy implementation support and governance, underpinning information, and infrastructure investment. In Section 6.3 we map these to aspects of vulnerability to highlight focus themes and gaps. For this purpose, we "coded" these response for use in the synthesis tables shown in Section 6.3.

Policy development (P):

1. Decrees for official constitution of a drought monitoring unit and a drought technical committee, and application decrees for collaborating entities such as water user associations, and river basin authorities;
2. There is a need for region-specific laws to empower officers auditing water use (supporting Law 444);
3. Introduction of the "polluter pays" principle to protect surface water, address pollution of Lake Karaoun, and protect catchment source areas;
4. Create protection zones around delineated water resources, especially springs (this relates to water rights);
5. Development of law on data sharing is crucial to empower inter-agency cooperation – activating the national centre for water information and capacity building (CIFME in its French acronym) is related to this.

Policy implementation support and governance (IS):

1. Enforcement of the Water Code 77/2018 (tariffs, and metering) and Law 221 on performance evaluation;
2. Design and enforce application decrees to support these laws including water quality monitoring, and application of regulation to apply law evenly and equitably;
3. Measures to control the increase of illegal wells and intensity of their usage;
4. Development of water conservation practices based on region-specific crop water requirement data, and subsidized state-of-the-art water-saving technologies applicable at the farm level, and incentives for uptake of good practice, such as lowering taxation.

Underpinning information (U):

1. Measures to identify illegal wells and establish an automated remote measurement of wells (ICT technology) in an effective database management system;
2. Information on aquifers' safe yield and recharge rates;
3. Strengthening the evidence base for water accounting to support water allocation decision-making including the development of a water auditing platform and improved seasonal forecasting;
4. Need for cultural change through education and awareness-raising; a key need for primary schools and professional journalists as well as behaviour change programs for the wider population.

Infrastructure investment (II):

1. Maintain and improve water infrastructure, starting with leakage issues and including expansion of storage and wastewater treatment infrastructure;
2. Focus surface water storage programs on large dams as well as check-dams to support groundwater recharge and hold back peak flows;
3. Embed quality treated wastewater in water management, particularly for agriculture and industry so fresh water can be prioritised for municipal use;

Overall, the results described here provide a relatively comprehensive starting point for stakeholders, especially government, to prioritise actions to support drought risk management planning. Rather than being overwhelming in its breadth, this information is helpful because it aids identification and prioritization of policy interventions at various "levels" of governance (and in various locations) to address specific problems.

However, we find several gaps in these government-prioritized needs compared to wider stakeholder-prioritized needs. In particular, they are weighted towards specific natural resource management issues rather than wider socio-environmental systems of concern. For instance, there are no prioritized needs that relate to agricultural sector access to finance or support for market access, both of which repeatedly came up as key needs in discussions with non-governmental stakeholders. Also, there is less emphasis on coordination and collaboration, which stakeholders (including government officials themselves) described as a key barrier to success.

6.2 Ongoing drought management planning

In 2017, the MoEW established, and has since coordinated, a Drought Technical Committee (DTC). The DTC is a multi-disciplinary and multi-institutional body including 14 engineers, representatives from MoEW, MoA, MoE, LARI,

the Meteorological Department of the Civil Aviation Authority, LRA, the Mount Lebanon, and Southern Water Establishments (water supply and sewerage utilities).

The DTC is tasked with undertaking drought monitoring and early warning and other relevant system outputs to enable effective drought response and coordination. It recently began producing the enhanced CDI (eCDI) monthly and intends to share eCDI outputs and related data with key high-level managers of public authorities that will be part of the National Drought Management Committee (NDMC) to be created in the future. Stakeholders' meetings could involve AUB, CNRS and the NGOs ACTED and STAMMOSE.

For instance, the drought early warning system will contribute to strengthening the information system of the national centre for water information and capacity building (CIFME in its French acronym), which the MoEW hosts. CIFME aims to build a national water information system that will collate and provide access to water-related information and be the main water management professional training centre for Lebanon. The CDI outputs will fill data gaps in this National Water Information System.

Currently, an IWMI project team is working with the DTC and the General Directorate of Hydraulic and Electric Resources (GDHER) at the MoEW to develop a proactive drought action plan. This will support Lebanese policymakers to implement the Water Code of Lebanon, Law No. 77 of April 13, 2018 (Water Code 77/2018), and the National Water Strategy (see Appendix F for a summary overview of the Water Code and National Water Strategy and Gharios *et al.* (2019) for a description of their implementation and coordination).

Improved drought planning therefore supports Lebanon's wider governance improvements. In addition, it will support Lebanon's delivery of international commitments such as to the United Nations Framework Convention on Climate Change (UNFCC), United Nations Convention on Combating Desertification (UNCCD), and the Sustainable Development Goals (SDGs) related to water (Goal 6) and climate change (Goal 13).

The implementation phase of the MENAdrought project is still underway. We are working with the GDHER to outline key components and activities. In the first instance, this will include a preliminary operational framework of roles and responsibilities for the different institutional stakeholders engaged in the implementation of the plan as well as wider "machinery of government" themes such as funding and resourcing arrangements.

6.3 Synthesis – Vulnerability to policy planning

We match the identified management needs shown in Section 6.2 with primary aspects of exposure and sensitivity as articulated in Sections 4.1 and 4.2. Further, we show how MENAdrought activities relate to the specific vulnerability aspects. We do this for the agriculture sector in Table 7 and the water supply sector in Table 8.

In other words, we state that addressing specific management needs would contribute to reducing specific components of vulnerability. This analysis feeds into our future research for development opportunities in Section 6.4, both in terms of what management needs are relevant across various aspects of vulnerability and also specific aspects of vulnerability that do not have government-prioritized management responses.

Table 7. *Comparison of identified aspects of vulnerability in the agriculture sector, governmental priorities, and MENAdrought activities to date.*

Aspect of agriculture sector vulnerability	Related government- prioritise management needs (as shown in Section 6.1)	How MENAdrought activities relate to vulnerability / management needs
Water availability and quality challenges	P1; P2; P3; P4; IS 1; IS2; IS3; U1; U2; U3; I2; I3	Related but not core component (supports understanding and targeting of support)
irrigation practices	P2; P3; IS3; IS4; U1	Informs targeting of support
weak regulation (and non-enforcement of it)	P1; P2; P3; P4; IS1; IS2; IS3; U1	Identified needs / gaps
Soil degradation due to land management and urban development	P4; IS4.	Will inform targeting of support
Poor access to credit and financial risk mechanisms	None	Identified needs / gaps
Political instability and flow-on effects on markets and refugees	None	Identified needs / gaps
Poor access to information and guidance support	P5; IS4; U2; U3	Key component

From Table 7 above, it is apparent that governmental priorities relate predominantly to the policy development and regulatory enforcement thematic areas, particularly in relation to water management.

There are markedly fewer priorities that relate to policy implementation support and underpinning information. Labour, financial, and market access components of vulnerability to drought impacts do not feature in governmental priorities. These are highly relevant findings because the participatory research with stakeholders, and especially smallholder farmers and herders, shows that these aspects of vulnerability are among the most important.

These are significant gaps in the stated priorities because in their absence, the impact and effectiveness of policies and enforcement on the ground is likely to be compromised.

Table 8. *Comparison of identified aspects of vulnerability in the water sector, governmental priorities, and MENAdrought activities to date*

Aspect of water sector vulnerability	Identified management needs	Response connected with MENAdrought
Infrastructure	P5; IS1; IS3; U1; U2; U3; II1; II2; II3	Tangentially related – drought history and hazard mapping
Water resources	P1; P2; P3; P4; P5; IS1; IS2; IS3; U1; U2; U3; II3	Related but not core component (supports understanding and targeting of support)
Regulatory enforcement	P2; IS1; IS2; IS3; U1; U4	Will inform targeting of support
Supply / demand	P2; P5; IS1; IS3; U1; U2; U3; U4; II1; II3	Will inform targeting of support
Management planning	P1; P2; P3. P4. P5; IS1; IS2; U2; U3;	Related but not core component (supports necessary collaboration and coordination; provides underpinning information)

Governmental priorities clearly cover the range of vulnerability challenges to the water sector. This is in stark contrast to the agriculture sector where water management components are well covered, but core components outside of natural resource management are not.

