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MENAdrought Synthesis of Drought Vulnerability in Jordan

Final Report

Photo: Seersa Abaza / IWMI

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Final Report

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Front cover photograph: Farmers after completing pesticide spraying at the Abu Kishik Farm in Mafraq, Jordan (Seersa Abaza / IWMI)

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Executive Summary

Purpose

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

The objective of the vulnerability studies has been to identify who and 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 sectors.

The problem context

Drought exacerbates Jordan's extreme water scarcity challenges. Paleoclimate studies, pre-instrumental records, and modern observations and modeling reveal that the 1998-2012 dry period in the Levant was more severe than any other in the past 500 years (Cook *et al.*, 2016). Anticipated future climate change will lead to higher drought frequency, which will cause significant disruptions in hydrological regimes (Kelley *et al.*, 2015) and the water supply sector, as well as attendant effects on the agriculture sector and the livelihoods and communities dependent on it.

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 as well as quantitative and geospatial analyses across multiple vulnerability assessment approaches per the typology developed through a recent review (King-Okumu, 2019).

The participatory research included the needs assessment conducted at the beginning of the programme and, more recently, focused engagements targeting rainfed and irrigated farming systems, primarily in Azraq. The former study was broad in remit; the latter focused on the impact of drought on livestock owners' and farmers' food security and livelihoods (income, debt, and access to finance) as well as the gender-differentiated impacts of drought on farmers and livestock owners. The quantitative and geospatial analyses primarily link to assessments of drought impacts. They included analysis of government expenditure, agricultural production, and water flows and abstraction.

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

Analysis using the enhanced Composite Drought Index (eCDI) shows two major drought events in the past two decades. These took place in 2001 and 2009. In these years, drought extent and intensity increased throughout the year, which amplified drought impacts nationally. Late-onset spring droughts occurred in 2008, 2011, and 2021. In these years, drought affected portions of the country in the fall and spring but winter months were more typical; severe impacts were therefore specific to some locations and farming systems, particularly those that integrate cropping and livestock. In 2002 and 2012, drought conditions almost exclusively affected the *Badia*. The 2014 "flash" drought had rapid onset and subsidence, particularly over the western highlands.

The hazard map illustrates that the Rift Valley mountain chain (from south to north on the western border) has high drought hazard. Likewise, Karak and Balqa' governorates have particularly high hazard, as do parts of Zarqa, Jarash, and Ma'an. The eastern area of the northern highlands in Irbid, Ajloun, and Jarash have lower hazard. Likewise, parts of Amman, Zarqa, Mafraq, and Tafileh governorates have lower hazard.

As Jordan's three primary surface water basins (Jordan Valley, Yarmouk, and Amman-Zarqa) are heavily modified and intensively farmed, the relationship between drought and surface water flows has weakened rapidly in recent years. Drought impacts on groundwater can be severe; in the case of multi-year droughts, spring discharge can take years to recover, if it ever does.

Drought's agricultural impacts are strongest on rainfed systems including cereals-based systems and staple crops for nationwide food security (chickpea, lentils, and olives), crop-livestock integrators, and rangelands pastoralism. Drought effects on the irrigated fruit sub-sector are significant but not straightforward and linear. Historically, drought effects on livestock have been severe, but the introduction of feed subsidies has significantly increased sector-wide coping capacity in recent years. Nonetheless, the distribution of benefits is uneven, with smallholders still facing severe impacts during droughts. This highlights the criticality of looking beyond macro-level indicators and assessing distributional impacts within a given sector and sub-sectors.

Government stakeholders prioritised a range of drought impacts to address through longer-term planning. These connect to agricultural productivity, labour markets, water supply, and related soil and water quality issues (especially salinisation), as well as social cohesion.

Drought events significantly affect the viability of rural livelihoods and generate a host of direct and indirect impacts, including on human health and rural out-migration. Our analyses show that drought, as assessed by precipitation alone, does not correlate with increased disease burden, but its wider effects on temperature and water availability do. Concerning migration, the literature indicates that drought typically leads to a short- and medium-term intensification of typical labour migration patterns but increased permanent migration is not the primary response to drought.

Core findings related to drought exposure and sensitivity: water and agriculture sector

We describe the exposure and sensitivity of the water and agriculture sectors writ large, as well as those aspects which are specific to smallholder livelihoods. Jordan's underlying water scarcity is a key component of its drought exposure and sensitivity: renewable water availability per capita is now 60% lower than in 1990. While economy-wide water use efficiency (in terms of economic productivity) has decreased in the last decade, this is likely due to the major increase in the share of the municipal water supply sector overall. This is driven by refugee influxes, which put immense pressure on the already-strained water supply infrastructure.

There is poor cost-recovery for the primary irrigation agency and municipal water supply and sewerage agencies (the Jordan Valley Authority and Water Authority of Jordan, respectively), leading to underinvestment. Likewise, because utilities' revenues do not cover long-term depreciation costs, and utilities are forced to pressurise systems regularly, they have struggled to maintain assets and provide human resources to address one of their main challenges: non-revenue water. Nationally, non-revenue water is about 50% of that which utilities produce. About 55% of this is estimated to be consumed but not billed (known as administrative losses), leaving an estimated less than 25% of the total supply lost to leakages (MWI, 2018a).

The cereals sub-sector is the most exposed and sensitive to drought impacts due to the predominance of rainfed and smallholder production systems. The fruit sub-sector, particularly trees, is also highly sensitive, though this is due to relatively low uptake of water and soil conservation technologies and practices. The vegetables sub-sector has lower exposure and sensitivity because much of the production occurs early in the year and efficient practices are more prevalent. However, sensitivity is increasing due to export challenges and increasingly stringent regulations on chemical residues in food that are challenging to address given the use of blended treated wastewater.

The livestock sub-sector is highly exposed but not sensitive at an aggregate level due to subsidised feed being the predominant source of food. Nonetheless, this results in the state being highly exposed to financial risks when uptake of subsidised feed increases enormously in drought years.

The agriculture sector faces increasing sensitivity over time due to desertification, particularly in *Badia* areas. Farmers' low access to credit and a lack of financial risk management mechanisms increase sensitivity. Likewise, the prevalence of crops with high water-demand and low use of drought-tolerant crop types increases exposure and sensitivity, as do challenges such as soil salinisation.

The agriculture sector is also sensitive to drought risks due to inter-sectoral water management and allocation policies as well as structural groundwater overdraft. Both of these issues link to Jordan's wider political economy: during droughts, municipal supply, industry, and tourism are favored above irrigation uses because their economic productivity is higher. Likewise, groundwater abstraction is particularly important as it underpins agricultural production during droughts, so challenging the basis of the production system is difficult.

Core findings related to drought exposure and sensitivity: rural livelihoods and communities

There are about 102,000 farming households, of which 85% are smallholders (owning less than 2ha), and of which about 1/3 live on their farms. Nearly a quarter of Jordanians below the poverty line rely on agriculture for their livelihoods.

Agriculture sector employment is predominantly informal and increasingly casual: while 7.7% of the formal labour force worked in agriculture in 2011, by 2017 it had shrunk to 3.9% (3% for men and 0.9% for women). Concurrently, informal employment is estimated to have increased markedly, reaching 5% for men and 16% for women, with the latter figure representing about half of the actively working rural Jordanian women in the sector (World Bank, 2018a; Netherlands Enterprise Agency, 2016). ILO (2018) reports little difference between the wages of female and male Syrian refugees, with the majority of these receiving a wage of 5JD/day. Since the influx of Syrian refugees, wages for farm labourers have fallen by approximately 50%, significantly increasing the sensitivity of rural populations to drought impacts.

Despite Jordan's improving scores in the Human Development Index, about 60% of households are vulnerable and at risk of food insecurity, with 12.8% experiencing severe food insecurity (DOS, 2018a; WFP and REACH, 2019). The population-wide incidence of nutritional deficiency increased markedly in recent years and has reached 13.5% in 2015-2017, compared with 6.6% in 2004-2006. Female-headed households are 62% more likely to be food insecure or vulnerable to food insecurity when compared to male-headed families. Moreover, about 1/3 of Syrian refugee families in Jordan are female-headed (World Bank, 2018b), indicating that they are particularly exposed to food insecurity impacts of drought.

There are no current datasets or ongoing national efforts to measure and evaluate the impacts of drought periods on household income, debt, or financial inclusion. Our results show that smallholder farmers most frequently rely on credit from local agricultural input and hardware suppliers, which contributes to significant inflation of input and hardware prices during drought seasons.

Commercial farms borrow money from commissioners with interest rates that are typically around the exorbitantly high rate of 20%. During droughts, suppliers commonly increase input prices to offset the increased loan repayment defaults, thus impacting the sector as a whole. Borrowing from family and members of the community (since access to formal financial services is very uncommon) to meet household expenditure considerably exposes smallholder farmers and casual farm labourers to inter-seasonal impacts of droughts. Women are particularly exposed to drought's financial impacts because of their reduced ability to access formal assistance or credit due to their lower rates of asset and land ownership (for collateral), lower earnings, lower rates of account holding, and cultural reasons including requirements for male guarantors.

Core findings related to coping and adaptive capacity including a community case study

We provide a conceptual typology of drought management mechanisms including post-impact interventions, pre-impact programmes for mitigation, and development of policies and preparedness plans. These, in sequence, range from coping to adaptation mechanisms.

In the agriculture sector, individuals, communities, and the government have a range of short-term coping mechanisms to reduce exposure and sensitivity. These include: short-term water demand reduction (annual crop types, season, use restrictions/incentives, and irrigation practices); water supply increase (groundwater abstraction and blending of treated wastewater); technologies and practices related to salinity; feed subsidies; agricultural planning guidance; and monetary relief.

Long-term adaptive mechanisms include: capital and energy-intensive technologies (e.g., small-scale desalination, the use of greenhouses, and increasing and improving wastewater treatment capacity and network infrastructure); reduction of leakage in irrigation networks; shifts in crop seasons, crop types, and crop varieties; improvements to irrigation practice; and, most prevalently, groundwater over-abstraction (including fossil groundwater).

In the water sector, utilities and the wider government take a range of short-term coping measures: increasing supply through groundwater over-abstraction, re-allocation from agriculture and other sectors, and purchase from the private sector; reducing demand within the infrastructure network and from the public through rules and information campaigns.

Long-term adaptive capacity is related to treaty agreements and integration in global market chains, inter-sectoral allocation arrangements, minimizing municipal non-revenue water, treated wastewater re-use, desalination, rainwater harvesting, and groundwater abstraction.

The integrative case study assessed how drought exposure, sensitivity, and coping mechanisms interact with drought impacts on both growers and herders in Azraq. Primary aspects of exposure relate to the large area of irrigated farms and livestock herds reliant on rangelands, integrated cropping systems, and imported feed. Aspects of sensitivity pertain to access to advisory services and veterinarians; price increases of energy (for farmers) and feed and water purchases (for herders); groundwater pollution and drawdown; food insecurity; and casualisation and reduction of employment on commercial farms.

During drought, smallholder farmers in Azraq can suffer production losses of around 50%. This is primarily due to the lack of adequate storage or processing of produce. Drought impacts hit poor growers in two forms: directly, through damage to assets and loss of productivity; and indirectly, through the coping mechanism of growing drought-tolerant but low-profit crops in the subsequent year to reduce the financial risk implications of a possibly poor year. Thus, some coping mechanisms can contribute to longer-term declines in income and indebtedness. However, during periods of drought, communities report greater collaboration and solidarity.

During droughts, settled and transhumant pastoralists rely on extended family, and most livestock keepers resort to spending their savings and increasing debt to cope with the loss of sales revenue and rising input costs during droughts. The sale of livestock to avoid losses and increased expenses, and provide some income during the drought period, has a major impact on capital retention and the speed with which post-drought recovery of herds can occur. Traditional pastoral practices are becoming less profitable, leading to uncontrolled changes in land use, with the conversion of rangelands into irrigated agricultural production. During droughts, coordination amongst pastoralists increases, and some aspects of the *Hima* system, including the communal agreement on herd movements, help communities to cope.

Core conclusions for drought management planning and future research for development

Early work in the MENAdrought programme identified stakeholder needs to improve drought risk management. These related to a range of themes, with the top need being for an official drought policy and clear drought declaration procedures linked to robust monitoring data and management plan responses. To develop the Drought Action Plan (DAP), government stakeholders prioritised impacts they wished to address in the first iteration. They chose to focus on water resource degradation, drinking water service quality, livestock and agriculture sector production, human health, and protection of key natural resources.

The DAP explicitly addresses most of the stakeholder-identified drought monitoring and management needs. However, it remains unclear to what extent it will meet the stakeholder needs for bottom-up public-private engagement. Whether and to what extent it will meet stakeholder needs and significantly contribute to the reduction of drought risk depends on how the plan is operationalised, especially the future theme- and sector-specific risk management plans. There is a major opportunity for that planning to occur in a participatory and collaborative fashion.

Finally, we identify a range of research for development opportunities to support the implementation of the DAP and reduce Jordan's vulnerability to primary drought impacts. These cover a range of themes, including:

1. Support for farmers;
2. Public-private engagement;
3. Policy and governance; and
4. Underpinning information and technical tools.

Photo: Seersa Abaza / IWMI

منطقة الشرق الاوسط وشمال افريقيا للجفاف : تقرير تاليفي حول مخاطر التعرض للجفاف والحساسية في الأردن

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 ، عماد الكرابليه ،كريم برقاوي، علي غانم ، لوسي لورنسون،و ريشيل ماكدونيل

صورة الغلاف الأمامي: المزارعين بعد الانتهاء من رش المبيدات في مزرعة أبو كشك في المفرق بالأردن (سيرسا اباز ا/ IWMI)

المصمم: ماريو بحر غرايس ويندز للاعلانات

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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.

إخلاء المسؤولية: أصبح هذا المنشور ممكناً من خلال دعم مكتب الدعم الفني و مكتب الشرق الأوسط و الوكالة الأمريكية للتنمية الدولية بموجب أحكام الجائزة رقم: .٧٢٠٠-ME-١٨-IO-٠٠٠٠١
الآراء الواردة في هذا المنشور هي آراء المؤلفين ولا تعبر بالضرورة عن آراء الوكالة الأمريكية للتنمية الدولية أو حكومة الولايات المتحدة.

ملخص تنفيذي

الغرض

يلخص هذا التقرير نتائج مشروع منطقة الشرق الاوسط وشمال افريقيا للجفاف فيما يتعلق بالأسباب الكامنة وراء خطر التعرض للجفاف والحساسية في الأردن. وهي بمثابة حلقة وصل بين تقييم الآثار وعملية تخطيط السياسات.

الهدف من دراساتمخاطر التعرض للجفاف هو تحديد ماهية اخطار الجفاف وما هي أسبابه وتأثيرات كيفية إدارة الجهات الفاعلةو يمكن أن يكون هذا مفيدًا لتخطيط إدارة الجفاف بحيث تستهدف التدخلات الأسباب الكامنة وراء هذه الحساسيةللمجتمعات والقطاعات المحددة.

سياق المشكل

يؤدي الجفاف إلى تفاقم تحديات شح المياه في الأردن. تكشفدراسات العصر الحجري القديم وسجلات ما قبل الآلات والملاحظات الحديثة والنمذجة الرياضية أن فترة الجفاف ١٩٩٨-٢٠١٢ في بلاد الشام كانت أكثر شدة من أي فترة أخرى في السنوات الخمسمائة الماضية[1]. سيؤدي تغير المناخ المتوقع في المستقبل إلى زيادة وتيرة الجفاف ، مما سيؤدي إلى اضطرابات كبيرة في النظم الهيدرولوجية[2] وقطاع إمدادات المياه ، فضلاً عن الآثار المصاحبة على قطاع الزراعة وسبل العيش والمجتمعات التي تعتمد عليها.

تعريف خطر التعرض للجفاف

خطر التعرضللجفاف هو ظاهرة اجتماعية بيئية. يستكشف ممارسو إدارة مخاطر الجفاف عادةً هذا التفاعل الديناميكي من خلال تقييم مفاهيمي للحساسية 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 للاصابة. يشير التعرض إلى وجود الأشخاص والممتلكات والنظم البيئية وما الى ذلك في المناطق المتأثرة بالجفاف. تشيرالقابلية للاصابة إلى العتبات المناخية التي تؤدي إلى تأثيرات سلبية.

القدرة على التعامل هي قدرة المجتمعات، الأشخاص أو الأنظمة على تحمل الجفاف دون تغييرات لا رجعة فيها في الحالة والوظائف بينما القدرة على التكيف هي قدرة الأنظمة والأفراد والمجتمعات على تغيير الشكل والوظيفة في ظل ظروف جديدة.

طرق البحث

استخدمنا طرق البحث التشاركية بالإضافة إلى التحليلات الكمية والجغرافية المكانيةعبر مناهج تقييم خطر التعرض المتعددة حسب التصنيف الذي تم تطويره من خلال مراجعة حديثة[3].

اشتمل البحث التشاركي على تقييم الاحتياجات الذي تم إجراؤه في بداية البرنامج بالإضافة إلى المشاركات المركزة مؤخرًا التي تستهدف أنظمة الزراعة البعلية والسقوية، ولا سيما في الأزرق. كانت الدراسة السابقة واسعة النطاق ؛ وقد ركزتعلى تأثير الجفاف على الأمن الغذائي وسبل عيش أصحاب الماشية والمزارعين (الدخل، الديون ، والحصول على التمويل) بالإضافة إلى تأثيرات الجفاف المتباينة بين الجنسين على المزارعين ومالكي المواشي.

ترتبط التحليلات الكمية في المقام الأول بتقييم آثار الجفاف. وشملت تحليل الإنفاق الحكومي والإنتاج الزراعي و تدفقات المياه واستخراجها.

تجميع النتائج المتعلقة بتاريخ الجفاف ، ورسم خرائط المخاطر، والتأثيرات

يُظهر التحليل باستخدام (مؤشر الجفاف المركب المحسن enhanced Composite Drought Index; eCDI) حدثين رئيسيين للجفاف في العقدين الماضيين. وقد حدث ذلك في عامي ٢٠٠١ و ٢٠٠٩. في هذه السنوات ، ازداد مدى الجفاف وحدته على مدار العام ، مما أدى إلى تضخيم آثار الجفاف على المستوى الوطني. حدثت موجات جفاف الربيع المتأخرة في أعوام ٢٠٠٨ و ٢٠١١ و ٢٠٢١. في هذه السنوات أثر الجفاف على أجزاء من البلاد في الخريف والربيع ، لكنأثر أشهر الشتاء كانت أكثر شيوعًا ؛ لذلك كانت الآثار الشديدة خاصة ببعض المواقع وببعض الأنظمة الزراعية ، لا سيما تلك التي تدمج بين المحاصيل والثروة الحيوانية.

في عامي ٢٠٠٢ و ٢٠١٢ ، أثرت ظروف الجفاف بشكل شبه حصري على البادية. شهد الجفاف «السريع» في عام ٢٠١٤ بداية سريعة وهبوطًا سريعًا ، لا سيما فوق المرتفعات الغربية.

[1] Cook, B. I., K. J. Anchukaitis, R. Touchan, D. M. Meko, E. R. Cook, 2016. Spatiotemporal drought variability in the Mediterranean over the last 900 years. Journal of Geophysical Research: Atmospheres, 121(5), pp. 2060-2074. https://doi.org/10.1002/2015JD023929
[2] Kelley, C.P., S. Mohtadi, M. Cane, R. Seager, Y. Kushnir, 2015. Climate change in the Fertile Crescent and implications of the recent Syrian drought. Proceedings of the National Academy of Sciences, 112(11), pp. 3241-3246. https://doi.org/10.1073/pnas.1421533112.
[3] King-Okumu, C., 2019. Drought Impact and Vulnerability Assessment: A Rapid Review of Practices and Policy Recommendations. Bonn: UNCCD.

توضح خريطة المخاطر أن سلسلة جبال الوادي المتصدع (من الجنوب إلى الشمال على الحدود الغربية)بها مخاطر جفاف عالية. وبالمثل ، فإن محافظات الكرك والبلقاء معرضة بشكل خاص لخطر كبير ، كما هو الحال في أجزاء من الزرقاء وجرش ومعان.في حين ان المنطقة الشرقية من المرتفعات الشمالية في إربد وعجلون وجرش بها مخاطر أقل. ونفس الشيء بالنسبة لأجزاء من محافظات عمان والزرقاء والمفرق والطفيلة فالمخاطر فيها أقل.

و نظرًا لتعديل أحواض المياه السطحية الرئيسية الثلاثة في الأردن (وادي الأردن واليرموك وعمان-الزرقاء) بشكل كبير واستزراعها بشكل مكثف ، فإن العلاقة بين الجفاف وتدفقات المياه السطحية قد ضعفت بسرعة في السنوات الأخيرة. يمكن أن تكون تأثيرات الجفاف على المياه الجوفية شديدة ؛و في حالة الجفاف لعدة سنوات ، قد يستغرق استرداد الينبوعسنوات حتى يتعافى ،هذا إذا حدث على الاطلاق.

تعد التأثيرات الزراعية للجفاف أقوى ما تكون على النظم البعلية بما في ذلك النظم القائمة على الحبوب والمحاصيل الأساسية لتحقيق الأمن الغذائي على المستوى الوطني (الحمص والعدس والزيتونالقمح والشعير) وادماج المزارع المختلطةلانتاج المواشي والمحاصيل والثروة الحيوانية)، والمناطق الرعوية.

ان آثار الجفاف كبيرة على القطاع الفرعي للفاكهة السقوية ولكنها ليست مباشرة وليست بسيطة . تاريخيا، كانت آثار الجفاف على الثروة الحيوانية شديدة ، ولكن إدخال دعم الأعلاف زاد بشكل كبير من القدرة على التكيف على مستوى القطاع في السنوات الأخيرة. ومع ذلك، فإن توزيع المداخيل غير متكافئ ، حيث لا يزال أصحاب الاراضي الصغيرة يواجهون آثارًا شديدة أثناء فترات الجفاف. هذا يسلط الضوء على أهمية النظر إلى ما وراء مؤشرات المستوى الكلي وتقييم التوزيعية داخل قطاع معين وقطاعات فرعية.

أعطى المتداخلون الحكوميون الأولوية لعدد من آثار الجفاف لمعالجتها من خلال التخطيط على المدى الطويل والتي ترتبط بالإنتاجية الزراعية و أسواق العمل و إمدادات المياه ، وما يرتبط بها من قضايا التربة ونوعية المياه (خاصة التملح) ، فضلاً عن التماسك الاجتماعي.

تؤثر أحداث الجفاف بشكل كبير على جدوى سبل العيش الريفية وتولد مجموعة من الآثار المباشرة وغير المباشرة ، بما في ذلك على صحة الإنسان والهجرة الريفية إلى الخارج. تُظهر تحليلاتنا أن الجفاف ، كما تم تقييمه من خلال هطول الأمطار وحده ، لا يرتبط بزيادة عبء الامراض ، ولكن آثاره الأوسع تكون على درجة الحرارة وتوافر المياه. فيما يتعلق بالهجرة، تشير الدراسات إلى أن الجفاف يؤدي عادة إلى تكثيف أنماط هجرة اليد العاملة العاديةعلى المستويين القصير و المتوسط ولكن زيادة الهجرة الدائمة ليست النتيجة الاولىالأساسية للجفاف.

النتائج الأساسية المتعلقة بالتعرض للجفاف والحساسية: قطاع المياه والزراعة

هنا نصف تعرض وحساسية قطاعي المياه والزراعة على نطاق واسع ، وكذلك تلك الجوانب الخاصة بسبل عيش أصحاب الملكية الصغيرة. تُعد ندرة المياه الأساسية في الأردن مكونًا رئيسيًا لتعرضه للجفاف وحساسيته: فقد انخفض معدل توافر المياه المتجددة للفرد الآن بنسبة ٦٠٪ مقارنة بما كان عليه في عام ١٩٩٠. بينما انخفضت كفاءة استخدام المياه على مستوى الاقتصاد (من حيث الإنتاجية الاقتصادية) في العقد الماضي ، ويرجع ذلك على الأرجح إلى الزيادة الكبيرة في حصة قطاع إمدادات المياه البلدية بشكل عام. ويعزى ذلك إلى تدفق اللاجئين ، الذي يشكل ضغطاً هائلاً على البنية التحتية لإمدادات المياه المتوترة من قبل.

هناك ضعف في استرداد تكلفة وكالة الري الأولية ووكالات إمدادات المياه والصرف الصحي البلدية (سلطة وادي الأردن وسلطة المياه في الأردن ، على التوالي) ، مما يؤدي إلى نقص الاستثمار. وبالمثل ، نظرًا لأن إيرادات المرافق لا تغطي تكاليف الاستهلاك على المدى الطويل ، تضطر المرافق إلى الضغط على الأنظمة بانتظام ، فقد كافحت للحفاظ على الممتلكات وتوفير الموارد البشرية لمواجهة أحد تحدياتهم الرئيسية: المياه غير المدرة للدخل. على الصعيد الوطني ، تشكل المياه غير المدرة للدخل حوالي ٥٠٪ مما تنتجه المرافق العامة. ٥٥٪ من هذا الرقم تستهلك ولا يتم اصدار فواتير في الاستهلاك (المعروفة باسم الخسائر الإدارية) ، مما يترك ما يقدر بنحو ٢٥٪ من إجمالي العرض مهدور بسبب التسرب[4].

يعتبر القطاع الفرعي للحبوب هو الأكثر تعرضاً وحساسية لتأثيرات الجفاف بسبب غلبة نظم الإنتاج البعلية واصحاب الملكية الصغرى. ان القطاع الفرعي للفاكهة، وخاصة الأشجار ، حساس للغاية ايضا ، على الرغم من أن هذا يرجع إلى الانخفاض النسبي في امتصاص المياه وتقنيات وممارسات الحفاظ على التربة. يتسم القطاع الفرعي للخضروات بتعرض وحساسية أقل لأن الكثير من الإنتاج يتم في وقت مبكر من العام والممارسات الفعالة منتشرة اكثر. ومع ذلك ، تتزايد الحساسية بسبب تحديات التصدير والقوانين الصارمة المتزايدة بشأن المخلفات الكيميائية في الأغذية التي يصعب معالجتها نظرًا لاستخدام مياه الصرف الصحي المعالجة المخلوطة..

يتعرض القطاع الفرعي للثروة الحيوانية لتأثيرات الجفاف بدرجة عالية لكنه ليس حساسا على المستوى الإجمالي نظرًا لأن الأعلاف المدعومة هي المصدر الرئيسي للغذاء. ومع ذلك ، فإن هذا يؤدي إلى تعرض الدولة بشدة للمخاطر المالية عندما يزداد الإقبال على الأعلاف المدعومة بشكل كبير في سنوات الجفاف.

يواجه قطاع الزراعة حساسية متزايدة بمرور الوقت بسبب التصحر ، خاصة في مناطق البادية. إن انخفاض قدرة المزارعين على الاقتراضوالافتقار إلى آليات إدارة المخاطر المالية يزيد من الحساسية. وبالمثل ، فإن انتشار المحاصيل التي تتطلب كميات كبيرة من المياه والاستخدام المنخفض لأنواع المحاصيل التي تتحمل الجفاف يزيد من التعرض والحساسية ، كما تفعل التحديات مثل تملح التربة.

كما أن قطاع الزراعة حساس أيضًا لمخاطر الجفاف بسبب سياسات إدارة وتوزيع المياه المشتركة بين القطاعات ، فضلاً عن السحب المتزايد من المياه الجوفية. ترتبط هاتان المسألتان بالاقتصاد السياسي الأوسع في الأردن: خلال فترات الجفاف ، يفضل الإمداد البلدي والصناعة والسياحة على استخدامات الري لأن إنتاجيتها الاقتصادية أعلى. وبالمثل ، فإن استخراج المياه الجوفية مهم بشكل خاص لأنه يدعم الإنتاج الزراعي أثناء فترات الجفاف ، لذلك من الصعب تحدي أساس نظام الإنتاج.

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[4] وزارة المياه والري ، ٢٠١٨ أ
Ministry of Water and Irrigation (MWI), 2018a. Annual Water Balance Budget. Government of Jordan, Amman.

النتائج الأساسية المتعلقة بالتعرض للجفاف والحساسية: سبل العيش والمجتمعات الريفية

هناك حوالي ١٠٢٠٠٠ أسرة زراعية ، ٨٥٪ منها من أصحاب الملكية الصغيرة (يمتلكون أقل من ٢٠ دونم) ، ويعيش حوالي ثلثهم في مزارعهم. حوالي ربع الأردنيين تحت خط الفقر يعتمدون على الزراعة لكسب عيشهم.

التشغيل في قطاع الزراعة هو في الغالب غير رسمي ويتزايد بشكل عرضي: في حين أن ٧,٧٪ من القوى الشغيلة الرسمية عملت في الزراعة في عام ٢٠١١ ، تقلص هذا العدد بحلول عام ٢٠١٧ إلى ٣,٩٪: (٣٪ للرجال و ٠,٩٪ للنساء). في الوقت نفسه ، تشير التقديرات إلى أن التشغيل غير الرسمي قد زاد بشكل ملحوظ ، حيث وصل إلى ٥٪ للرجال و ١٦٪ للنساء ، ويمثل الرقم الأخير حوالي نصف النساء الأردنيات الريفيات العاملات بنشاط في هذا القطاع [5,6].

تشير منظمة العمل الدولية [7] إلى وجود فرق بسيط بين أجور اللاجئين السوريين من الإناث والذكور ، حيث تحصل غالبية هؤلاء على أجر قدره ٥ دينار / يوم. منذ تدفق اللاجئين السوريين ، انخفضت أجور عمال المزارع بنحو ٥٠٪ ، مما زاد بشكل كبير من حساسية سكان الريف لتأثيرات الجفاف.

على الرغم من تحسن نتائج الأردن في مؤشر التنمية البشرية ، فإن حوالي ٦٠٪ من الأسر هشة ومعرضة لخطر انعدام الأمن الغذائي ، و يعاني ١٢,٨٪ من انعدام الأمن الغذائي الشديد. زاد معدل الإصابة بنقص التغذية على مستوى السكان بشكل ملحوظ في السنوات الأخيرة ووصل إلى ١٣,٥٪ في ٢٠١٥-٢٠١٧ ، مقارنة بـ ٦,٦٪ في ٢٠٠٤-٢٠٠٦. تزداد احتمالية تعرض الأسر التي تعولها نساء بنسبة ٦٢٪ لانعدام الأمن الغذائي أو التعرض لانعدام الأمن الغذائي بالمقارنة مع الأسر التي يرأسها رجال [8,9].علاوة على ذلك ، فإن حوالي ثلث أسر اللاجئين السوريين في الأردن تعولها نساء [10]، مما يشير إلى أنها معرضة بشكل خاص لتأثيرات الجفاف بسبب انعدام الأمن الغذائي.