The evidence from Lebanon is clear that drought impacts on farmers are determined by SES interactions, but the prioritised responses are currently focusing almost exclusively on the natural resource components only.

6.4 Future research for development

Here we suggest, based on the information produced above and knowledge we have gained though the MENAdrought project, several potential future research for development opportunities. These relate to both some of the most cross-cutting management needs (ie., those that relate to numerous aspects of vulnerability) as well as those aspects of vulnerability not currently prioritized by government agencies. Table 9 below provides a summary description, how it relates to vulnerability and prioritized management needs, the methods that could be used, the type of output that could be produced, and the potential scale of the undertaking.

6.5 Section summary

Early work in the MENAdrought program identified stakeholder needs to improve drought risk management that relate to a range of themes. These include policy-settings, financial systems, institutional coordination, drought management plans and institutional capacity to deliver them, extension services and crop planning, water management regimes, and underpinning science and information, governance, and policy implementation support.

Government officials subsequently prioritized several discrete components related to policy development, policy implementation support and governance, underpinning information, and infrastructure investment. We identified and mapped aspects of vulnerability for the agriculture and water sector against these government-prioritized management needs as well as MENAdrought activities to date.

This highlighted that several government-prioritized management needs relate to numerous aspects of vulnerability, as do MENAdrought activities. They also highlighted gaps between aspects of vulnerability and government priorities: for

the water supply sector, these align very well with stakeholder-identified needs, though for the agriculture sector they were weighted far more towards explicitly natural resource issues rather than wider socio-environmental systems.

Finally, considering these cross-cutting interventions, and government priority gaps in relation to vulnerability, we identify future research for development opportunities connected to drought impacts and vulnerabilities, drought monitoring, water management science, information products and systems, policy and governance mechanisms, financial risk mechanisms, and irrigation improvement. These are shown, in no particular order, in Table 9 below.

Table 9. *Applied research opportunities to support development efforts. Groupings shown in the "summary description column" are as follows: * = support for farmers; # = public-private collaboration; ! = policy and governance; ^ = underpinning information and technical tools*

Summary description	Aspects of vulnerability (per headings in Tables 7 and 8 in Section 6.3)	Stakeholder-identified management needs (Per list in Appendix E)	Methods to use	Output	Scale
Support adoption of efficient irrigation and water conservation technologies and practices[7] through a Market System Development (MSD) approach that considers institutional supporting functions for practice change and incentives. * + #	Irrigation practices; soil degradation;	Enhance outreach and education; use efficient irrigation;	Facilitate market foundation: market assessment, linking lead dealers with pioneer farmers through business-oriented pitches of collaboration and accelerate win-win arrangement based on data/ knowledge-driven processes; Market chain support analysis for staple food commodities; Support uptake through professional and private-sector oriented extension services.	Technology and practice technical and non-technical guidance packages; Development of social networking and uptake mechanisms including supporting private sector embedded extension services via input and hardware suppliers.	Ideal to start with lead dealers and pioneer farming communities or agribusinesses, specific crop(s) and/or farm typology(ies) and upscale if successful.
Establishment of drought monitoring regional validators/feedback network and related development of technical (for extension services and water authorities) and non-technical (for users associations and farming communities) crop guidance materials and distribution mechanisms. * + # + ^	Water availability and quality challenges; Water sector supply / demand; water sector management planning; Poor access to information and guidance support	Enact a national water management policy and connect it with drought; Enhance outreach and education; Formalize ministerial and interagency cooperation; Connect with disaster programs	Linking local officials and stakeholders to drought monitoring unit; Training in the application of validation methods and development of guidance; Application of validation and concurrent dissemination of guidance.	Improvements to eCDI (and potentially seasonal forecasting) over time; Improved collaboration between agencies, local representatives, and stakeholders.	Could be national or targeted to the specific region and/or farming communities.
Undertake spatial vulnerability mapping focused on the water supply sector and/or specific agricultural sub-sectors (e.g. annual and perennial crops such as fruit orchards).[8] ^	Poor access to credit and financial risk mechanisms; Political instability and flow-on effects; Poor access to information and guidance support	Enhance outreach and education; Insurance and financial reform; Address underlying social vulnerabilities; Connect with disaster programs.	Co-develop methods and application software, and train local staff in their use; Undertake data collation and primary data collection given that quantitative measures of sensitivity and coping or adaptive capacity would not be available nationally	Spatial vulnerability maps targeted to specific sub-sectors or communities. To inform government intervention programs.	Could be national or targeted to specific regions, sub-sectors, and/ or communities.
Establishment of a drought impact conditions information system. This would include primary data collection and collation to enable drought economic impact evaluation. ! + ^	Poor access to credit and financial risk mechanisms	Enact a national water management policy; Insurance and financial reform;	One or more of: 1. survey methods during and shortly after a drought 2. substantive statistical data collation from relevant agencies; 3. crop modelling to estimate agricultural productivity losses due to drought.[9]	Monetised and quantified drought impacts to support drought management planning, particularly in identifying Establishment of a drought impact conditions information system gathering the scale of the problems	Likely regional and specific to certain sub-sectors.

[7] For example, USAID Jordan Water Innovation Technologies Project: 2017-2022.
[8] This would require methods development and likely primary data collection, as opposed to collation from existing records, given that we anticipate quantitative measures of sensitivity and coping or adaptive capacity would not be available nationally.
[9] This could build off methods developed by MOE, 2015

Summary description	Aspects of vulnerability (per headings in Tables 7 and 8 in Section 6.3)	Stakeholder-identified management needs (Per list in Appendix E)	Methods to use	Output	Scale
Support development of drought action plan and water management frameworks including for water user associations. !	Water availability and quality challenges; weak regulation (and non-enforcement of it); Water resources; Regulatory enforcement; Supply / demand; Management planning;	Enact a national water management policy; Address underlying social vulnerabilities; Formalize ministerial and interagency cooperation; Connect with disaster programs.	Support drought action plan and/or policy development processes by providing technical inputs and/or support for participatory processes or other coordination and collaboration.	Comprehensive draft drought action plan, water management plans, policies, governance mechanisms, and/or strategies.	Theme-specific, and potentially also region-specific.
Support development of central government water-auditing platform including relevant information-sharing and operational governance mechanisms. ! + ^	Supply / demand; Management planning; Water availability and quality challenges; Water resources	Understand groundwater recharge; Formalize ministerial and interagency cooperation.	Technical expertise to identify indicators of relevance; Integration of seasonal forecasting, drought, and hydrological models, and support development of IT infrastructure; Develop governance mechanisms to ensure data provision and accessibility, as well support development of guidance for use of the data and information.	IT systems with appropriate data retrieval and archival workflows; Operational governance agreements; Guidance documents for use and application of data.	Specific to the scope of the information-sharing platform.
Support targeted hydrological monitoring (including in relation to snow, groundwater recharge, small-scale storage, and surface water) to improve integrated hydrological modelling capabilities, water accounting, CDI components and staple crops yield forecasting, and. rangelands monitoring (strongly related to item above). ^	Supply / demand; Management planning; Water availability and quality challenges; Water resources	Understand groundwater recharge; Formalize ministerial and interagency cooperation.	For example, development of stratified sample and monitoring protocols for hydrological purposes; potential to test application high-resolution (spatial and temporal) satellite imagery and modelling approaches for this purpose; Integration of outputs into applicable hydrological model(s).	Improved hydrological models to underpin water accounting.	Likely basin-specific (e.g. Orontes or Litani).
Support development of financial risk management mechanisms. * + # + ^	Poor access to credit and financial risk mechanisms; Political instability and flow-on effects on markets and refugees.	Insurance and financial reform; Address underlying social vulnerabilities; Connect with disaster programs.	Detailed analysis of potential financial risk mechanisms and threshold development process to pitch a business case to Lebanese government, private sector, and/or international institution stakeholders; If successful, progress pilot development of financial product and related monitoring/modelling system to underpin its implementation in consultation with government and local private sector firms.	Business case; If successful, develop pilot financial product and underpinning monitoring / modelling system	Likely regional (e.g. Bekaa) or sub-sector specific, dependent on initial scoping exercise and business case.
Unlock more effective institutional capacity through analysis of drought management's position within the strategic objectives and institutional processes of key ministries, agencies and other stakeholders. ! + #	Management planning; Poor access to information and guidance support.	Enact a national water management policy and connect it with drought; Formalize ministerial and interagency cooperation; Connect with disaster programs.	Participatory engagement with key ministries, agencies, and related stakeholders to understand institutional dynamics and core drivers for, and barriers to, implementation of drought management plans; institutional analysis related to resourcing and governance processes.	Assessment of barriers to, and enablers of, implementing drought risk management; analysis of available capability and capacity (funding, personnel, expertise) and mechanisms for collaboration.	At least central government; ideally inclusive of local government representatives and non-governmental entities