لا توجد مجموعات بيانات حالية أو جهود وطنية جارية لقياس وتقييم آثار فترات الجفاف على دخل الأسرة أو الديون أو القدرة على الحصول على التمويل. تظهر نتائجنا أن المزارعين أصحاب الملكية الصغيرة يعتمدون في الغالب على القروض من المزودين المحليينللمدخلات الزراعية والأجهزة مما يساهم في تضخم كبير في أسعار المدخلات والأجهزة خلال مواسم الجفاف.

تقترض المزارع التجارية الأموال من المفوضين بأسعار فائدة تكون عادة حول معدل مرتفع للغاية يبلغ ٢٠٪. خلال فترات الجفاف ، يقوم المزودون عادة بزيادة أسعار المدخلات لتعويض التخلف عن سداد القروض المتزايدة ، مما يؤثر على القطاع ككل. الاقتراض من الأسرة وأفراد المجتمع (حيث إن الوصول إلى الخدمات المالية الرسمية أمر غير شائع جدا) لتغطية نفقات الأسرة بشكل كبير يعرض المزارعين أصحاب الاراضي الصغيرة وعمال المزارع العرضيين للآثار الموسمية للجفاف. تتعرض النساء بشكل خاص للآثار المالية للجفاف بسبب انخفاض قدرتهن على الحصول على المساعدة الرسمية أو الاقتراضبسبب انخفاض معدلات الاملاك وملكية الأراضي (للضمانات) و انخفاض الدخل و انخفاض معدلات امتلاك الحسابات ولأسباب ثقافية بما في ذلك متطلبات ضامنين ذكور.

النتائج الأساسية المتعلقة بالقدرة على التعاملو التكيف بما في ذلك دراسة حالة من المجتمع

نحن نقدم تصنيفًا مفاهيميًا لآليات إدارة الجفاف بما في ذلك تدخلات ما بعد التأثير ، برامج ما قبل التأثير للتخفيف ، وتطوير السياسات وخطط التأهب. وتتراوح هذه ، بالترتيب ، من آليات التعامل إلى آليات التكيف.

في قطاع الزراعة ، يمتلك الأفراد والمجتمعات والحكومة مجموعة من آليات التعامل قصيرة المدى لتقليل التعرض والحساسية. و تشمل خفض الطلب على المياه على المدى القصير (أنواع المحاصيل السنوية و الموسم واستعمال القيود / الحوافزو الري) ؛ زيادة إمدادات المياه (استخراج المياه الجوفية وخلط مياه الصرف الصحي المعالجة) ؛ التقنيات والممارسات المتعلقة بالملوحة ؛ دعم العلف؛ إرشاد التخطيط الزراعي؛ والتخفيف النقدي.

تشمل آليات التعامل طويلة المدىتقنيات ذات راس مال عالي و استعمال مكثف للطاقة (على سبيل المثال ، تحلية المياه على نطاق صغير ، واستخدام البيوت المحميةوزيادة وتحسين القدرة على معالجة مياه الصرف الصحي والبنية التحتية للشبكة) ؛ تقليل التسرب في شبكات الري ؛ التحولات في مواسم المحاصيل وأنواع المحاصيل وتنوع المحاصيل ؛ تحسينات على ممارسات الري ؛ وعلى الأغلب ، الإفراط في استخراج المياه الجوفية (بما في ذلك المياه الجوفية الأحفورية الغير متجددة.

[5] وكالة المشاريع الهولندية ، ٢٠١٦ أ
Netherlands Enterprise Agency, 2016. *Export Value Chain Analysis Fruit and Vegetables Jordan*. Available at: http://www.bureauleeters.nl/data/103-wsXTPO1yf418/export-value-chain-fruit-vegetables-jordan-2016.pdf

[6] البنك الدولي ، ٢٠١٨ أ
World Bank, 2018a. *The role of food and agriculture for job creation and poverty reduction in Jordan and Lebanon*. Agriculture Sector Note (P166455). 22p. http://documents1.worldbank.org/curated/en/325551536597194695/pdf/Agricultural-Sector-Note-Jordan-and-Lebanon.pdf

[7] منظمة العمل الدولية ، ٢٠١٨
International Labour Organisation (ILO), 2018. *Decent work and the agriculture sector in Jordan: evidence from workers' and employers' surveys*. Available at: https://www.ilo.org/beirut/projects/WCMS_711760/lang--en/index.htm

[8] منظمة الأغذية والزراعة وآخرون ، ٢٠١٨
Department of Statistics (DOS), 2018a. *Statistical Yearbook 2018*. No. 69. Government of Jordan. Amman, Jordan. Available at: http://dosweb.dos.gov.jo/products/jordan-statistical-yearbook-2018-2/

[9] World Food Programme (WFP) and REACH, 2019. *Jordan – Comprehensive Food Security and Vulnerability Assessment*. Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/70245.pdf

[10] البنك الدولي ، ٢٠١٨ ب
World Bank, 2018b. How Does Poverty Differ Among Refugees? Taking a Gender Lens to the Data on Syrian Refugees in Jordan (L. Hanmer, D. Arango, E. Rubiano, J. Santamaria, M. Viollaz). Policy Research Working Paper 8616. Available at: https://documents1.worldbank.org/curated/en/374541539781178899/pdf/WPS8616.pdf

في قطاع المياه ، تتخذ المرافق العمومية والحكومة الموسعة إجراءات تعامل قصيرة المدى : زيادة الإمداد من خلال الإفراط في استخراج المياه الجوفية وإعادة التوزيع من الزراعة وقطاعات أخرى و الشراء من القطاع الخاص و تقليل الطلب داخل شبكة البنية التحتية ومن عموم الناس من خلال قواعد وحملات إعلامية.

ترتبط القدرة على التكيف طويلة الأجل باتفاقيات معاهدات والاندماج في سلاسل السوق العالمية و ترتيبات التوزيع بين القطاعات و تقليل المياه البلدية غير المدرة للدخل و إعادة استخدام مياه الصرف الصحي المعالجة و تحلية المياه و تجميع مياه الأمطار واستخراج المياه الجوفية.

قيمت دراسة الحالة المتكاملة كيفية تفاعل التعرض للجفاف والحساسية وآليات التعامل مع آثار الجفاف على كل من المزارعين والرعاة في الأزرق. تتعلق الجوانب الأولية للتعرض بالمساحة الكبيرة للمزارع السقوية وقطعان الماشية التي تعتمد على المراعي وأنظمة المحاصيل المدمجة والأعلاف المستوردة. ترتبط جوانب الحساسية بالحصول على الخدمات الاستشارية والأطباء البيطريين و ارتفاع أسعار الطاقة (للمزارعين) ومشتريات الأعلاف والمياه (للرعاة) و تلوث المياه الجوفية وانحسارها و انعدام الأمن الغذائي؛ وإضفاء الطابع العرضي وتخفيض التشغيل في المزارع التجارية.

خلال فترة الجفاف ، يعاني المزارعون من أصحاب الحيازات الصغيرة في الأزرق من خسائر في الإنتاج تصل إلى حوالي ٥٠٪. و يرجع هذا في المقام الأول إلى نقص التخزين المناسب أوتحويلالمنتج. تصيبتأثيرات الجفاف المزارعين الفقراء في شكلين: بشكل مباشر من خلال الأضرار التي تلحق بالممتلكات وفقدان الإنتاجية ؛ وبشكل غير مباشر من خلال آلية التعامل لزراعة محاصيل مقاومة للجفاف ولكن منخفضة الارباح لتقليل مخاطرالآثار السلبية المالية التي قد تنجم عن عام سيئ. وبالتالي ، يمكن لبعض آليات التعامل أن تسهم في حدوث انخفاض طويل الأجل في الدخل والمديونية. ومع ذلك ، خلال فترات الجفاف ،تبلّغالمجتمعات عن قدر أكبر من التعاون والتضامن.

خلال فترات الجفاف ، يعتمد الرعاة المستقرين والعاديين على الأسرة الممتدة ، ويلجأ معظم مربي الماشية إلى إنفاق مدخراتهم وزيادة الديون لمواجهة خسارة عائدات المبيعات وارتفاع تكاليف المدخلات أثناء فترات الجفاف. إن بيع الماشية لتجنب الخسائر وزيادة النفقات ، وتوفير بعض الدخل خلال فترة الجفاف ، له تأثير كبير على الاحتفاظ برأس المال والسرعة التي يمكن أن يحدث بها انتعاش القطعان بعد الجفاف. أصبحت الممارسات الرعوية التقليدية أقل ربحا، مما أدى إلى تغييرات غير خاضعة للرقابة في استخدام الأراضي ، مع تحويل المراعي إلى إنتاج زراعي سقوي. خلال فترات الجفاف ، يزداد التنسيق بين الرعاة،وتساعد بعض جوانب نظام حمية ، بما في ذلك الاتفاق الجماعي على تحركات القطيع،المجتمعات على التكيف.

الاستنتاجات الأساسية لتخطيط إدارة الجفاف والبحث المستقبلي من أجل التنمية

حدد العمل في برنامج منطقة الشرق الاوسط و شمال افريقيا للجفاف MENAdrought احتياجات الفاعلين لتحسين إدارة مخاطر الجفاف. تتعلق هذه بمجموعة من المواضيع ، مع الحاجة القصوى إلى سياسة رسمية للجفاف وإجراءات واضحة للتاكيد عن الجفاف مرتبطة ببيانات مراقبة قوية واستجابات خطة الإدارة. لتطوير خطة عمل الجفاف Drought Action Plan (DAP) ، أعطى المتداخلون الحكوميون الأولوية للتأثيرات التي يرغبون في معالجتها في المحاولة الأولى. اختاروا التركيز على تدهور الموارد المائيةو جودة خدمات المياه الصالحة للشرب وإنتاج قطاع الثروة الحيوانية والزراعة و صحة الإنسان وحماية الموارد الطبيعية الرئيسية.

يشتمل الاستعدادلخطة عمل الجفاف وإجراءات التخفيف وتدابير الاستجابة ، على مكونات تتناول بشكل صريح جميع الجوانب المحددة لهشاشة المجتمعات الريفية وقطاعي الزراعة والمياه. يتم تغطية جميع الجوانب تقريبًا من خلال العديد من الأجوبة في هذهالخطة أو وثائق التخطيط الحكومية الأخرى. ترتبط جوانب خطر التعرض للجفاف القليلة التي لم تتم تغطيتها على نطاق واسع بآليات إدارة المخاطر المالية وديناميكيات سوق العمل ، وهناك مجال لإدراجها في المحاولات المستقبلية لخطة عمل الجفاف.

كما تتناول خطة عمل الجفافبوضوح معظم احتياجات مراقبة وإدارة الجفاف التي حددها المتداخلون و لا يزال من غير الواضح إلى أي مدى ستلبي احتياجات المتداخلين للمشاركة من القاعدة إلى القمة بين القطاعين العام والخاص. حيث ان الاجابة عن السؤال المتمثل في ما اذا و الى اي مدى ستلبي الخطة احتياجات المتداخلين وستساهم بشكل كبير في الحد من مخاطر الجفاف ،تعتمد على كيفية تشغيل الخطة ، كما سيعتمد نجاح خطة العمل الخاصة بالجفاف على وجه الخصوص على كيفية تنفيذ خطط إدارة المخاطر الخاصة بالموضوع المحدد والقطاع. توجد فرصة كبيرة لتفعيل هذا التخطيط بطريقة تشاركية وتعاونية.

أخيرًا ، نحدد مجموعة من الابحاث من أجل فرص التنمية لدعم تنفيذ خطة عمل الجفاف (DAP) وتقليل تعرض الأردن لآثار الجفاف الأولية.وهي تغطي مجموعة من المواضيع ، بما في ذلك:

١) دعم المزارعين

٢) المشاركة بين القطاعين العام والخاص

٣) السياسة والحوكمة ،

٤) دعم المعلومات والأدوات الفنية.

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1. Introduction

The MENAdrought project works through the Integrated Drought Management Program's (IDMP) "three pillars" approach to improve overall drought management (WMO and GWP, 2014). The three pillars are:

1. drought monitoring and early warning;
2. impact and vulnerability assessments; and
3. mitigation, preparedness, and response planning.

This report focuses on MENAdrought and the predecessor MENA-RDMS projects' activities and findings related to the vulnerability[11] assessment in Jordan. 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 Jordan.

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 primarily on the agriculture and water supply sectors and secondarily on the health sector and overall economy. In particular, they included analysis of national datasets on agricultural production, hydrological records, disease incidence, government expenditure, and other observation datasets.
- 2019 - present:
  a. enhanced Composite Drought Index (eCDI) improvements including the completion of drought history (2000-present) and drought hazard mapping;
  b. case study participatory research primarily amongst smallholder irrigated and livestock farmers, and pastoralists in Azraq. This took a micro-level livelihoods approach (UNDRR, 2009), and it focused on the following aspects of drought vulnerability: livelihoods (income, debt, and access to finance), food security, and gender-specific aspects of drought impacts; and
  c. Support to the Drought Technical Committee, which has recently completed Jordan's Drought Action Plan.

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 to drought impacts is a socio-environmental phenomenon. Drought risk management practitioners typically explore this dynamic interaction within socio-environmental systems (SES) through a conceptual definition 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

[11] 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.

Potential impact

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

Sensitivity is a highly variable characteristic in a given system. In contrast, exposure is usually 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, etc. 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, etc. In both cases, the exposed assets (the crops or the water for municipal systems) would be the same.

Therefore, within each region, economy, sector, community, etc., sensitivity is highly variable as a feature of numerous sub-systems, whereas exposure varies between regions, economic sectors, communities, etc. In Appendix A we provide substantial detail on the Jordanian context that can help to understand these elements.

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, the provision of subsidised fodder during droughts may help pastoralists cope with drought but will not, on its own, encourage changing practices. In contrast, drought insurance may help people cope with, or adapt to, drought conditions by reducing financial risks associated with drought impacts. While coping would entail a general continuity of practices over time, adaptation would entail a change in practices over time. The line between these two concepts is porous but differentiating between them is particularly useful when consideration of climate change enters the picture.

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 below:

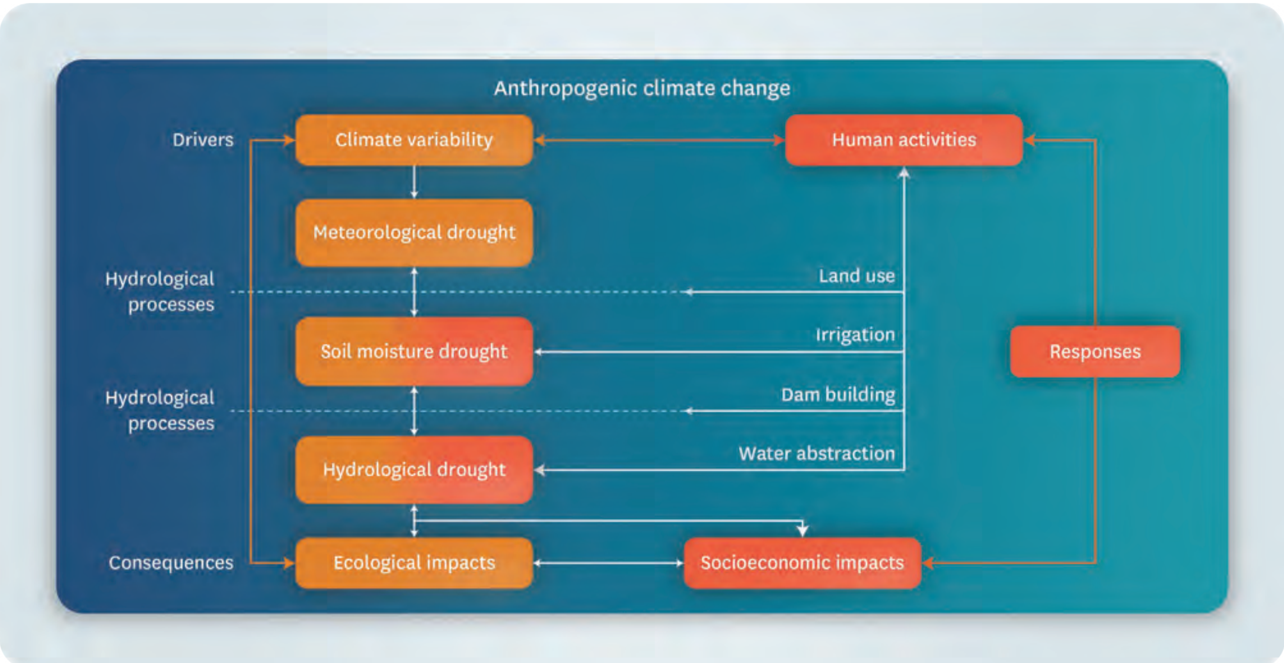

Figure 1. *Drought propagation - effects, responses, and impacts*

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 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 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, thereby reducing the land's future productive capacity. The conceptual diagram in Figure 2 below 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. 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 the 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 is linked directly with the development of the eCDI. 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 eCDI and precipitation indices). This certainly relates to drought vulnerability, but we would need to develop additional methods to support robust scenario modeling 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 at-risk communities, underlying causes of risk, and potential interventions to reduce risks. Table 1 below shows a summary of the project method(s) in relation to each of these approaches, the general types of information produced, specific content on vulnerability components, and comment on its role in understanding drought vulnerability. In addition to the primary research, we reviewed relevant literature, which is not included in Table 1.

The rest of the report is structured as follows:

- Section two provides findings on drought history, hazards, and impacts;
- Section three provides findings on drought exposure and sensitivity;
- Section four provides findings on drought coping and adaptive capacity;
- Section five concludes the report by linking drought management planning to aspects of vulnerability and related research for development needs; and
- 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	Sensitivity	Coping / adaptive capacity	Comment
Community-based resilience and livelihoods assessment	1. Participatory research 2. Focused drought vulnerability case study and 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 the description of primary impact types and locations 2. Key focus on vertical exposure within sectors (from producers to consumers via market chains)	1. From the description of drought management needs 2. Key focus on agro-ecological and socio-economic aspects of sensitivity	1. From the 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 asses 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. eCDI-based drought history assessment 2. eCDI-based drought hazard mapping 3. Statistical evaluation (shown in macro-economic assessment below)	1. Time-series of drought severity 2. Hazard hot spots (frequency of drought events)	1 & 2 Information is hazard-focused; can be coupled with impact data to assess exposure, sensitivity, and adaptive capacity between areas, sectors, etc	1 & 2 As for exposure	1 & 2 As for exposure	1 & 2 We have produced the critical climatological information on which to base spatialized eCDI-based vulnerability mapping and scenario modeling; other components produce relevant data on exposure, sensitivity, and adaptive capacity
Water balance accounting and basin management	1. Participatory research; 2. Quantitative impact evaluation	1. Information on water management including sector monitoring, impacts, and responses including case examples; 2. Primarily information on storage, flows, water quality, and sectoral usage during drought and normal years	1. Types and location of water resources most affected, and flow-on effects 2. Scale of impacts on water resources and sectoral supply and demand	1. Hydrology and water sector characteristics and context that contribute to impacts 2. Limited, but evaluation links to management regimes	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, management planning, monitoring, and capacity for coordination and collaboration
Macro-economic assessment	Statistical evaluation and review of sectoral impacts and government expenditure;	Information on drought effects on agriculture (focus on rainfed systems), forest fires, health, and government expenditure.	Focus on the relative exposure of various sub-sectors	Limited, but this data helps to inform assessment of sensitivity through other approaches	Examination of how coping mechanisms (e.g. feed subsidies) affect sub-sectors	This information is particularly useful in terms of determining sectors of relative importance to focus on, and it informs the analysis of sensitivity and coping mechanisms evaluated through other approaches and methods
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 exposuresurfaced by participants and considered in the 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 eCDI to evaluate drought history and spatial aspects of drought hazard in the 2000-2021 period[12]. We then provide an overview of historical drought impacts and discuss impacts specifically in the water and agriculture sectors.

2.1 Drought history

Drought history using the eCDI

Results from the eCDI analysis (see Figure B1 in Appendix B) show two major drought events from 2000-2019: 2000-2001 and 2009. In these years, drought progressed throughout the year across large areas and increased in intensity, which led to severe impacts. The driest year of the series is 2001 - the whole country was severely impacted by drought in the winter and spring, and it was the fourth consecutive dry year (since 1998). We note that the major drought of 1999 was not captured in this analysis as the necessary remote sensing data to produce the eCDI are only available from 2000 onwards.

In contrast, in 2008 and 2011, drought affected portions of the country in the fall and spring but winter months were more typical and so impacts were far less severe. In 2002 and 2012, drought conditions affected almost exclusively the *Badia* and desert areas. The 2014 “flash” drought had rapid onset and subsidence, particularly over the highlands, and it had severe effects.

Drought frequency in the period is about 42%, which is an indication of the country’s aridification. The eCDI maps are particularly useful for identifying drought in rangelands where ground measurements are scarce.

Characterising drought history with observation data

The Jordan Meteorological Department's (JMD) data (MWI, 2018b) show that droughts of record – defined as annual Standardized Precipitation Index values below (-1) – include 1933; 1958-62; 1983-1984, 1998-2000, 2007-2009 and 2013-2014. We present analyses of drought history per governorate using precipitation data only in Figure B2.

The Jordanian government has declared drought once – in 1999 when total precipitation led to an SPI of -2.8 and the national estimated precipitation deficit was over 75% (Al-Karablieh, 2017; Al-Adaileh *et al.*, 2019). This is a very high threshold compared to the WMO’s recommendation of drought declaration for precipitation deficit exceeding 40% (Verner *et al.*, 2018). Several droughts stand out for their effects on Jordan’s economic growth patterns and governance: 1958-1962, 1998-2000, 2007-2009, and 2014. We describe these further in Section 2.3.

2.2 Drought hazard

Figure 3 shows the drought hazard results for Jordan according to district. It identifies areas 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.

[12] Here 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. Other tables in this report use calendar years; as a result, some figures and tables will show effects in the year prior to drought years listed here.

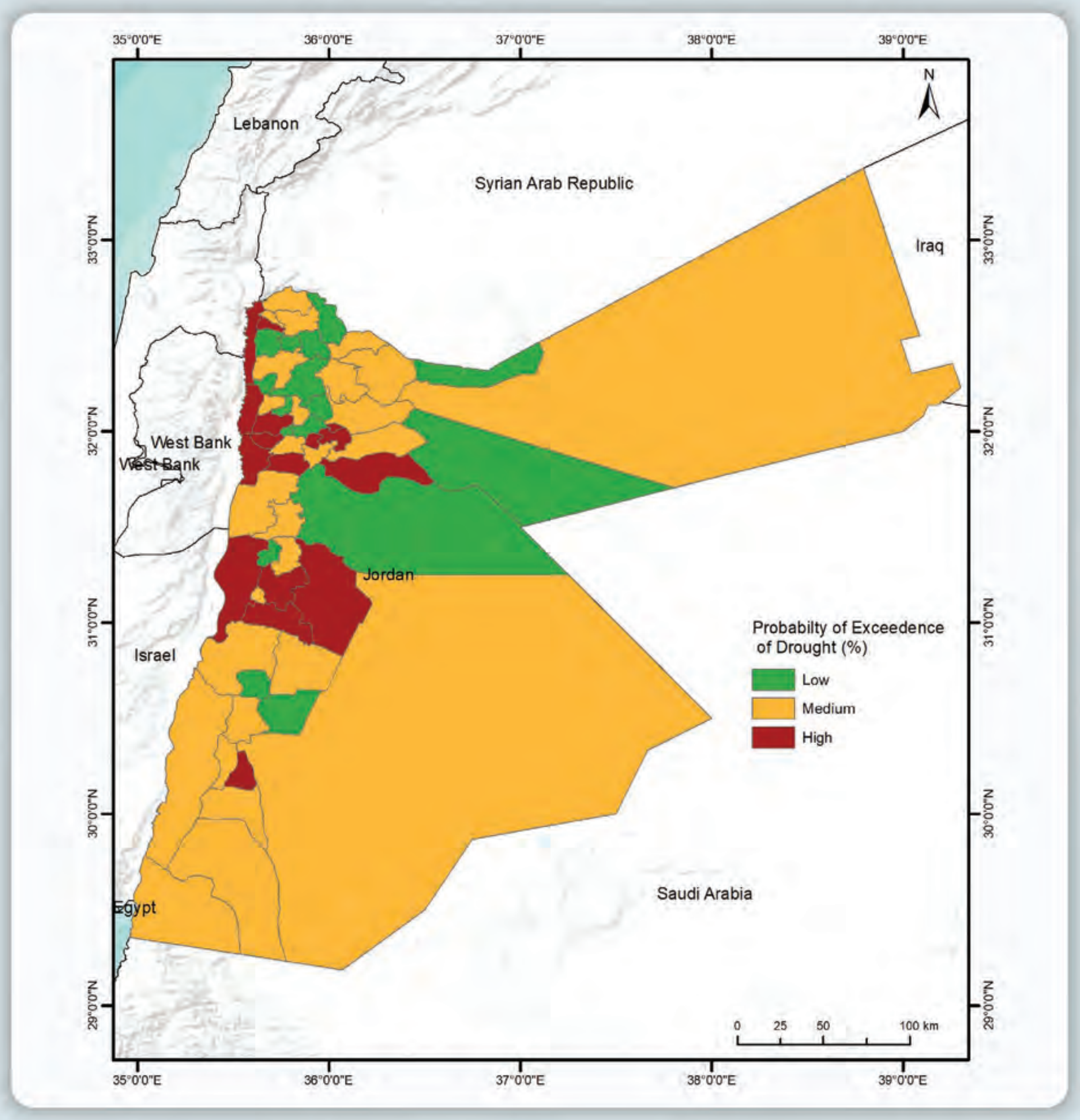

Figure 3. *Drought hazard map for Jordan*

The map illustrates that the Rift Valley mountain chain (from south to north on the western border) has high drought hazard. Likewise, Karak and Balqa' governorates have particularly high hazard, as do parts of Zarqa, Jarash, and Ma'an. The eastern area of the northern highlands in Irbid, Ajloun, and Jarash have lower hazard. Likewise, parts of Amman, Zarqa, Mafraq, and Tafileh governorates have lower hazard.

2.3 Drought impacts – historical overview

Brief characterisation of impacts from historical and modern droughts helps to illustrate the scale and range of negative effects. Of course, drought impacts cannot be separated from management responses, and so we provide more detail on these themes in Section 5. We provide a conceptual diagram showing the interaction of drought impacts on various SES components in Figure B3.

Historical drought of record

The 1958-1962 drought caused major migration from rural areas to cities and virtually ended camel husbandry as an economic activity in Jordan. As a result, the government incentivized the settling of nomads by establishing villages and providing electricity, groundwater abstraction permits, land farming authorization, and the development of agricultural credit schemes (Lancaster and Lancaster, 1999). Many nomads abandoned pastoralism and the traditional *Hima* system in which the tribe moved to seek good forage while heavily grazed land was allowed to lie fallow to recover (Myint and Westerberg, 2014). Likewise, the post-drought period saw the initial expansion of irrigation and beginning of significant groundwater mining.

Modern drought of record

The 1998-2001 drought saw precipitation declines over 75%. As reservoirs fell to their lowest historical levels, the Jordanian government imposed restrictions on irrigation that became a lasting template to address water insecurity for municipalities (Molle *et al.*, 2008).

Moreover, the drought caused a major food insecurity problem and so the government of Jordan requested World Food Programme (WFP) assistance. The FAO and WFP (1999) assessment of drought impacts concluded that the domestic cereals harvest dropped from 10% of total domestic requirements to 1%, which they considered an alarming status. To help farmers cover the losses in 1999-2000, the government introduced a direct subsidy to farmers in the Jordan Valley who had water allocations cut due to the drought (UN-ESCWA, 2005).

"Flash drought" of 2014

The 2014 drought can be considered a "flash drought" – quick onset, intense, and short-lived – at the scale of the country and the Levant, respectively (Bergaoui *et al.*, 2015). Despite the global food commodity price spikes in 2008 and 2011 (World Bank and FAO, 2012), and the sizeable influx of Syrian refugees starting in 2012-2013, this drought did not affect food security severely. However, it did cause social unrest and other impacts. Farmers organized protests using social media to push the government to declare a drought, and several parliamentarians supported these claims.

However, the Ministry of Agriculture considered that the impacts were localized and did not affect exports significantly, and the precipitation deficit did not hit the threshold of 75% below normal. The rationale not to declare drought due to lack of impact on agricultural exports angered farmers as most of them, particularly smallholders, rely on domestic sales (Netherlands Enterprise Agency, 2016).

Late onset droughts in 2008 and 2021

Late onset droughts have particular patterns of impacts, particularly on rainfed cereals and crop-livestock integrators. These droughts do not have major total aggregate economic impacts because the specific sectors and populations most affected are relatively small proportions of the total, and also they tend to be poorer. This also means that impacted populations are less able to cope effectively. For instance, severe late onset drought in *Tafileh* this year is anticipated to exacerbate food insecurity significantly, especially since people have not recovered from COVID-related economic shocks.

2.4 Drought impacts on water resources and water supply

Surface water

Droughts decrease surface water availability, but the relationship is complex because of upstream storage, diversions, withdrawals, unconventional water supply, and interactions with groundwater discharges. The three primary surface water basins are heavily modified and intensively farmed (see Figure 6 at the bottom of Section 2.5) and the relationship between drought and surface water flows has weakened rapidly in recent years. More detail is provided in Appendix B.

Yarmouk River outflows to Jordan dropped from approximately 300MCM/year by 1980 to 150 MCM/year in 1997, and during the drought years of 1998-1999 this decreased to 65MCM and 55MCM/year, respectively (Hazzouri, 2006). Additional Syrian dams and abstraction reduced flows further until 2012 when the outbreak of the Syrian war resulted in significantly increased flows to Jordan (MWI, 2018b). Precipitation is now only roughly correlated (R^2 of 0.36) with streamflow. Thus, clearly distinguishing between the effects of drought as compared to increased abstraction and water storage is difficult.

The Zarqa River, in contrast, has substantially increased total discharges in the past two decades due to augmentation from treated wastewater. However, numerous small tributaries have dried completely due to drops in spring discharges, and drought impacts on natural baseflows are significant (ibid).

Overall, Jordan Valley water availability declined from an average of over 370MCM/year in the 1990s to about 250 MCM per year during the 1997-2000 drought period (Hazzouri, 2006). At present, discharge from the Jordan River into the Dead Sea ranges from 20-200MCM/year compared to the natural baseline of approximately 1,300MCM (UN-ESCWA and BGR, 2013).

Groundwater

Drought impacts on springs are severe, and they are exacerbated by the fact that groundwater pumping increases dramatically in drought years. In the case of multi-year droughts, spring discharge can take years to recover, if it ever does. Figure 4 below illustrates this clearly for spring discharges in each major groundwater basin (MWI, 2018b). The effects of the 1998-2001 drought are stark; effects from the 2009 and 2014 droughts are also evident in the discharge data.