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Appendix A – Detailed content from Section 1: Introduction

National and stakeholder data inventory includes:

- **Precipitation and temperature** observed precipitation from ground stations (Source: GDCA - Meteorological Services, LARI). *In-situ* monthly data (per station, are not readily accessible and lacks long time records for most of the stations). See also Fragaszy *et al.* 2020.
- **Streamflow and spring discharge** (Source: LRA), *in-situ* monthly data (per gauging stations, lacks long time records and are highly influenced by human activities. With the lack of naturalized flow records, this dataset has limited capacity in capturing drought conditions).
- **Cold waves and heatwaves**, Similarly, to precipitation, most of the data on cold waves and heatwaves is not readily accessible.
- **Agricultural areas and crop production**: yearly agricultural census from the Ministry of Agriculture (MoA), including agricultural production, irrigated areas etc. are available between early 2000 and 2007 and at national scale.
- **Socio-economic data** and census limited to one- or two-years' census. Fragmented and of little use for assessing drought impacts.
- **Snow**: Observed snow depth, snowfall[10] between 2013 - present.
- **Groundwater**: Observations from water wells at a pilot area and observations from spring discharge in mountain regions (Karst groundwater) are fragmented
- **Water**: Water supply from water establishment (MOEW) not available for pilot areas study. This lack of data availability limits the assessment of drought impact on the water sector.
- **Forest Fires**: Forest fires census from the MOE, the Directorate General of Civil Defence, and the National Council for Scientific Research (CNRS) are available for a limited number of years.

[10] Three data sources from Amazon Web Services (AWS): see https://registry.opendata.aws

Appendix B – Detailed content and figures from Section 2: drought history, hazard, and impact

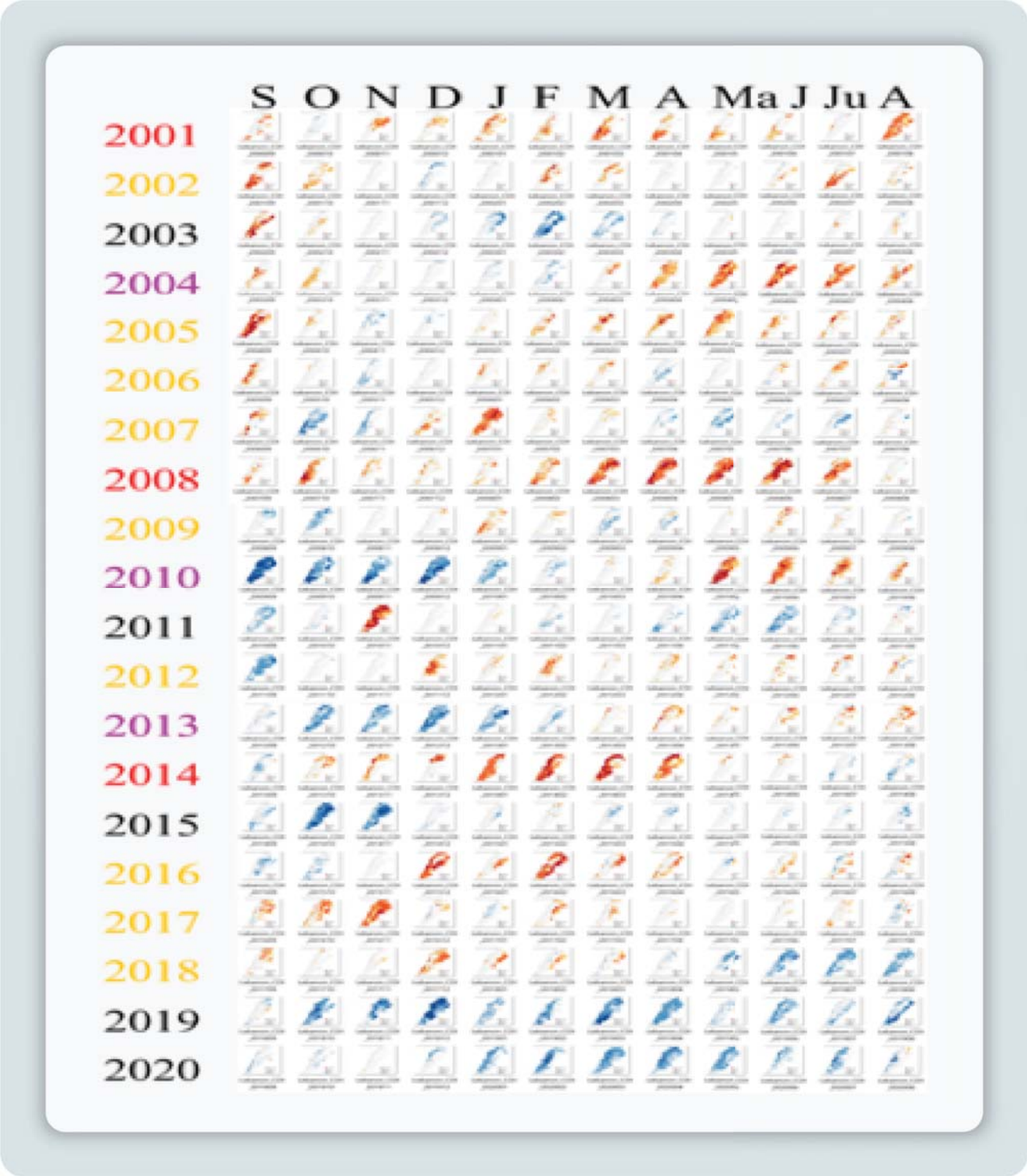

Figure B1. *Full results of the eCDI in Lebanon 2001-2020*

At present, Lebanon has no official legal or policy-relevant definition of drought, though agencies are in the process of developing these through the MENAdrought project. Relevant observed climatological and hydrological datasets (see Table 4 of Fragaszy *et al.* 2020) have short and interrupted records and are not spatially representative. Thus, comparison of results amongst studies is challenging because of definitional issues and overall data paucity (see Appendix A for more detail on available data).

Most assessments of drought history in Lebanon have used highly limited precipitation datasets or vegetation indicators derived from remote sensing datasets that are not specifically calibrated for Lebanon. For example, only the rain gauge in Beirut has uninterrupted records from before the 1930s, and using these data, the FAO *et al.* (2018) reported that 9 drought events (defined as precipitation falling under 60% of the long-term average) occurred between 1930 and 2005. Likewise, Faour *et al.*, 2015 assessed agricultural drought in Lebanon from 1982 to 2014 using the temperature condition index (TCI), the vegetation condition index, and the vegetation health index (VHI). Unfortunately, they only reported results for 2002 and 2014. They reported that drought in 2014 had little extreme (<10) extent and was severe (<20) to moderate (<30) in northern areas, while Tyr and the Bekaa experienced mild drought (<40). LARI officials stated that observed precipitation data from Bekaa (near Zahle) showed precipitation drops of over 55% compared to normal. The CDI showed more severe drought conditions compared to those results.

Prior to development of the CDI through this MENAdrought program, the FAO's GIEWS was the only regularly produced drought monitoring product we identified that covers Lebanon, though it is not specifically produced for Lebanon[11]. The CDI and GIEWS product are generally concordant.

Table B1. *Drought impacts in Lebanon reported by stakeholders. Impact themes are noted in the column headings and related impacts are noted below each heading. Text in blue is a national-level priority; text in green are regional level priorities in the Kelb and/or Litani basins; highlighted text is a priority at both national and regional levels.*

Climatological/ Hydrological	Agricultural	Environmental	Socio-economic
Decrease and shift in precipitation Temperature extreme anomalies (heat and cold/changes in frost timing and seasonal)	Decreased crop/fruit production quantity and quality (rainfed systems); the Increasing prevalence of crop diseases and pests Increased nomadism/ transhumance to access rangelands	Tree decline / mortality Change in species range (shifts in altitude) Pest species' infections Wild plants phenology shifts Over-grazing and rangeland degradation	Rise in diesel prices (x 3 than before drought due to speculation on imported fuel) Losses through agricultural finance and inputs suppliers Higher expenditure on water purchases (private) Cost of new or supplemental water resource development Rural exodus
Decreasing snowpack and/or more rapid snowmelt, decrease in stream flows, and spring outflow	Increased irrigation water demand (+supplementary) and shift in seasonality (changes in planting schedules and crop growth stages)	In-stream ecosystem integrity loss	Social/political/management conflict over water resources, and additional strain on refugee populations reverting to use of unsafe drinking water supplies Increase in WASH disease burden, especially in refugee communities
Decreased surface water storage and losses by siltation / sedimentation	Surface water rationing/ restrictions for irrigation	Vulnerability to flooding due to low soil water retention of eroded horizons	Disrupted food supply and increased importation Institutional constraints on water use
Drop-in groundwater tables (for both shallow and deep aquifers)	Increased pumping of groundwater	Bee population decline and honey quality issues	Increase in illegal access to piped water supply Disruption of water suppliers Municipal water cuts earlier, more frequent, and longer Increased well digging, pumping, and irrigation costs
Surface/groundwater degradation (chemical, biological, and siltation)	Damage to irrigation equipment (siltation)	Air/water quality effects	Hydro-power losses and more frequent brown-outs
Seawater intrusion		Fisheries degradation	The loss to tourism industries
			State revenue loss from the reduced tax base

National impacts

Generally, respondents think that past droughts differ from current droughts in that impacts used to be more limited to water resources and supply; that is, in the past they had lesser impacts on the economy and agriculture sector as well as ecological impacts mainly limited to forest fires. Also, current droughts are believed to have much greater societal impacts overall.

They think that current droughts have greater economic impacts of all types, particularly in relation to crop production losses. In addition, they think the environmental impacts of droughts are greater and wider now, especially in relation to water resources.

Overall, stakeholders do not think that future drought impacts, in and of themselves, will generally intensify, except in relation to social impacts. Crop yield, ecological, and hydrological impacts, such as groundwater depletion and

[11] See FAO's Lebanon Earth Observation (online).

reservoir storage reduction, are anticipated to increase in severity. However, some impacts are anticipated to decrease, such as irrigation costs and supplemental water supply. These responses reflect stakeholder anticipation of improved infrastructure but increasing water scarcity challenges over time.

In recent years, farmers have shifted towards higher value crops such as fruits and vegetables rather than cereals production. This has increased the economic productivity per unit land (European Commission 2014: 4), but it has also increased reliance on imports, which meet some 80% of Lebanon's food needs (MoA 2014: 12). Drought events are likely to further increase food import dependence and deplete foreign currency reserves.

Full results are shown in Tables B2-B4 below.

Regional impacts (Kelb and Litani basins)

Stakeholders think that there is strong regional variation in the severity of current drought impacts and whether specific impacts are increasingly severe over time. Table B5 below shows current and projected drought impacts in the El Kelb basin, a typical snowfed coastal catchment, and the Litani basin, one of Lebanon's major inland rivers important for water supply, irrigation, and hydropower generation.

Drought events in the El Kelb basin have significant impacts on hydrology, economic activities, especially tourism, and the ecosystem. In contrast, in the Litani, droughts have more severe impacts on agriculture, water availability and quality, and society. Impacts on other sectors such as public health and energy sector are less pronounced but expected to increase in the future.

Table B2. *Drought-related economic impacts (H = Historical; C = Current; P = Potential future). Ranking ranges from low impact (+) to extreme (++++) impact.*

Impact Description	H	C	P
Economic: Loss from crop production	+	+++	++/+++
Annual and perennial crop losses	+	++	++
Damage to crop quality		++	++
Income loss for farmers due to reduced crop yields	+	++	+++
Plant disease	+	++	++
Increased irrigation costs	++	++++	+++
Cost of new or supplemental water resource development (wells, dams, pipelines)	+	++++	++
Economic: Decline in food production/disrupted food supply		+++	++
Increase in food prices		++	++
Increased importation of food (higher costs)		+++	++
Economic: Loss from dairy and livestock production		+/++	+/++
High cost/unavailability of water for livestock		++	++
Economic: Loss from timber production and or forest cover	+	+/++	+/++
Range fires	++	++	++
Impaired productivity of forest land		++	++
Direct loss of trees, especially young ones		++	++
Economic: Loss from fishery production			
Damage to fish habitat		++	+++
Loss of fish and other aquatic organisms due to decreased flows		++	++
Reduction and degradation of fish and wildlife habitat	+	++	++
Economic: Loss from economical activities	o/+	+/++	+/++
Loss to industries directly dependent on agricultural production (e.g., machinery and fertilizer manufacturers, food processors, dairies, etc.)	+	++	++
Rural population loss	+	++	++
Revenue shortfalls and/or windfall profits (water supply firms)	+	++	++
Cost of water transport or transfer	++	++	++
Cost of new or supplemental water resource development	++	+++	++
Loss to recreational and tourism industry		+++	++

Table B3. *Drought-related environmental impacts. Legend as for Table B2*

Impact Description	H	C	P
Environmental: Damage to fish species		++	+/++
Reduction and degradation of fish and wildlife habitat due to increased water pollution		++	++
Environmental: Damage to animal species		+/++	+/++
Reduction and degradation of animal and wildlife habitat	+	++	++
Lack of feed and drinking water		+++	++
Environmental: Damage to plant species	+/++	++	++
Loss of biodiversity	+	++	++
Range fires	++	++	++
Tree disease	+	++	++
Insect infestation	+	++	++
Direct loss of trees, especially young ones	+	++	++
Environmental: Ecosystem	o/+	+/++	+/++
Air quality effects (e.g., dust, pollutants)	+	++	+++
Environmental: Water resources	++	++/+++	++/+++
Lower water levels in reservoirs, lakes, and ponds	++	+++	+++
Reduced flow from springs	++	+++	+++
Reduced streamflow	++	+++	+++
Increased groundwater depletion, land subsidence, reduced recharge	+	++	+++
Water quality effects (e.g., salt concentration, increased water temperature, pH, dissolved oxygen, turbidity)	+	+++	++
Disruption of water supplies	++	+++	+++
Reservoir, lake and drawdown/reduced levels (including farm ponds)	++	++	+++

Table B4. *Drought-related social impacts. Legend as for Table B2*

Impact Description	H	C	P
Social: Public health	+	+/++	+/++
Mental and physical stress (e.g., anxiety, depression, domestic violence)	+	++	++
Health-related low-flow problems (e.g., contamination, diminished sewage flows, increased pollutant concentrations, reduced firefighting capability, etc.)	+	++	++
Social: Increased conflicts	+	++	+++
Water user conflicts	+	+++	+++
Political conflicts	+	++	+++
Management conflicts	+	++	+++
Other social conflicts (e.g., scientific, media-based)	+	+	++
Social: Reduced quality of life, changes in lifestyle	+	+/++	+/++
In rural areas	+	++	++
In specific urban areas	+	+	+
Increased data/information needs, coordination of dissemination activities	+	++	++
Recognition of institutional restraints on water use	+	++	+++
Inequity in the distribution of drought relief	+	+	++

Table B5. *Drought impacts in El Kelb and Litani basins. +=low impact, ++=moderate impact, +++=high impact, ++++=severe impact. N = not likely, L = likely; Y = probable growing risk; Y* = positive growing risk*