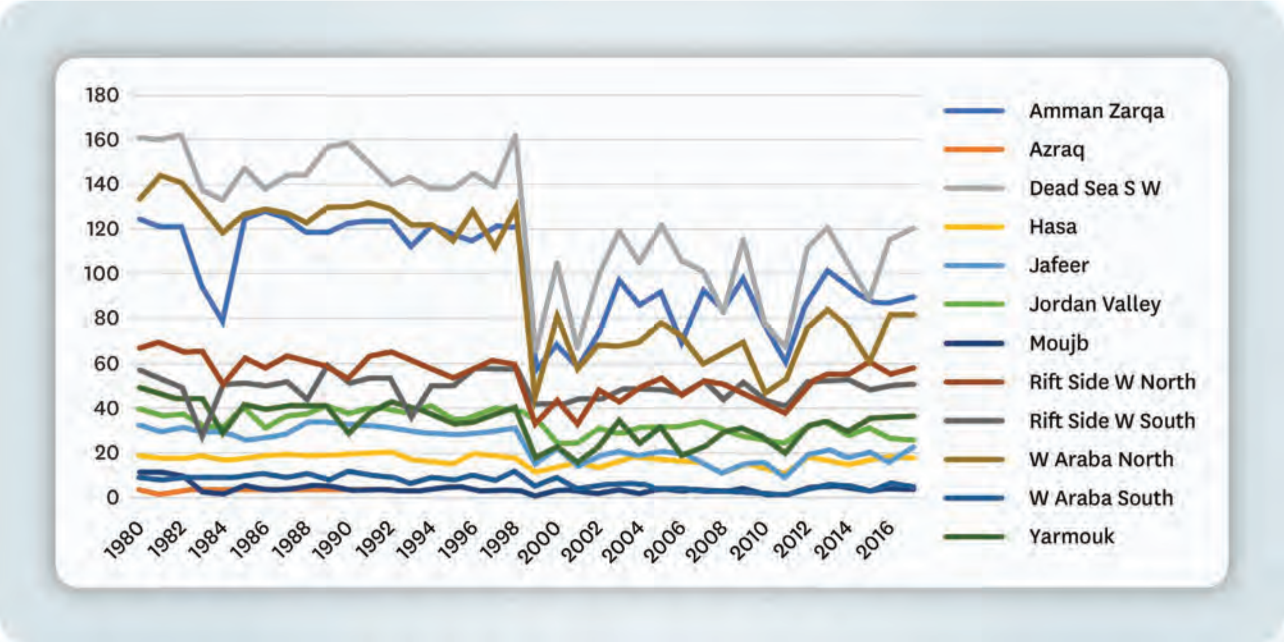

Figure 4. *Annual spring discharge (y-axis in MCM) per groundwater basin ("w" in the legend is short for wadis). Source: MWI, 2018b.*

Monitoring wells in major basins show water table declines of about 1m/year (Azraq) to over 3m/year (Yarmouk). Drought increases the speed of declines with lag times dependent on the specific aquifer. Groundwater abstraction has increased significantly in recent decades and exceeds recharge rates, often dramatically, as shown in Figure 6 at the end of Section 2.5.

Water quality

Drought and over-abstraction also affect groundwater quality. Spring discharges have increased in salinity over time, and available data show salinity increasing in several major springs in the Amman-Zarqa basin following the 2007 and 2014 droughts (ibid). Likewise, drought reduction in Zarqa flows leads to salinity and other water quality issues as the ratio of treated wastewater to river flows increases substantially in drought years.

Municipal water supply

Drought leads to lower municipal water supply. Figure 5 below shows typical supply per month in normal and drought years. The difference can be large (about 10% in late summer, for instance).

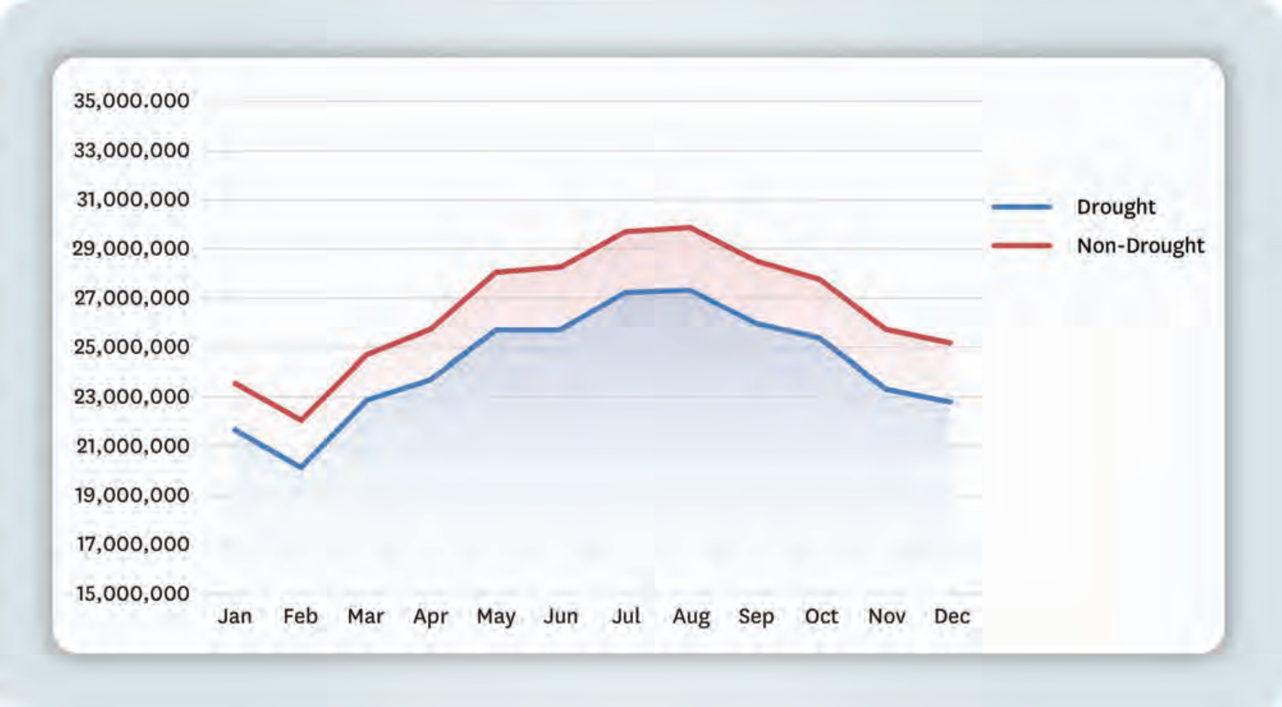

Figure 5. *Municipal water supply in drought and normal years*

2.5 Drought impacts on agriculture

Due to the intense drought, agricultural GDP in 2000 was 40% lower than 1990 levels, and it did not recover to pre-drought (1998) levels until 2003. Drought costs from the flash drought of 2014 reached an economic loss of $90 million. When we derive statistical relationships between precipitation and agricultural GDP, we estimate that a modern extreme drought would lead to losses of $225 million in agricultural GDP, exclusive of government expenditure (MWI, 2018b; DOS, 2018a). Also, we found that agricultural employment drops significantly following drought years. Below we provide summary information on drought impacts in various sub-sectors. Figure B4 shows precipitation values in relation to production values for agricultural sub-sectors.

At a macro-level, drought impacts on economic output from the irrigated vegetable and livestock sub-sectors are not substantial, whereas they are significant (but complex) for the irrigated fruit and olives sub-sectors. Impacts are highest on the cereals sector because it is predominantly rainfed. We provide additional detail in Appendix B.

Irrigated vegetables and fruit

Vegetable output is not significantly affected by drought whereas fruits may be. The difference is likely partially due to the location and source of irrigation water given that vegetable production is concentrated in the Jordan Valley and is reliant on treated wastewater blended with King Talal dam surface water.

In the fruit sub-sector, deep and/or long (multi-year) droughts affect output significantly, though there are not straightforward relationships between wet and dry years' total productivity. Drought severity threshold and longevity effects, and likely commodity market changes, complicate the relationship. For instance, 1999 had a very deep drought and the lowest fruit sector earnings in a decade. However, 2000 had a moderate drought and fruit sector earnings in constant prices were higher than 2002, which was a moderately wet year. The olives sub-sector is highly impacted by drought, though like with fruit, not in a predictable linear fashion.

Cereals

Drought effects on the cereals sub-sector are severe because it is predominantly rainfed. For instance, during the deep 1999 drought, output in current values was only $6.06 million compared to $20.16 million in 1998 (an average precipitation year) and $24.25 million in 2002 (a wet and therefore bumper year; ibid). Wheat output tends to relate more strongly to drought than barley output.

Livestock

Historically, livestock were a source of farmers' overall resilience to drought, and herd-sizes fluctuated significantly. The beginning of mass feed importation and subsidies altered these systems drastically and the total sheep population has increased by six times since 1960 with particularly high rates of growth during the mid-1980s, to early 1990s partially due to major influxes from Iraq (DOS, 1975; DOS, 1980; DOS, 1985; DOS, 1990; DOS, 2016).

Drought and feed subsidy effects on the livestock sub-sector are difficult to disentangle – we discuss these themes further in Section 4.2.

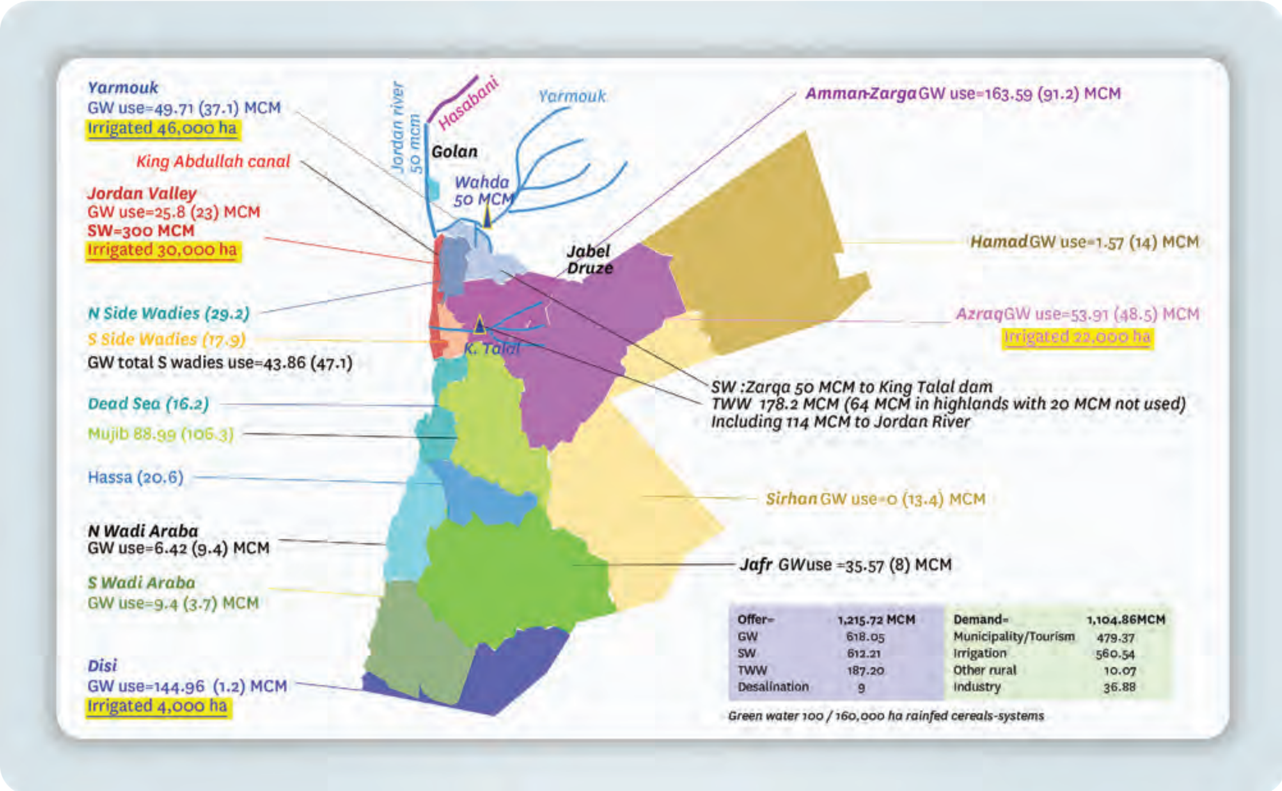

Figure 6. *Hydrological basins and irrigation in Jordan (developed by the authors using data from MWI 2018).*

2.6 Drought impacts on communities

Drought events significantly affect the viability of rural livelihoods and generate a host of direct and indirect impacts. These include rural-urban migration, food insecurity, farmer indebtedness, health and nutritional impacts, and a general decline in sector productivity and investment as producers seek to avoid risk and employ short-term coping strategies to the detriment of medium- and long-term stability and profitability. Here we discuss human health and rural out-migration. We explore other themes in Sections 3.4 and 4.4.

Human health

We evaluated relationships between drought and diarrheal disease incidence. Overall incidence has dropped significantly over the last 20 years due to investment in municipal water supply, sewerage, and the health sector (all adaptive capacity elements), especially in rural areas.

The analysis showed that precipitation deficit (using SPI) did not correlate with diarrhoeal incidence, but the temperature difference index did. Likewise, the analysis showed that per capita water availability and consumption were negatively correlated with disease, and drought affects these indicators. Location (governorate) was the most important overall factor, which strongly signals that wider socio-economic factors of sensitivity drive diarrhoeal disease burden.

In sum, drought, as assessed by precipitation alone, does not correlate with increased disease burden, but its wider effects on temperature, water scarcity, and water availability do.

Rural out-migration

There has been no comprehensive assessment of the role of drought in rural out-migration within Jordan. Case studies show that drought typically leads to a short- and medium-term intensification of typical labor migration patterns; this is in contrast to sudden-onset disasters, which lead to major local displacement (Raleigh *et al.*, 2008).

With drought, only a small share of migrants chose to relocate permanently, with case studies noting 0-30% become permanent migrants (Perch-Nielsen, 2004). Thus, on its own, drought is unlikely to cause the mass rural exodus envisioned in environmental catastrophe literature and reminiscent of that which Syria experienced from 2005 onwards (Raleigh *et al.*, 2008).

To date in Jordan, increased permanent migration is not the primary response to drought. This is partially because such substantial labour migration already takes place and is part of a fluid system in which rural households continue to rely on family networks in both rural and urban areas. Internal migration underpins rural household stability and coping in the face of continued pressures including drought (ibid).

The issue of external migration from Syria, Iraq, and Palestine, which in some cases is linked to drought and water scarcity, contributed to the discourse of water scarcity as a national security theme in Jordan (Weinthal *et al.*, 2015). However, because there is no definition in international law of climate and environmental refugee status, limited information is available on the scale of the issue in connection to drought in particular.

2.7 Priority drought impacts

As part of this research, we convened a group of government officials, researchers, and civil society organizations to prioritise the sectoral impacts on which drought management planning activities should focus. They evaluated the relative importance of specific drought impacts in the past, present, and their prediction of the future. They undertook this exercise for a range of impacts thematically grouped as follows:

1. Field crops;
2. Crops and fruit trees;
3. Seasonal vegetables;
4. Livestock;
5. Forests;
6. Socio-economic impacts on farmers and other directly-affected industries;
7. Economy and labour;
8. Water supply;
9. Human health;
10. Critical habitats and the environment; and
11. Social impacts and quality of life.