Potential impacts of drought	El Kelb	Growing Problem?	Litani	Growing Problem?
A. Agriculture and food supplies and consumption				
1. Reductions in agricultural production	o/+	L	++/+++	Y
2. Reductions in rainfed agricultural production	++	Y*	+++	Y*
3. Reductions in arable land	o/+	L	+/++	Y*
4. Reductions in animal production	o/+	N	+	Y*
5. Reductions in fish production	o/+	N	+	Y
B. Water				
1. Increased water scarcity	++/+++	Y*	+++	Y*
2. Decreased water quality	++	Y*	+++/++++	Y*
3. Reduction in surface water flow	++/+++	Y*	++/+++	Y*
4. Decreasing water storage and falling water tables	++	Y*	+++	Y*

Potential impacts of drought	El Kelb	Growing Problem?	Litani	Growing Problem?
5. Drought-related changes in the spatial and temporal distribution of water resources	++	Y*	++	Y
6. Reduction in exploitable water supply	+/++	Y	++/+++	Y*
7. Reductions in agricultural water supply	+	Y	+++	Y*
8. Reductions in domestic /industrial water supply	++	Y	++	Y
9. Reductions in water supply for generation of hydroelectricity	+	L	++	Y
C. Drought-related natural disasters				
1. Increases in droughts events	+/++	Y	++	Y
2. Increases in drought durations	+/++	Y	++	Y
3. Increases in drought severity	+/++	Y	+/++	Y
D. Tourism				
1. Reduction in summer and winter tourism attractiveness: ski season, sandy beaches, forest and natural reserves	++	Y	o/+	P
2. Reductions in attractiveness of coastal areas	++	Y	o	N
3. Reductions in attractiveness of mountain and snow related activities	++	Y	o	N
D. Tourism				
1. Energy (increased demand in peak season)	++	Y	++	Y
2. Increases in demand (electricity consumption) for cooling	+	Y	++	Y*
F. Public health (vector-borne diseases, heat waves)				
1. Increases in risk of death	o/+	N	o/+	N
2. Increases in risk of illness and disability (e.g., diarrhoea, malaria, cardiovascular disease)	+	L	+	L
3. Increased risk of infant illness, disability, and/or death	o/+	L	+	L
4. Increased heat stress risks	+	Y	+	Y
5. Increased malnutrition	+	Y	+	Y
G. Ecosystems				
1. Reductions in biodiversity (loss of species)	+/++	Y	+/++	Y
2. Drought-related impacts on snow season	++/+++	Y*	+	Y
3. Decreases in forested lands and/or forests health	++/+++	Y	+/++	Y
4. Increases in land degradation	+/++	Y	++	Y
5. Increases in desertification	+	Y	+/++	Y
6. Increases in forest fires	++	Y*	+	Y
H. Society				
1. Increases in violence from higher temperatures	o/+	N	o/+	N
2. Reductions in workers' productivity from heat stress	++	Y	++	Y*
3. Social impacts (rural livelihoods, conflict migration, poverty, economic growth)	+	Y	++	Y
4. Increases in drought-related displacement and internal migration (rural-urban migration, security problems)	+	N	+	Y
I. Economy				
1. Increased water storage and supply cost	++/+++	Y*	++/+++	Y*
2. Increased cost to replace the lost water	++/+++	Y *	+++	Y*
3. Increases in global food prices	+	Y	+	Y
4. Drought-related increase in local food prices	+/++	Y	++	Y
5. Increased cost to producers from reductions in agricultural production	+/++	Y	++/+++	Y*
6. Increased cost to consumers from increases in the local and/or global price of food	+	Y	+	Y
7. Reduced agricultural expenditure in Lebanon	+	Y	++	Y*
8. Increased agricultural imports in Lebanon	+	Y	++	Y
9. Increased costs to the coastal fishing industry and aquaculture producers from reductions in fish harvest	+	Y	+	Y
10. Increased energy cost (increased demand for heating and cooling, reduced hydropower)	+	Y	++	Y
11. Increased cost of additional electricity consumption in Lebanon	++	Y	++	Y
12. Reduction in GDP from the reduction of the number of tourists	++	Y	+	Y

Appendix C – Detailed content and figures from Section 3: drought exposure

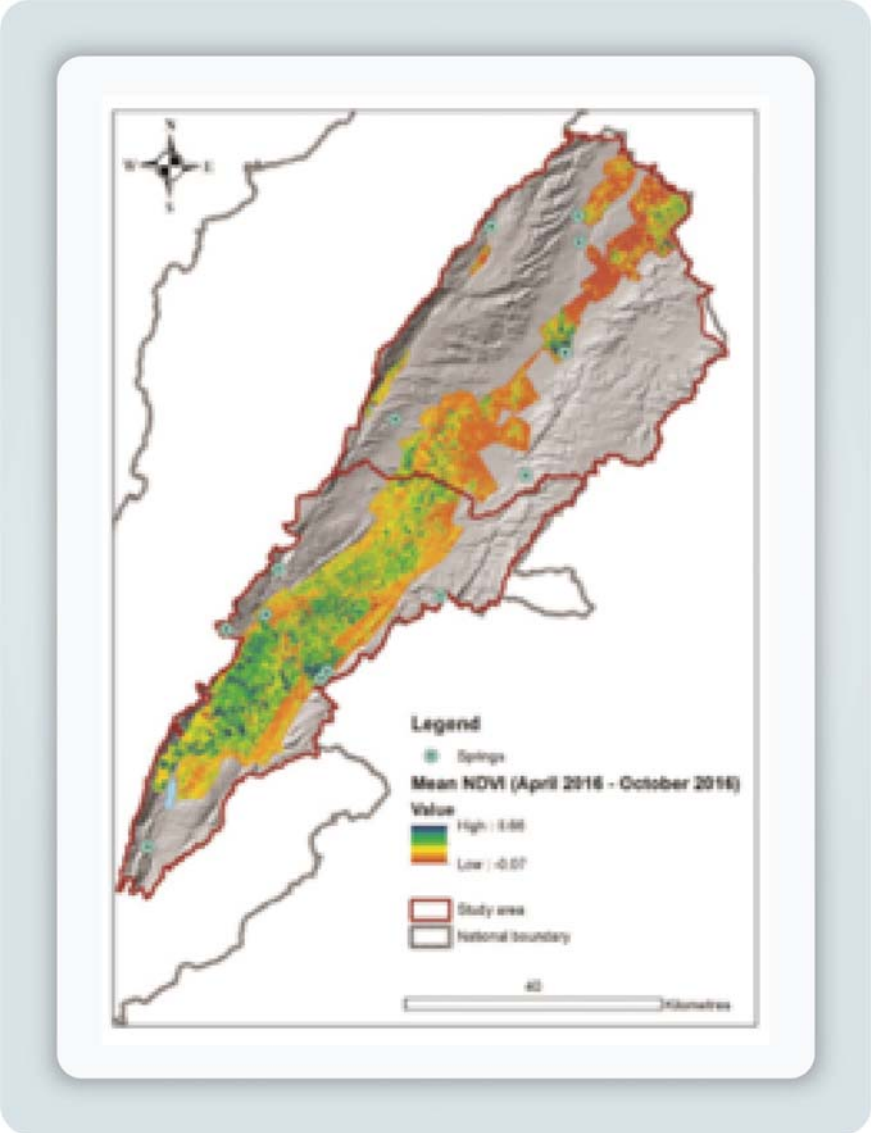

Figure C1. *Cultivated lands in the project basins (Jaafar et al. 2016).*

Table C1. *Vulnerability to impacts of drought. +=low impact, ++=moderate impact, +++=high impact, ++++=severe. Note that the table reflects responses from multiple respondents and so there may be scores in multiple boxes. This reflects various individuals' considerations of the vulnerability score. For example, item B2, decreased water quality, has ++++ in "high" and ++ in "moderate" reflecting differences of opinions about how vulnerable water quality is to drought impacts.*

Sector	High	Moderate	Low
A. Agriculture and food supplies and consumption	++/+++	+/++	
1. Reductions in agricultural production	+++		
2. Reductions in rainfed agricultural production	++++		
3. Reductions in arable land	++		
4. Reductions in animal production		++	
5. Reductions in fish production		+++	
B. Water	+++	+/++	o/+
1. Increased water scarcity	++/+++	++	
2. Decreased water quality	++++	++	
3. Reduction in surface water flow	+++		
4. Decreasing water storage and falling water tables	++++		