In relation to the primary sector production themes (1-5 above), total productivity was the overriding concern, with quality issues and shifting patterns of production coming in second. For farmers and other affected individuals, unemployment themes were the most salient, with farmer bankruptcy coming second.

For the wider economy, the increase in food prices and overall effect on economic development were the most important issues. This connects to prioritised social impacts that had relatively low differentiation between top themes: increasing conflicts between water users, public safety and dissatisfaction with the government, and increasing indebtedness, particularly of farmers.

For water supply, priority themes included the shortage of water supply to agriculture, groundwater table declines and increasing cost of abstraction, and challenges meeting drinking water needs. This links to priority health impacts, which included increase in water-related diseases (those associated with lack of water for hygiene, sanitation, and cleaning purposes) as well as vector-borne diseases.

They also relate to prominent environmental impacts such as loss of wetlands and swamps, erosion and changes in the landscape including those associated with desertification and salinization of soil and water.

The full prioritisation rankings are shown in Figures B5-B14.

2.8 Section summary

Analysis using the enhanced Composite Drought Index (eCDI) shows two major drought events in the past two decades. These took place in 2001 and 2009. In these years, drought extent and intensity increased throughout the year, which amplified drought impacts nationally. Late-onset spring droughts occurred in 2008, 2011, and 2021. In these years, drought affected portions of the country in the fall and spring but winter months were more typical; severe impacts were therefore specific to some locations and farming systems, particularly those that integrate cropping and livestock. In 2002 and 2012, drought conditions almost exclusively affected the *Badia*. The 2014 “flash” drought had rapid onset and subsidence, particularly over the western highlands.

The hazard map illustrates that the Rift Valley mountain chain (from south to north on the western border) has high drought hazard. Likewise, Karak and Balqa’ governorates have particularly high hazard, as do parts of Zarqa, Jarash, and Ma’an. The eastern area of the northern highlands in Irbid, Ajloun, and Jarash have lower hazard. Likewise, parts of Amman, Zarqa, Mafraq, and Tafileh governorates have lower hazard.

As Jordan’s three primary surface water basins (Jordan Valley, Yarmouk, and Amman-Zarqa) are heavily modified and intensively farmed, the relationship between drought and surface water flows has weakened rapidly in recent years. Drought impacts on groundwater can be severe; in the case of multi-year droughts, spring discharge can take years to recover, if it ever does.

Drought’s agricultural impacts are strongest on rainfed systems including cereals-based systems and staple crops for nationwide food security (chickpea, lentils, and olives), crop-livestock integrators, and rangelands pastoralism. Drought effects on the irrigated fruit sub-sector are significant but not straightforward and linear. Historically, drought effects on livestock have been severe, but the introduction of feed subsidies has significantly increased sector-wide coping capacity in recent years. Nonetheless, the distribution of benefits is uneven, with smallholders still facing severe impacts during droughts. This highlights the criticality of looking beyond macro-level indicators and assessing distributional impacts within a given sector and sub-sectors.

Government stakeholders prioritised a range of drought impacts to address through longer-term planning. These connect to agricultural productivity, labour markets, water supply, and related soil and water quality issues (especially salinisation), as well as social cohesion.

Drought events significantly affect the viability of rural livelihoods and generate a host of direct and indirect impacts, including on human health and rural out-migration. Our analyses show that drought, as assessed by precipitation alone, does not correlate with increased disease burden, but its wider effects on temperature and water availability do. Concerning migration, the literature indicates that drought typically leads to a short- and medium-term intensification of typical labour migration patterns but increased permanent migration is not the primary response to drought.

3. Vulnerability – exposure and sensitivity

In this section, we describe aspects of drought exposure and sensitivity determined through participatory research conducted with government stakeholders and smallholder farmers as well as statistical and qualitative analyses undertaken for the drought impact studies.

3.1 Water supply exposure and sensitivity

Overview

Jordan's water supply is highly exposed to drought impacts. Jordan's water availability has decreased from 714 m^3/capita/year in 1990 to 292 m^3/capita/year in 2017 (MWI, 2018b; CBJ, 2018). This is amplified by the fact that Jordan is a downstream riparian country and so surface and groundwater inflows (which also affect water quality) depend on upstream usage and storage. Surface and groundwater basin characteristics are shown in Figure 6 above.

Water consumption in the municipal supply sector quadrupled in the past 30 years, and its share of total economy-wide water use increased from about 18% to 45% in that period. Despite rapidly increasing supply, produced liters per capita per day have decreased due to population growth and reduced from 141 l/capita/day in 1990 to 126 l/capita/day in 2017 (MWI, 2018b; CBJ, 2018).

Here we describe several aspects of exposure and sensitivity that interact and result in high potential impacts from drought in Jordan's water supply sector:

- National water stress;
- Economy-wide water use efficiency;
- Refugees increasing pressure on water infrastructure;
- Lack of financial sustainability for water and sewerage utilities;
- Non-revenue water and leakage;
- Interrupted pumping and non-reliable service;
- Reservoir management; and
- Energy subsidy policy for agriculture and water pumping.

National water stress

Water stress – total water usage compared to renewable resources and environmental flow requirements – has increased rapidly since the 1990s. This is possible due primarily to the consumption of non-renewable groundwater. Drought years increase water stress and wet years reduce water stress, though in all years after 2003, economy-wide use of water surpasses renewable resources. As a national aggregate, this masks local variation in over-abstraction, as indicated in Figure 6.

Figure 7 below shows water stress increase over time with spikes during drought years as determined by SPI values. We provide the relevant formula and data tables used to calculate Figure 7 in Appendix C.

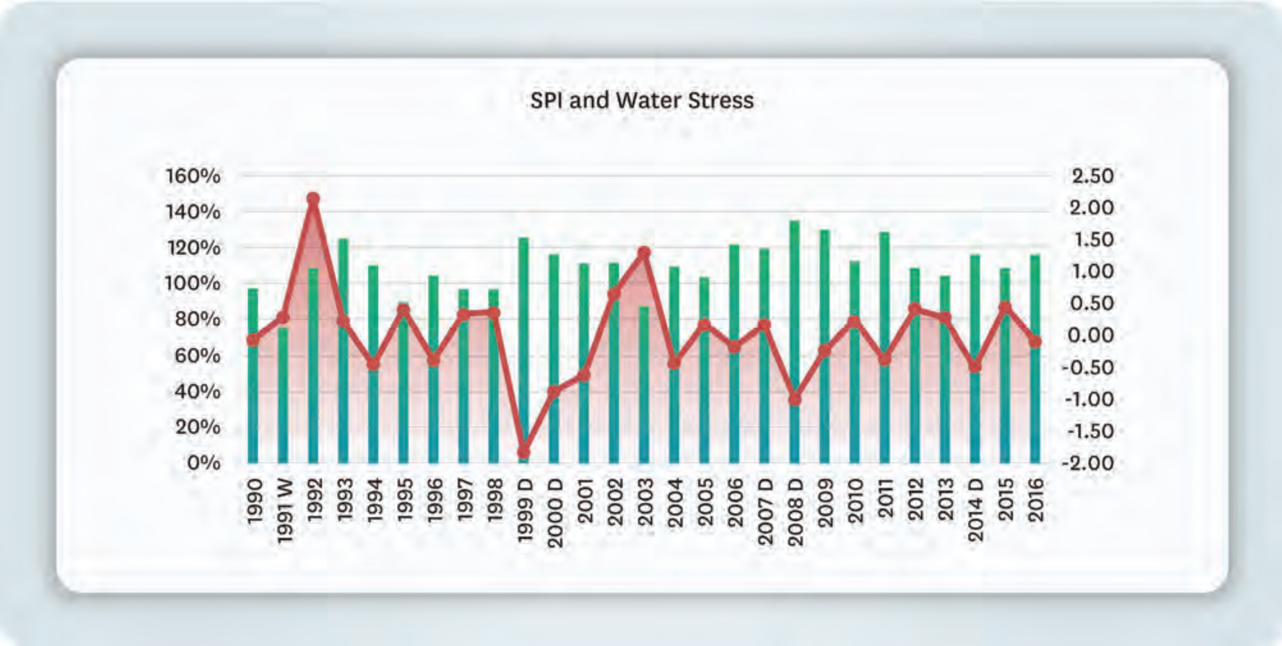

Figure 7. *Water stress (Blue bars: water abstraction compared to renewable water supply, left Y-axis) and SPI (Red line, right y-axis) in Jordan from 1990-2016. Source MWI, 2018b.*

Structural groundwater over-abstraction increases the municipal supply sector's sensitivity to drought impacts because it increases overall production costs and increases reliance on an inherently non-renewable resource. Likewise, drought exacerbates water quality challenges such as pollution, salinization, and seawater intrusion. These issues result from limited environmental law enforcement, solid waste risks for surface and groundwater contamination, urbanisation, and poor agricultural practices.

Economy-wide water use efficiency

Total economy-wide water use efficiency ($ output/m^3 water consumed) has dropped significantly in the last 20 years. Declines in the services sector, which includes municipal water supply as a sub-sector, are the major cause.

The period of rapid decrease (2006-2015) in services sector efficiency coincides with the global financial crisis and the arrival of Syrian and Iraqi refugees, which caused a dramatic shift in the makeup of sectoral water use. In this period, municipal supply increased its share of economy-wide water use by more than 10%. Due to subsidies (direct and embedded), municipal water is billed well below costs (under $1/$m^3$ for the first 15m^3/month); any increase in its proportional makeup of the sector will drive down overall efficiency.

The decline in services sector efficiency, therefore, reflects general economic conditions as well as the structure and makeup of the sector and proportional water use within it. Some perspective is helpful: water value in the agriculture sector is about 0.2-0.4 JD/m^3 – in some cases, this is less than the total embedded cost without subsidies – whereas it is about 70 JD/m^3 in industry.

Refugees increasing pressure on water infrastructure

Jordan has a local population growth rate of 2.2%, but its population grew from 6.1 million in 2010 to around 10.3 million (of whom about a quarter are migrants and refugees) in the middle of 2018 due to the influx of refugees, mainly from Syria and Iraq. Of the foreign population, 1.3 million are Syrians (DOS, 2018b), of whom nearly 700,000 are "persons of concern" and therefore highly vulnerable. Jordan comes second only to Lebanon in terms of refugee populations per capita globally (UNHCR, 2018).

Given that pre-existing water supply and treatment infrastructure were inadequate to provide all Jordanians and long-term Palestinian residents access to piped supply and continual service, significant population increases in a short time-period has resulted in pronounced difficulties for utilities.

Permanent, reliable water delivery infrastructure is often lacking in refugee areas. Where limited services exist, there is governmental hesitation to make them permanent, and non-governmental organizations have often provided leadership and resources for sanitation delivery (Breulmann, 2021). Drought exacerbates all of the impacts and difficulties described above, and the effects of this are more pronounced for refugees because of their socio-economic precarity.

Lack of financial sustainability for water and sewerage utilities and Jordan Valley Authority

Municipal water is relatively expensive to provide in Jordan because of scarcity and the high cost (largely from electricity consumption) involved in its acquisition, treatment, transport, and distribution. In 2005, the sector accounted for 1.32 kWh/m^3 of water used, compared to 4.43 kWh/m^3 in 2015 for both irrigation and municipal systems. Energy intensity was much higher for municipal supply (8 kWh/m^3) than for irrigation (0.17 KWh/m^3) in 2015 (World Bank, 2018a). The average cost of water service for all Jordan can be estimated to be 0.89 JD/m^3 of billed water and 0.51 JD/m^3 of water supply (Al-Assa'd *et al.*, 2011), and 0.065 JD/m^3 for irrigation in the Jordan Valley (Van den berg and Al Nimer, 2016).

Cost analysis shows that the government of Jordan has been subsidizing these water services. For example, the Jordan Valley Authority (JVA) has charged the extremely low rate of 0.011 JD/m^3 since 1994 for irrigation water (ibid). Lack of financial sustainability in the JVA and municipal water and sewerage sector is a source of sensitivity as it leads to long-term under-investment in infrastructure and increasing public debt burden (ibid). For example, operating losses for the JVA in 2012 were 40% of the total budge (ibid) and by 2018 the government was subsidising JVA with transfers of about JD 35 million, whereas revenues were under JD 10 million (World Bank, 2019).

The Water Authority of Jordan (WAJ) and three distribution companies reached 89% of cost recovery by end-2017. However, WAJ and the water distribution companies ran an overall deficit of 1.3% of GDP in 2019, up from 0.9% of GDP in 2018. The sector also accumulated new arrears to the electricity sector estimated at 0.25% of GDP for 2019 (IMF, 2020).

To strengthen the financial position of the water sector, authorities are implementing a strategy at the behest of international creditors and the IMF in particular. It plans to centralize WAJ's debt-management and investment funding within the Ministry of Finance, and cover WAJ's gross financing needs through budget transfers.

Efforts to return utilities to cost recovery currently underway will include increasing the water and wastewater tariff, reducing water losses, and improving relative improvement of performance and bill collection (Van den Berg and Al Nimer, 2016). With increased financial hardship among increasingly impoverished rural communities, non-payment of water bills, illegal boring, and the unlicensed removal or vandalism of water meters are likely to increase, despite improvements in enforcement.

It is important to note that a significant proportion of increasing expenses and debt accumulation in recent years is due to the influx of refugees in the northern and central parts of Jordan. This necessitated re-arrangement of water supply schemes across the country, such as diversion of Disi wellfield water to central and northern governorates rather than Amman, and increasing surface and groundwater pumping from the Jordan Valley to Amman.

Non-revenue water and leakage

Non-revenue water is the ratio between total water supply and billed water. It has two primary components: administrative losses (water that is consumed but not billed), and physical losses (water that is lost from the system). Administrative losses can be caused by metering errors, illegal connections, and other reasons. Physical losses are due to leaks, pipe breakage, etc.

Jordan's aggregate non-revenue water reported in 2017 was about 50%, and this has ranged between 42% in 2011 to 52% in 2014 as shown in Table 2 below. The estimated physical losses in the network are consistently about 45% of all non-revenue water, while the rest is due to administrative loss, illegal connections, metering errors, etc. This national aggregate masks major regional variation in non-revenue water – ranging from 28% to 73% in different governorates as shown in Table C2 in Appendix C. This variation is attributed to reasons such as the age and condition of pipes, pressure, water quantity, supply duration, metering errors, illegal connection, and theft.

Table 2. *Water supplied and water consumption including non-revenue water for the period (2005-2017; MWI, 2018a).*

Year	Population (DOS data)	Municipal Water Suppled (MCM)	Municipal Billed Water	Non-Revenue Water (mcm)	% non-revenue water	Physical loss in network (mcm)	Per Capita Water Uses, All purposes (m³/ capita/yr)	Per Capita Domestic Water Supply (l/c/d)	Per Capita Domestic Water Consumption (l/c/d)
2005	5,758,000	282	153.7	128.3	0.45	57.7	444	134	107
2006	5,928,000	286.3	163.2	123.1	0.43	55.4	423	132	107
2007	6,106,000	300.9	171.5	129.4	0.43	58.2	417	135	109
2008	6,293,000	310.4	173.8	136.6	0.44	61.5	402	135	108
2009	6,490,000	313.4	175.5	137.9	0.44	62.1	397	132	106
2010	6,698,000	327.7	186.8	140.9	0.43	63.4	362	134	108
2011	6,993,000	330	191.4	138.6	0.42	62.4	350	129	105
2012	7,427,000	339.6	180	159.6	0.47	71.8	308	125	99
2013	8,114,000	369	191.9	177.1	0.48	79.7	300	125	98
2014	8,804,000	428	205.4	222.6	0.52	100.2	299	133	102
2015	9,559,000	439	213.8	225.2	0.51	101.3	288	126	97
2016	9,798,000	449.5	224.8	224.8	0.50	101.1	291	126	97
2017	10,013,556	460.8	230.4	230.4	0.50	103.7	292	126	98

This high proportion of non-revenue water contrasts unfavourably with the situation in other countries. For example, non-revenue water is only 8% in Singapore (one of the lowest worldwide), and about 30% in Bangkok, which is around the average among developing countries. It is unclear whether the rapid increase in non-revenue water from 2011 is due to the influx of refugees, but this is highly likely given the significant institutional burden placed on water utilities as they attempted to meet rapidly increasing demand. Also, regions with higher proportions of refugees such as Amman, Irbid, Zarqa, and Karak have seen increases in non-revenue water since 2011.