Sector	High	Moderate	Low
5. Drought-related changes in the spatial and temporal distribution of water resources	+++	++	
6. Reduction in exploitable water supply	+++	+	+
7. Reductions in agricultural water supply	+++	+	+
8. Reductions in domestic /industrial water supply	++	++	+
9. Reductions in water supply for generation of hydroelectricity		++	+
C. Tourism	+/++	++	+
1. Reduction in summer and winter tourism attractiveness: ski season, sandy beaches, forest and natural reserves	+++	++	
2. Reductions in attractiveness of coastal areas		+	++
3. Reductions in attractiveness of mountain and snow related activities	++	+++	
D. Energy (electricity consumption)	++	++	+
1. Energy (increased demand in peak season)	++	+++	+
2. Increases in demand (electricity consumption) for cooling	++	++	+
E. Public health (vector-borne diseases, heat waves)	+/++	++	o/+
1. Increases in risk of death		+	++
2. Increases in risk of illness and disability (e.g., diarrhea, malaria, cardiovascular disease)	+	++	
3. Increased risk of infant illness, disability, and/or death	+	+++	
4. Increased heat stress risks	+++	++	
5. Increased malnutrition	+	+++	
F. Ecosystems	+++	+/++	o/+
1. Reductions in biodiversity (loss of species)	+++	+	+
2. Drought-related impacts on snow season	++++	+	
3. Decreases in forested lands and/or forests health	+++	++	
4. Increases in land degradation	+++	++	++
5. Increases in desertification	++	+	+
6. Increases in forest fires	+++	++	
G. Society	+/++	+/++	o/+
1. Increases in violence from higher temperatures	+	+	+
2. Reductions in workers' productivity from heat stress	+++	++	
3. Social impacts (rural livelihoods, conflict migration, poverty, economic growth)	++	+++	
4. Increases in drought-related displacement and internal migration (rural-urban migration, security problems)	+	++	+
H. Economy	++/+++	++/+++	o/+
1. Increased water storage and supply cost	++++	++	
2. Increased cost to replace the lost water	+++	+++	
3. Increases in global food prices	+++	++	
4. Drought-related increase in local food prices	++	+++	+
5. Increased cost to producers from reductions in agricultural production	++++	+	
6. Increased cost to consumers from increases in the local and/or global price of food	++	+++	
7. Reduced agricultural expenditure in Lebanon	++	+++	++
8. Increased agricultural imports in Lebanon	+++	++	+
9. Increased costs to coastal fishing industry and aquaculture from reductions in fish harvest	++	+++	
10. Increased energy cost (increased demand for heating and cooling, reduced hydropower)	++	++	
11. Increased cost of additional electricity consumption in Lebanon	++	+++	
12. Reduction in GDP from the reduction of the number of tourists	+	+++	

Agricultural social hierarchies in Hermel

Large farms: owners are families of notables who are well connected to the market and local politicians through domestic relationships. They have solid finances allowing intensification, integration into value chains (such as the production of wines and high-quality local products), and priority access to financing and water resources as evidenced by their possession of large surface water reservoirs and canals linked to natural springs, and deep wells. For these farmers, who are a growing minority, drought, which has been short-lived until now, is manageable due to the continuous pace of expansion and intensification, and the control on prices and informal employment of refugees.

Small and medium landholders: These farmers are settled on land divided by inheritance. They survive locally through agriculture and construction work. The medium-sized farmers employ seasonal labor (organized in bands) who are primarily refugees. In contrast, small-scale farmers and herders rely on familial labour. For these farmers, drought can constitute an existential threat.

Herders: Herders rely on livestock as assets that they can sell when it is required. During droughts, they tend to sell their animals at variable prices. This generates cash to repay creditors and avoids added costs from inputs: water, fodder, and veterinary services. Disease outbreaks among livestock are more common in drought years due to the lack of clean water and low levels of access to veterinary services. This cycle of herd sell-off can affect the availability of dairy products in households.

Milk and the dairy sector more widely are primary sources of income in poor rural communities in the Bekaa. Indeed, nearly two-thirds of the country's livestock farmers depend on dairy products as their main source of income; more than 70% of dairy farmers are considered poor or very poor (FAO, 2011). The dairy sector, which primarily produces goat and sheep milk, has faced increasing challenges since the onset of the Syrian conflict. They have resulted in significant losses and reductions in income due to droughts combined with conflict and lack of access to affordable credit. This is manifested in low levels of investment in refrigeration and pasteurization, higher levels of losses, and poor integration of small producers into more profitable supply chains.

Appendix D – Detailed content and figures from Section 4: drought sensitivity

Sources of borrowing

For large farm owners, the Investment Development Authority of Lebanon (ADIL) offers services including data and access to export markets, as well as subsidized participation in international trade/producer fairs. The AGRI PLUS program works with fresh produce exporters and cooperatives to streamline production, improve packaging, marketing, and industry standards. Subsidies are offered to encourage exporters to improve product quality, and some producers have received compensation for increased transportation costs following the closure of the Syrian border.

The Kafalat loan guarantee program, supported by the Central Bank, issues loan guarantees for SMEs in the agricultural and other sectors to access loans from commercial banks, based on a business plan and feasibility studies. Kafalat - owned by the National Deposit Guarantee Institute (75%) and fifty Lebanese banks (25%) - helps commercial banks offer "reduced" interest rates on loans by approving the Central Bank's exemption from the statutory reserve requirements usually in place to ensure that banks lend responsibly. Borrowers can obtain loans from commercial banks with fewer collateral requirements than expected. Through the application, Kafalat can seek approval from the Central Bank to reschedule or extend additional credit through the commercial bank. Farmers interviewed felt that the application process and interest rates were not appropriate for their businesses, although some mentioned agribusiness SMEs that had benefited from loans in the region after the 2006 war and fire damage.

Disaster risk finance mechanisms

Development of national, sub-national, or individual disaster risk finance options such as bonds or insurance is a “pre-impact program for mitigation” and potentially also “development of preparedness plans and policies”. The pay-outs associated with them facilitate “post-impact interventions”. As such, development of risk finance options covers both coping and adaptation mechanisms.

Government agencies typically face difficulties funding pre-impact programs for mitigation as well as development of preparedness policies and plans. Because drought impacts are rarely defined fully in economic terms and the inherent difficulty of assessing counterfactuals, it is difficult to evaluate the relative benefit to cost ratio of undertaking preparedness or mitigation actions, though evidence suggests it is likely to be high (WMO and GWP, 2017).

When catastrophes such as drought occur, there are obligations for both public and private sector organizations (Figures D1 and D2). In MENA countries, as well in many other parts of the world, governments have provided financial and logistical support for drought management. This typically occurs through drought declaration and then putting in place management actions.

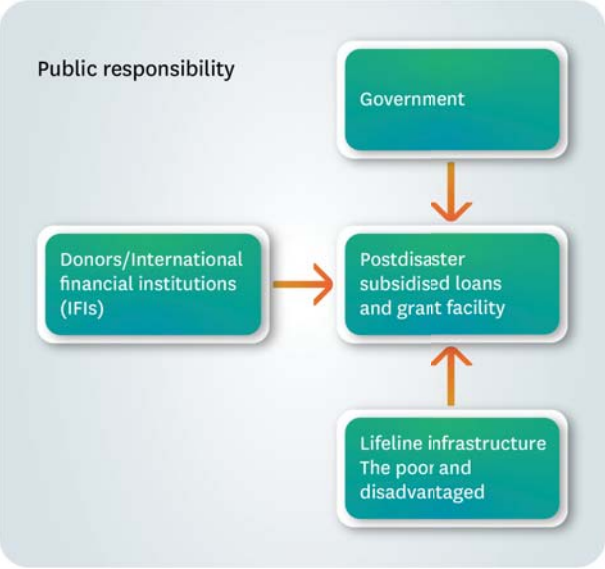

Figure D1. *Public sector responsibility in managing catastrophe risk (Source: Munich Re, 2017)*

The specific management actions, and their scale and scope of implementation vary between countries. In relation to agriculture and food security, they generally include sourcing food and often livestock feed supplies through global markets and local distribution, extension of credit for farmers, and other safety nets to help offset losses and support recovery once drought conditions ease. In low-income countries, donors and international financial institutions often support these government activities. Emergency relief interventions have major financial repercussions for national governments.

Various actors are essential to support the development and marketing of climate risk insurance in developing economies, with national agencies and private sector firms as well as international organizations and re-insurance companies all playing important roles. While this safety net cannot reduce the meteorological, hydrological, or agricultural impacts of climatic events, it can help the community and the economy recover and re-establish itself more quickly (ODI, 2017). In an ideal world, this would be the safety net of last resort and would be part of an

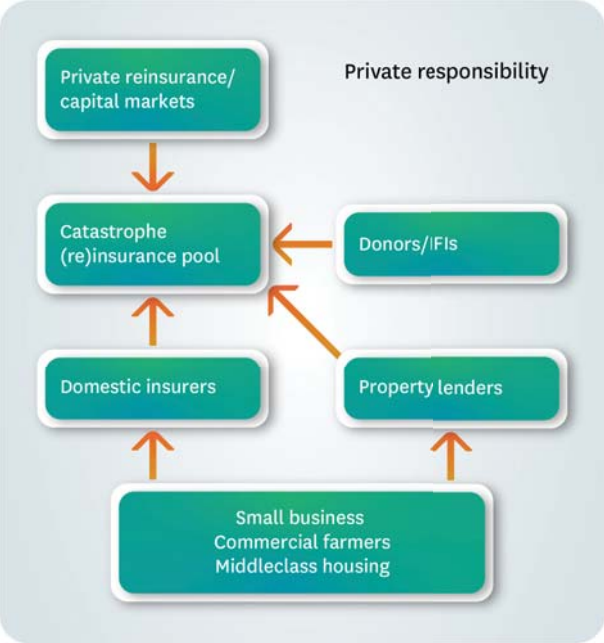

Figure D2. *Private sector financial responsibilities in drought relief support. Source: Munich Re 2017*

integrated approach to drought risk management (Kron, 2017). However, until there is greater adoption of adaptation measures, and in conjunction with implementation of the IDMP's approach of pro-active planning, insurance or other financial mechanisms such as bonds can help governments, big and small businesses, and communities cope with and recover from the devastating impacts of drought.

Table D1 provides summary analysis of the strengths, weaknesses, opportunities, and threats (risks) associated with different types of drought insurance products. Given Lebanon's relatively mature financial system, development of relevant financial products is likely an attainable objective, though the paucity of climatological and/or hydrological information, or agricultural production statistics, to underpin pay-out thresholds could be a challenge. However, already some of the research points towards substantial use of convergence of evidence remote sensing and modelling products, so that may enable future product development, for instance for the Bekaa specifically, or for risk transfer mechanisms associated with production losses at the macro-economic level rather than at the producer level.

Table D1. *SWOT analysis of various insurance types.*

STRENGTHS (+)		
All index & indemnity insurance	**Indemnity insurance only**	**Weather & climate index insurance***
Rapid catastrophe response	Multi-peril insurance	Transparent and largely indisputable
Smoothing farmer's income between seasons	Indemnity insured relates to actual losses	Fast claim settlement
Long-term social impact	Acceptance from and clients	Named-peril insurance
Unlock opportunities to increase productivity	Traditional products for insurance forms	Low assessment costs
Promising market for insurance companies		No moral hazard

*area-yield index slightly different

WEAKNESSES (–)		
All index & indemnity insurance	**Indemnity insurance only**	**Weather & climate index insurance***
Costs & subsidy requirements	Moral hazard & adverse selection	Basis risk
Availability & credibility of data	Slow claim settlement	Complex to understand
Need for local adaptation and design	High loss assessment costs	Costly data input technology (meteorological observation network/ satellite data expertise)
Moderate success		Studies & expertise to design products

*area-yield index slightly different

OPPORTUNITIES (+)		
All index & indemnity insurance		
Latent demand	Climate change	Technology & innovation
Increased policy awareness of food security issues	Increased global awareness of poverty issues	Increased social awareness of environmental issues

THREATS (–)		
All index & indemnity insurance		
Political instability	Climate change	Legal and regulatory frameworks
Implementation challenges	Financial illiteracy	Market immaturity

Appendix E – Detailed content and figures from Section 5: drought coping and adaptive capacity

Table E1. *Adaptive approaches for reducing the impacts of drought in Lebanon. Note that the table reflects responses from multiple respondents and so there may be scores in multiple boxes. This reflects various individuals' considerations of the vulnerability score. For example, item HC2 has + in "high" and + in "low" reflecting differences of opinions about the relative priority of that specific theme for building adaptive capacity.*

Code	Actions	High Priority	Moderate	Low
	Category 1. Strengthen human capital			
HC1	- Improve individual awareness of drought and climate-related risks.	++	+	
HC2	- Improve education, nutrition, health, etc.	+		+
HC3	- Reduce marginalization of women and others.	+	+	
HC4	- Reduce number of people in poverty.	++	+	
HC5	- Diversify economic skills and activities.	++	++	
HC6	- Strengthen resilience skills for responding to climate related stresses that will occur.	++	+	
	Category 2. Conserve natural capital			
NC1	- Reduce non-climate stressors on ecosystems.	++	+	+
NC2	- Conserve wetlands, soils, aquifers, and other core resources.	+++	++	+
NC3	- Implement ecosystem- and community-based management of natural resources.	++	+	+
NC4	- Reduce risks of species extinction and loss of habitat.	+		++
NC5	- Strengthen ecosystems' resilience to climate-related stresses that will occur.	+	++	
	Category 3. Reduce vulnerability of physical capital			
PC1	- Improve community understanding and awareness of climate risks, in general and to specific types of built capital.	++		+
PC2	- Withdraw development from high-risk areas, such as floodplains.	+		+
PC3	- Reinforce housing and workplaces against climate risks, such as storms.	+	+	
PC4	- Reduce risk of impairment of essential infrastructure: communication, transportation, water, wastewater, healthcare, electricity, etc.	++	+	
PC5	- Strengthen resilience of essential infrastructure to climate related stresses that will occur.	+++	+	
	Category 4. Strengthen social capital			
SC1	- Improve community understanding and awareness of climate risks, in general and to specific institutions and human relationships.	+	++	
SC2	- Improve adaptation plans and disaster-risk management systems.	++	++	
SC3	- Reduce risk of impairment of essential services.	+	+	
SC4	- Encourage development of and participation in insurance programs.	+	+	+
SC5	- Improve access to information, finance, and technology.	++	+	+
SC6	- Strengthen resilience of social systems to climate-related stresses that will occur.	++	++	
	Category 5. Strengthen cultural capital			
CC1	- Improve community understanding and awareness of climate risks to culturally important resources and activities.	+	++	
CC2	- Reduce risk to heritage sites and other cultural resources important to different cultural groups and communities (rural and urban).		++	+
CC3	- Strengthen resilience of cultural capital to climate-related stresses that will occur.		++	+

Table E2. *Drought risk management options to address water shortage. Note that the table reflects responses from multiple respondents and so there may be scores in multiple boxes. This reflects various individuals' considerations of the vulnerability score. For example, item W2, "conservation – water demand reduction…" has ++ in "high", + in "moderate", and + in "low" reflecting differences of opinions about how useful that set of action would be to improve drought risk management.*

Code	Actions	Uses*	High	Moderate	Low
	Category: Water resources				
W1	Strategies to reduce water demand, increase water efficiency by minimizing losses in all uses of surface and groundwater sources, and leakage control.	U I A	++++	++	
W2	Conservation- water demand reduction; Reform water tariff system to account for domestic consumption.	U I A	++	+	+
W4	Updating legislation, reviewing regulations and enhancing enforcement institutional and administrative reforms new approach to water rights.	U I A	+++	+	
W5	Reform government agencies responsible for the water sector and repair deteriorated infrastructure.	U I A G	++	++	
W9	Groundwater management: Strengthening the capacity of water and wastewater establishments to monitor groundwater abstraction and developing a comprehensive database of groundwater wells.	G	++++	++	
W10	Protect groundwater through increased regulation and new legislation.	G	++	+	+
W11	Develop watershed management plans: - Prioritize watersheds and initiate development of management plans on the most vulnerable ones; - Assess water balance in each watershed; - Prepare a management plan that considers future uses.	U I A G	++++	+	
W12	Develop a water database: - Develop and implement a long-term river and spring monitoring program; - Develop a comprehensive database of groundwater well; - Develop and implement a snow cover monitoring program.	U I A G	++	++	+
W17	Reduce pollution of water resources through better wastewater management. Build wastewater treatment plants and sewer networks.	U I	+++	++	
W20	Promoting water reuse at all levels: - Reuse of greywater, water harvesting; - Best Management Practices for stormwater runoff management, collecting and storing storm wale, for reuse in irrigation, and reuse of treated sewage.	A I G	++	+	+
W22	Emphasize the importance of aquifer recharge in water sector plans and strategies. Establishing recharge dams and other structures to increase groundwater reserves.	D I A G	+++	++	

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment; G: Groundwater aquifer.
+ lesser priority and ++++ higher priority based on the number of stakeholder feedback.