Jordanian efforts to reduce the high rate of non-revenue water have focused on the replacement of networks to minimize leakage and illegal connections. For example, USAID Jordan is strengthening the water sector through the construction, restructuring, and rehabilitation of water networks, pressure management, and supply of equipment and tools, in addition to introducing smart metering and rapid leak detection technologies to help Jordan achieve its planned target of reducing water losses from the current 47% to 36% by 2040. To date USAID's non-revenue water reduction activities have reduced water losses from 44% to 26% in eleven water distribution zones (DMAs) across Jordan[13].

Interrupted pumping and non-reliable service

Interrupted pumping was introduced in Jordan in the early 1980s when the volume supplied became insufficient to meet network requirements for pressurisation. Interrupted pumping has led to two major impacts: construction of cisterns and roof tanks and accelerated degradation of water supply networks. Household storage capacity has to cover the needs for at least one week. Interrupted pumping causes damage to the water supply infrastructure and increases maintenance requirements.

Drought impacts on municipal water supply include reduced total supply as shown in Figure 5 above and longer times between network pressurization.

Reservoir management

Stakeholders mentioned that reservoir management has been an aspect of sensitivity in the past. For instance, during the dry years of 2007–2009, there were unplanned water releases early in 2007 without adequate consideration of the drought's continuation. This contributed to the severe lack of surface water storage during 2008 that was exacerbated by low rainfall. It is unclear to what extent this is a common or widespread aspect of sensitivity.

Energy subsidy policy for agriculture and water pumping

Energy subsidies reduce the cost of water abstraction, which is particularly relevant for irrigation water use. The electricity tariff for legal wells has been cross-subsidized by other consumer groups. Tariffs increased in 2012 to JD 0.066 per kWh, in 2015 increased to JD 0.087 kWh, and water pumping is now charged at a flat rate price of

[13] See USAID's Non-Revenue Water (NRW) Phase 1 and 2 activity in Jordan.

94 fils/kWh. Yet the actual cost recovery-based tariff is likely to be about double that and in the range of JD 0.145-0.178 per kWh. Therefore, groundwater abstraction is subsidised, and pricing already does not reflect scarcity value. Given that much groundwater is taken without payment (via illegal or unregistered wells), the primary use cost is related to pumping. We provide more detail on this theme in Appendix C.

3.2 Agriculture exposure and sensitivity – sector overview

Estimated water use in the agriculture sector has dropped considerably, from about 600 MCM/year in the mid-1990s to under 500 MCM/year in the mid-2010s (with high uncertainty in total volumes due to illegal groundwater pumping). Meanwhile, sectoral value-added has stayed relatively stable when using constant prices, which indicates rising water productivity.

Still, Jordan imports 99% of its cereal requirements, 80% of animal feed requirements, and 42% of its red meat and dairy products requirement, with a combined value of JD546 million. In fact, the country imports three times what it exports from agricultural products, some JD2.4 billion in imports, compared to JD727 million in exports in 2017 (CBJ, 2018). As such, the country is highly vulnerable to international price fluctuations of basic commodities.

Political and economic growth imperatives are also related to drought exposure and sensitivity. For instance, the 2018-2022 economic growth plan (GOJ, 2018) encourages agricultural expansion in rural areas despite water scarcity and the existence of other options including the development of industrial and services sectors.

Cereals

Cereals are highly exposed to drought risk because they are primarily cultivated in rainfed systems in areas with high hazard risk (northern highlands bordering the Jordan Valley). Additionally, the sub-sector has high sensitivity because little could possibly be irrigated, and most cultivation is on small landholdings with minimal inputs, mechanization, and access to credit. Therefore, it is a highly vulnerable sub-sector, which has major implications for Jordan's overall food importation characteristics (Belhaj Fraj, 2018).

Fruit and vegetables

Irrigated fruit and vegetables, overall, are highly exposed to drought impacts but have relatively low sensitivity. This is because virtually all production is irrigated, and the majority of vegetables (~55%) are now grown during the winter season and with good water management practices, which enables high crop water economic productivity. While fruits are grown in increasingly capital-intensive systems, the sub-sector is less advanced in terms of good water management practice uptake (Belhaj Fraj, 2018) and is more sensitive than vegetables to drought impacts.

It is useful to differentiate between this sub-sector in the Jordan Valley and other areas. This is because fresh surface water allocated to irrigation in the northern Jordan Valley is dropping, and in the middle and south Jordan Valley it is being replaced by blended treated wastewater, particularly for vegetables.

Other areas of intensive cultivation, predominantly in northern Jordan, are reliant on groundwater and therefore face higher increases in sensitivity over time due to structural over-abstraction of groundwater and attendant rising costs of production.

Livestock

The livestock sub-sector is highly exposed to drought, though under current policy conditions it is not highly sensitive at an aggregate scale. This is primarily because feed subsidies and fodder provision represent strong adaptive capacity, and the large majority of the national herd is dependent on them as discussed in Section 4.2.

However, Jordan's exposure to food and feed price volatility means that the impacts of drought on the national economy due to the livestock sector's reliance on imported feed are very significant. If the government altered feed subsidy regimes, the sector's sensitivity to drought impacts would increase significantly.

Also, the aggregated description masks the sensitivity of pastoralists with small flocks who are more reliant on rangelands than commercial operators who make up the majority of the sector by value and livestock holdings. Smallholder pastoralists are disproportionately affected by drought because even with subsidized feed prices, they are unable to purchase enough to maintain herd sizes.

3.3 Agriculture exposure and sensitivity – thematic components

Below we discuss several aspects of drought risk exposure and sensitivity that stem from stated stakeholder needs and impacts assessments. We note that water availability and quality issues, as discussed above, are major components of the agriculture sector's exposure and sensitivity to drought.

Desertification

Historical thinking about land degradation and desertification in Jordan has primarily focused on changing pastoral practices, intensification of land use, and reduction in the utilisation of soil conservation practices. However, analysis of soil profiles from the early Islamic period shows that historical land degradation and desertification in northern Jordan relate more strongly to prolonged drought periods with more frequent extreme events than land-use change (Schmidt *et al.*, 2006). Indeed, it is the cycle of droughts followed by intense flooding that has a particularly strong impact on soil profiles given their connection to erosion patterns.

In the modern era, changes in grazing and migration patterns have led to the degradation of rangelands, especially in the *Badia* regions. This is especially relevant for community-specific and livelihoods aspects of drought vulnerability.

In the Eastern governorates, over 1 million hectares have degraded from rangeland classification to marginal steppe as a result of over-grazing combined with drought impacts. In 2006, rangeland production dropped to cover only an estimated 20-25% of national livestock needs (EU Commission, 2014). In Appendix C, we provide additional detail on the impacts of rangeland degradation during past droughts.

Lack of financial relief mechanisms

In the past, financial relief has only been triggered through drought declaration, which had an extremely high threshold (precipitation below 30% of long-term mean). As such, it only occurred once in the modern era, during the 2000 drought. Also, farmers stated that payouts went to irrigated agriculture and not rainfed systems, which led to inequity in its distribution.

Sensitivity to drought impacts is exacerbated by lack of credit (this theme is covered at length in Section 3.4) and financial relief mechanisms. While state funds have recently been capitalised for drought relief measures (see Section 5), farmers still do not have access to drought insurance or other products for financial risk management. Appendix C has more information on potential drought insurance or other financial risk management mechanisms.

Extension services – irrigation, crop selection, and adaptation to drought

Water demand management is a key facet of sensitivity. This relates to crop type, lack of drought-tolerant varieties, and irrigation and water management practices. Throughout the Jordan Valley, high water-demanding crops like bananas are prevalent, increasing exposure to drops in water availability. Also, there is relatively low uptake of drought-tolerant varieties of many crops, which increases sensitivity.

Moreover, soil and groundwater salinisation increases sensitivity to drought impacts. There is an opportunity to address this through technological treatments and conservation practices such as saline irrigation and low tillage to reduce water consumption and soil erosion. These practices could be coordinated to achieve the targets of soil improvement and better soil moisture retention. In tree-based farming in particular, there is relatively low uptake of equipment, and training to use it, for such new practices.

A recent review of the agricultural extension services system in Jordan (Boubaker *et al.*, 2017) described how contemporary concerns are focusing on international market chains, and associated product quality, given border closures. It also describes changes needed in the system to match skills training with employer demand given the refugee context and agricultural development objectives.

Inter-sectoral water management

Over time, surface water allocation to irrigation has dropped considerably. During drought events when flows decrease, irrigation takes the first cuts, while municipal supply, tourism, and industry are favored. This leads to a reduction in water availability and decrease in water quality for irrigation, which increases sensitivity to impacts. Figure 8 below shows these water management planning components and their interactions to produce impacts on agricultural production.

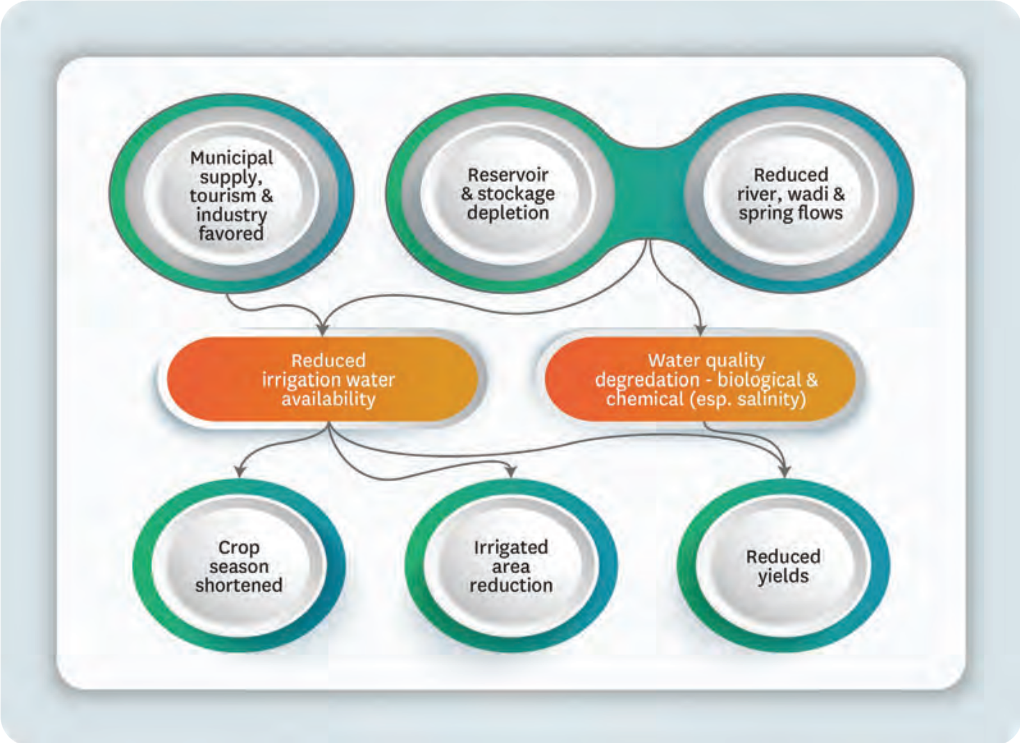

Figure 8. *Water management planning and drought effects on agricultural production.*

Both short- and long-term reallocation of water resources is highly contested. Despite long-term shifts in surface water redirection towards cities and municipal supply, some rural areas have successfully resisted attempted shifts in groundwater abstraction to cities (Liptrot and Hussein, 2020).

Groundwater overdraft and regulatory enforcement

Groundwater overdraft is a major component of the agriculture sector's sensitivity to drought impacts as it increases the cost of, and potentially removes, one of the primary drought coping mechanisms for the agriculture sector: irrigation. During droughts in particular, it also increases sensitivity due to water quality degradation.

Groundwater overdraft is a structural feature of the Jordanian agriculture sector. Some is a result of illegal wells drilling and weak control of abstraction limits, which can link to speculation inland. A recent review (Molle and Closas, 2020) notes the challenges state attempts to wind back over-abstraction have faced. Given that groundwater is the main source of freshwater in Jordan and that it underpins much of the production of the agriculture sector, which is an important part of Jordan's overall political economy, dealing with this problem is particularly challenging.

We discuss the complex relationship between groundwater-dependent irrigation, drought vulnerability and resilience, and Jordanian political economy themes in more detail in Appendix C.

3.4 Livelihoods and communities aspects of exposure and sensitivity

Here we discuss a range of livelihoods and community-specific aspects of exposure and sensitivity, primarily at the national level:

- smallholder systems, rural poverty, and the agriculture labour market;
- food security and drought effects on the above;
- Rural debt and access to finance; and
- Women- and children-specific components.

In Section 4.4 we provide an integrated case study of drought exposure, sensitivity, coping mechanisms, and impacts on farmers and herders in the Azraq governorate.

Smallholder systems

There are about 102,000 farming households, of which about 1/3 live on their farms. This implies a high proportion for whom farming is a secondary economic activity. 85% of farming households have less than 20 dunams (2ha), which prevents industrialisation and integration in the agri-food industry. 25% of farmers are herders. Women owning the means of production (land, livestock, and partial produce transformation) account for 30% of farming households and are mainly smallholders. Less than 20% of farming households are involved in formal financial markets (DOS, 2018a).

Rural poverty and agriculture labour market

The most recent publicly available data on poverty in Jordan come from 2010 as the government has not published more recently collected data. In 2010, about 14.5% of the population was below the poverty line, with rural areas having proportionally higher rates. We provide additional detail on this theme in Appendix C including Table C3 and Figure C4.

Most of the rural poor live in areas with low investment in industrial and services activities and are reliant on agricultural activities for income. The main rural poverty pockets are in *Mafraq* governorate in the Hamad basin (Al-Ruwayshid area) and others include Taibah, Wasityah, Beni Kenaan, and Ramtha districts in the Irbid governorate (ibid), as reflected in Figure C4.

The agriculture sector's relevance for employment is complex. In 2011, only 7.7% of the labour force was employed in agriculture, and by 2017, the formal sectoral employment shrunk to about 3% - 4% for men and 0.9% for women (OAMDI and DOS, 2017). However, informal employment is estimated to be far higher, reaching 5% for men and 16% for women (ILO, 2018). Also, nearly half of rural Jordanian women work in the sector, and nearly a quarter of Jordanians below the poverty line rely on agriculture (World Bank, 2018a; Netherlands Enterprise Agency, 2016).

The sector, and particularly high-value horticultural production, is highly reliant on skilled and unskilled migrant labour from Egypt and, since the mid-2010s, nearly 90,000 Syrian refugees. While it is an important contributor to refugees' livelihoods, their participation drives down wages approximately 50% sector-wide (ILO 2018). The Government of Jordan (GOJ) is incentivizing and supporting increasing Jordanian national participation in the agriculture sector as part of its 2018-2022 economic growth plan (GOJ, 2018).