Table E3. *Drought risk management options to address the agricultural and socio-economic sectors*

Code	Actions	Uses*	High	Moderate	Low
	Category: Agriculture				
A5	Adopt sustainable agriculture practices such as conservation agriculture, adequate crop rotation including fodder species and organic farming.	A	++	++	
A11	Adopt sustainable agricultural practices and integrated pest management techniques.	A	++	+	+
A14	In Bekaa: Shift to less water consuming crops, e.g., barley instead of wheat, snake cucumber instead of cucumber, figs instead of kaki, grapes instead of peaches; and to more drought and heat tolerant crops such as industrial hemp, avocado and citrus as opposed to bananas.	A	++	+	
A15	In coastal plains: Adopt plantation schemes and greenhouse systems to facilitate air circulation among plants.	A	+	+	+
A16	In coastal zones: Introduce crops tolerant to higher levels of humidity and temperature i.e., citrus, tropical fruit trees, and to higher salinity concentrations i.e., legumes, cucurbits and solanaceous rootstocks.	A		+	+
A17	Shift to more efficient irrigation systems such as drip irrigation or sprinklers, and adjust irrigation schedules as well as water quantities according to the increasing crop water demand.	A	+++	++	++
	Category: Public Health				
P1	Enhancing the Early Warning Alert and Response System to improve the capacity of the current system to respond to unexpectedly occurring disasters.	U A	++	++	
P3	Improving access to health care and proper sanitation.	U I A	+++		+
	Category: Tourism				
T2	Developing/promoting alternative and sustainable types of tourism, supporting protected area management; enhancing and restoring the forest cover in order to promote sustainable tourism for natural areas at risk.	U I A		++	+

* U: Urban/Domestic; A: Agriculture; I: Industry; R: Recreation/Environment; G: Groundwater aquifer.
+ lesser priority and ++++ higher priority based on the number of stakeholder feedback.

Appendix F – Detailed content and figures from Section 6: Informing drought risk management

Drought management needs

The list of drought management needs comes from the needs assessment as reported by Jedd et al. (2020). The text below it describes the top 3 needs in detail.

1. Enact a national water management policy and connect it with drought, and coordinated planning between water use sectors;
2. Enhance outreach and education for civil society including working directly with farmers to issue crop planting guidance, and to understand market needs;
3. Use efficient irrigation methods: use new technologies for water supply and maintain yield productivity;
4. Insurance and financial reform for agricultural operations to reduce risk-prone production practices;
5. Address underlying social vulnerabilities (related to access and capacity) that plague water resources;
6. Focus on municipal supply, pumping capacity, eliminate leaks and theft to ensure water delivery is efficient;
7. Understand groundwater recharge, build recharge infrastructure (MAR), and manage drought in years when rain is plentiful;
8. Build surface water infrastructure that is capable of managing additional demand as well as flooding;
9. Formalize ministerial and interagency cooperation; and
10. Connect with disaster programs and provide funding for drought relief programs.

Enact a national water management policy and connect it with drought.

Even apart from drought, participants overwhelmingly emphasized the need for a national water management strategy and an updated and integrated water law. One agency official expressed that "There's no national coordination on [water] and in the department, we don't know our own authority in some cases." Central coordination and planning would allow for the proper authorization and funds to be allocated to departments from the central government. Many participants see this as the basis on which future policy rests.

A national plan would ease tensions between sectoral water uses, especially in areas with changing patterns of development. For example, one participant estimated that in the Kasimie irrigation district in Southern Lebanon, about 10-20% of the total irrigation water is diverted to industry. It is also difficult to provide a coherent framework for the Water Establishments and improve their technical capacity when a national strategy is lacking.

A national strategy would provide a framework through which municipal, irrigation and industrial water supply and demand could be balanced. Furthermore, a linked strategic drought policy could consider various levels of governance. This is critical considering the varying water governance regimes throughout Lebanon. Thus, national water and drought planning efforts can help connect municipalities as they manage their needs in relation to others' and also permit improved oversight of the process by central agencies.

Enhance outreach and education for civil society. Work directly with farmers to issue crop planting guidance, and to understand market needs.

Drought management consists of a suite of actions based on information available. Farmers and civil society stakeholders expressed a strong desire to have increased guidance on seasonal water availability and crop planting. This connects to drought monitoring but also more basic water management issues. In rainfed areas, issuing advice

earlier in the year could help farmers reduce risks and optimize their planting choices. This sometimes requires advanced tools and monitoring (which the CDI can provide) to provide solid evidence, but the guidance can be relatively straightforward such as advising farmers on the best times and crop varieties to plant based on climatic and water availability conditions.

Irrigation as the solution to drought is not possible at all places and all times, and farmers feel that extension services offer few specific strategies and alternative advice. In some areas, the groundwater systems are non-renewable or have little natural recharge so the impacts of abstraction for irrigation during droughts are permanent. In the coastal areas sea water intrusion is another impact that cannot be ameliorated. A USAID project on apple production in Mount Lebanon (likely the LIVCD project) was referenced as a helpful example that provided clear guidelines on integrated soil and pest management to help maintain production levels even in poor years. Farmers say that they are more likely to be engaged with research projects than by extension officers who they wish to see more frequently. In the absence of extension services, agricultural products sales agents are the main source of information. However, farmers question their neutrality since they are perceived to push particular products regardless of actual needs.

The MoA, NGOs, and cooperatives are not expected to manage drought issues on their own but could do better given flexible operating environments. However, at present the centralization of authority stifles local extension agents from issuing guidance independently and does not provide them adequate funds to initiate their own interventions; likewise, the lack of funding from the centre precludes adequate outreach efforts and information campaigns during periods of drought. This mismatch in capacity and authority is a major barrier to drought management.

Use efficient irrigation methods, new technologies for water supply and maintain yield productivity.

Participants mention wanting complementary solutions for water resources in Lebanon. This requires increasing uptake of modern irrigation methods, expansion of storage capacity, improved management of groundwater resources and improved municipal and irrigation infrastructure. In terms of irrigation, this incorporates the need for better information on current consumption because few wells or irrigation networks are adequately metered. Stakeholders describe irrigation from spring and surface water systems as most vulnerable to drought and so demand forecasting to anticipate volumes required to maintain yield productivity is a major concern.

Overview of the Water Code and National Water Sector Strategy

The Water Code is intended to:

1. Regulate, develop and guide the water sector for the economical use and exploitation of water resources (national wealth);
2. Protect water from overexploitation and improve efficiency of water supply and distribution systems; and
3. Ensure good operation, maintenance, and governance of hydraulic infrastructures in relation to sustainable management.

The National Water Sector Strategy, approved in 2012, aims to guide the sector to achieve the following outcomes:

1. access to safe water;
2. increased access to improved, sustainable, and culturally and gender-appropriate sanitation services including wastewater management, vector control, and mitigation of flood risks (stormwater drainage) for target populations; and
3. ensure preparedness for possible risks including by developing relevant studies, plans, strategies and contingency stocks to improve targeting, prioritization and response.

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