Food security during extreme and moderate droughts

During the 1998-2000 drought, food security for around a quarter of the total population (of ~4.75 million) was threatened, out of which some 180,000 people were badly affected, particularly small farmers and herders. FAO-WFP assessments concluded that there was a drop in domestic cereal harvests by 13,000 tonnes, which represented a reduction in production from 10% of total demand to just 1% (FAO, 2004).

Similarly, the severe drought of 2007-2008 is reported to have impacted hay production by 85% and irrigated crops by between 30-50% (DOS, 2018a). Drought impacts from the moderate drought of 2014 were understood to have more localized impacts, and mostly affecting cereal production and summer crops. Drought effects on crop yield and productivity threaten the livelihoods of rural farmers, and both the availability and affordability of food at the national level are reduced.

National data on food security and links to livelihoods

Despite the Human Development Index (HDI) rising from 0.62 in 1990 to 0.74 by 2017, and the number of households dependent on agriculture decreasing from 6% to under 4% in the same period (ILO, 2018), food security remains a major feature of sensitivity to drought impacts, especially in rural areas.

In Jordan, the Global Hunger Index (GHI) score is 10.5 showing a 'moderate' level. According to research conducted by WFP and REACH (2019), approximately 60% of households are vulnerable and at risk of food insecurity and 12.8% are under severe food insecurity (DOS, 2018a).

The recent Multi-Sectoral Rapid Needs Assessment of vulnerable Jordanians and refugees (Syrian and other nationalities) conducted by UNHCR, UNICEF, WFP highlighted that 32% of households reported not having enough food to eat. Lack of funds was the primary reason (83%), while 36% blamed a lack of available food stocks. The Food Consumption Score showed a decrease from 16% to 15% of households for the period 2018-2020. 18% of Syrian refugee households living outside camps had poor or borderline food consumption in early 2020, compared to 15% in 2018 (WFP and REACH, 2019).

The population-wide incidence of nutritional deficiency reached 13.5% (2015-2017) compared with 6.6% in 2004-2006. Additionally, 7.7% of children under 5 years suffer from malnutrition (FAO *et al.*, 2018). For Syrian children living both in camps and in host communities, dietary diversity is problematically restricted.

Nationally, 32% of children in Jordan suffer from anaemia, but the figure is 38% in the north of the country. Children of Syrian mothers have slightly elevated levels of anaemia compared to those of other nationalities (DHS, cited in UNICEF, 2020). Anaemia also affects many women: about 43% of tested women were anaemic. The prevalence of anaemia is worsened during droughts where these communities are normally required to make financial decisions about food groups, work longer hours and find alternative means to access meat, dairy and legumes.

Jordan's reliance on international markets for its food supply has become increasingly challenging since the disruption of traditional trade routes due to the conflict in Syria. At the household level, reliance on international markets for food exposes the population to major food price increases. This results in a significant increase in the share of money spent on food and financial burden for the average household. Also, the shift towards higher value crops and drop in cultivation of staples has likely affected food security for farming households in particular. Food insecure households have lower per capita expenditures, more debt, and must allocate most of their expenses on food, as opposed to medical services or education. It also results in less varied and protein-rich diets, which contributes to nutritional deficiency.

Access to finance and debt

There are no current datasets or ongoing national efforts to measure and evaluate the impacts of drought periods on household income, debt, or financial inclusion. Such data would include the additional costs incurred by farmers, agri-business producers, and farm laborers generated as a result of drought conditions. However, our qualitative evaluation provides a rich set of information about drought effects on rural finance and debt dynamics.

Access to financial services is significantly limited among rural communities, and our fieldwork showed that interest rates for small- and medium-sized farmers are typically in the range of 20%, which can be considered predatory. This indicates a further challenge for rural communities in responding to drought events and the associated decreased viability of agricultural livelihoods (CBJ, 2017).

Only 33% of adults in Jordan, and 27% of women, have access to an account with a financial institution. Some 38% remain completely excluded from the formal financial system. Disparities in the majority of the population remain, particularly among vulnerable groups such as: refugees and migrants, women, youth, and low-income segments including poor rural populations. Smallholder farmers most frequently rely on credit from local agricultural input and hardware suppliers. Likewise, borrowing to meet household expenditure considerably exposes casual farm labourers to inter-seasonal impacts of droughts.

Farmers most frequently rely on deferred payment from local suppliers. Suppliers can also borrow seeds under contract that are then paid for after the season has ended, and suppliers can also extend credit for inputs until crops have been harvested, which prevents additional interruption of agricultural activities even when farmers face liquidity issues. During droughts, suppliers commonly increase input prices to offset the increased loan repayment defaults, thus impacting the sector as a whole. Farmer costs also increase significantly for deepening wells and hiring water tankers. We provide more extensive detail on farmers' and herders' access to finance and debt issues in Appendix C. This information comes from the case study described in Section 4.4.

Women- and children-specific aspects of food security

Across Jordan, female-headed households are 62% more likely to be food insecure or vulnerable to food insecurity, when compared to male-headed families. In particular communities, this likelihood is more pronounced. About 1/3 of Syrian refugees are female-headed households (World Bank, 2018b).

Female-headed households are more likely than male-headed households to experience poor food consumption and lower dietary diversity, and thus experience the impacts of drought more palpably. In smallholder farms, women typically handle both the maintenance of the rural or nomadic household as well as the cultivation of crops for home consumption and sale; the processing of olives and pickles; and the rearing of livestock and processing of by-products.

Women- and children-specific aspects of employment

The major disparity reported above between men and women in formal and informal employment in the agriculture sector is primarily because women have a far greater role in subsistence farming activities (as part of unpaid household labour) and far greater proportional employment on commercial farms as casual and seasonal labour. Women are consequently under more strain than men when completing agricultural labour and duties, and yet their typical wages are only 50% that of their male counterparts (around 150 JD/month) for unskilled and manual seasonal tasks. These mainly occur during the spring and summer seasons and include activites such as weeding, pruning, harvesting, packaging, and sorting.

Drought increases employment casualization (shift to informal, non-contractual employment) and deteriorates wages. Access to employment is limited for women due to issues of mobility related to social norms, traveling conditions, household obligations, and safety. Women have low bargaining power and few representative organisations to improve their socio-economic conditions. The availability of cheaper labour from neighbouring refugee communities also limits women's ability to organise, communicate and negotiate around employment issues, including those stemming from drought impacts.

Working conditions on farms affect women particularly due to their exposure to agrochemicals. These can negatively affect pregnant women and in *utero* fetuses. Also, there can be additional health complications for women who work on farms reliant on treated wastewater for irrigation.

Relatedly, the sudden influx of Syrian refugees has placed additional stress on the Jordanian health system. Estimates from a recent health sector vulnerability assessment indicate that upwards of 22% of the population may be inadequately catered for by local comprehensive health centres, because they serve more than the national standard of one centre for every 60,000 residents (EPC, 2017). This increased stress on health systems also increases the likelihood of the drought-related health risks identified above being adequately anticipated and responded to, particularly in rural communities.

Women and school-aged children in transhumant herding households are more sensitive to drought impacts because they are expected to handle the grazing and milking of livestock. Grazing becomes harder when moving long distances, and looking for pastures with suitable carrying capacity and clean and sufficient water sources. Decisions to move to remote areas reduce children's school attendance. Drought conditions also lead to increased expenditure on medicine and veterinary services.

Women- and children-specific aspects of access to finance

Women in the agriculture sector face particular challenges in accessing finance due to their weaker financial situation overall. Jordanian women own 10.3% of all land by area and constitute 16.7% of landowners, which also limits access to institutional lending due to collateral requirements (World Bank, 2017). Nationally, only 27% of women hold an account with a financial institution. This figure can be expected to be considerably lower in rural communities (CBJ, 2017).

Women are more likely to be land tenants, which impacts farm investments and preparedness for responding to drought events, especially given that women tend to have primary responsibility for managing household budgets. With lower rates of asset and land ownership (for collateral), lower earnings, and lower rates of account holding, women are less well-positioned to access credit or formal assistance for coping with drought impacts.

Household indebtedness and the instability of agricultural livelihoods increase the pressures for people to search for employment out of the agriculture sector, and for men, in particular, to migrate to cities for work. Likewise, the increasing financial and work strains lead to increased poverty and household and communal tensions.

3.5 Section summary

We describe the exposure and sensitivity of the water and agriculture sectors at large, as well as that which is specific to smallholder livelihoods. Jordan's underlying water scarcity is a key component of its drought exposure and sensitivity: renewable water availability per capita is now 60% lower than in 1990. While economy-wide water use efficiency (in terms of economic productivity) has decreased in the last decade, this is likely due to the major increase in the share of the municipal water supply sector overall. This is driven by refugee influxes, which put immense pressure on the already-strained water supply infrastructure.

There is poor cost-recovery for the primary irrigation agency, the Jordan Valley Authority, leading to underinvestment. Likewise, because municipal water and sewerage utilities' revenues do not cover long-term capital costs, and utilities are forced to pressurise systems regularly, they have struggled to maintain assets and provide human resources to address one of their main challenges: non-revenue water. Nationally, non-revenue water is about 50% of what utilities produce, with 55% of this estimated to be consumed but not billed, which leaves about 22.5% of the total supply lost to leakages.

The cereals sub-sector is the most exposed and sensitive to drought impacts due to the predominance of rainfed and smallholder production systems. The fruit sub-sector, particularly trees, is also highly sensitive, though this is due to relatively low uptake of water and soil conservation technologies and practices. The vegetable sub-sector has lower exposure and sensitivity because much of the production occurs early in the year and efficient practices are more prevalent. However, sensitivity is increasing due to export challenges and increasingly stringent regulations on chemical residues in food which are challenging to address given the use of blended treated wastewater. The livestock sub-sector is highly exposed but not sensitive at an aggregate level due to subsidised feed being the predominant source of food. Nonetheless, this results in the state being highly exposed to financial risks when uptake of subsidised feed increases enormously in drought years.

The agriculture sector faces increasing sensitivity over time due to desertification, particularly in *Badia* areas. Farmers' low access to credit and lack of financial risk management mechanisms increase sensitivity. Likewise, the prevalence of crops with high water-demand and low use of drought-tolerant crop types increases exposure and sensitivity, as do challenges such as soil salinization.

The agriculture sector is also sensitive to drought risks due to inter-sectoral water management and allocation policies as well as structural groundwater overdraft. Both of these issues link to Jordan's wider political economy: during droughts, municipal supply, industry, and tourism are favored above irrigation uses because their economic productivity is higher; likewise, groundwater abstraction is particularly important as it underpin agricultural production during droughts, so challenging the basis of the system is difficult.

There are about 102,000 farming households, of which 85% are smallholders (owning less than 2ha), and of which about 1/3 live on their farms. Nearly a quarter of Jordanians below the poverty line rely on agriculture for their livelihoods.

Agriculture sector employment is predominantly informal and increasingly casual: while 7.7% of the formal labour force worked in agriculture in 2011, by 2017 it had shrunk to 3.9 % (3% for men and 0.9% for women). Concurrently, informal employment is estimated to have increased markedly, reaching 5% for men and 16% for women, which represents about half of the actively working rural Jordanian women within the sector (World Bank, 2018a; Netherlands Enterprise Agency, 2016).

The ILO (2018) reports little difference between Syrian refugee men and women's wages, with the majority receiving a wage of 5JD/day. Since the influx of Syrian refugees, wages for farm labourers have fallen by approximately 50%, significantly increasing the sensitivity of rural populations to drought impacts.

Despite Jordan's improving scores in the Human Development Index, about 60% of households are vulnerable and at risk of food insecurity, with 12.8% experiencing severe food insecurity. The population-wide incidence of nutritional deficiency has increased markedly in recent years and has reached 13.5% in 2015-2017, compared with 6.6% in 2004-2006. Female-headed households are 62% more likely to be food insecure or vulnerable to food insecurity when compared to male-headed families (FAO *et al.*, 2018). Moreover, about 1/3 of Syrian refugee families in Jordan are female-headed (World Bank, 2018b), indicating that they are particularly exposed to food insecurity impacts of drought.

There are no current datasets or ongoing national efforts to measure and evaluate the impacts of drought periods on household income, debt, or financial inclusion. Our results show that smallholder farmers most frequently rely on credit from local agricultural input and hardware suppliers, which contributes to significant inflation of input and hardware prices during drought seasons.

Commercial farms borrow money from commissioners with interest rates typically around the exorbitantly high rate of 20%. During droughts, suppliers commonly increase input prices to offset the increased loan repayment defaults, thus impacting the sector as a whole. Borrowing from family and members of the community (since access to formal financial services is very uncommon) to meet household expenditure considerably exposes smallholder farmers and casual farm labourers to inter-seasonal impacts of droughts. Women are particularly exposed to drought's financial impacts because of their reduced ability to access formal assistance or credit due to their lower rates of asset and land ownership (for collateral), lower earnings, lower rates of account holding, and cultural reasons including requirements for male guarantors.

4. Vulnerability – Coping and adaptive capacity

In this section, we start with a conceptual overview of drought management typologies and then we describe existing coping mechanisms. Then we show results from a case study of smallholder farming communities from the Azraq region.

4.1 Conceptual descriptions of drought management

Drought management ultimately falls on 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[14].

Drought policy and management broadly fall into three categories: post-impact interventions for emergency relief (coping), pre-impact programmes 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 3 below (McDonnell *et al.*, 2019).

Table 3. *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 programmes; water rationing and pricing regimes; expansion of groundwater pumping.	Relief measures for those affected by drought; reduce long-term impacts of the drought event.	Implementation without reducing incentives for risk reduction measures; timeliness of interventions.
Pre-impact programmes 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	Organisational 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.

4.2 Coping mechanisms national overview

National overview

The Jordanian government's drought mitigation efforts primarily focus on the water supply and agriculture sectors. Past government-led interventions during drought focused primarily on emergency management, though some policy changes resulting from drought events have become permanent as adaptive measures to deal with long-term water scarcity. Jordan's long-term water management strategies formulated in the past few years all prioritize reducing sensitivity and improving adaptive capacities to ameliorate water scarcity (al-Karablieh, 2017).

The following are a sampling of interventions taken by the government during the 2006 drought in relation to irrigated agriculture and constitute typical interventions in the recent past as well (Al-Habbab and Haddad, 2006; EU Commission, 2014; Fragaszy *et al.*, 2020):

- Enforce area limits on crops with high water requirements;
- Mix treated wastewater with fresh surface water for irrigation in areas of the Jordan Valley affected by transfer of surface water to cities;
- Ending summer cropping in the Jordan Valley;
- Discourage planting fruit trees and limit planting of banana trees;

[14] In reference to Brazil, see Bretan and Engle, 2017. For Mexico, see Aguilar-Barajas *et al.*, 2016 and Ortega-Gaucin *et al.*, 2018.

- Encourage advanced irrigation methods and subsidize equipment;
- Install pressure pipe network for irrigation water conveyance and distribution;
- Penalties introduced for those who violate water usage regulations;
- Seasonal retirement of farmland to avoid irrigation (paid for by government);
- Encourage farmers to build small-scale reverse osmosis desalination units;
- Reduced water supply to Jordan Valley irrigators;
- Prohibited provision of public agricultural credit for irrigated olives in the highland and bananas in the Jordan Valley;
- Expanded and expedited livestock vaccination campaign;
- Provision of irrigation water for trees to survive and not to produce; and
- Alert farmers to any degradation in water quality to enable them plan the use of such water for the suitable farming purposes.

In the domain of water supply for municipal purposes during droughts, the government takes a range of actions. Due to long-term water scarcity and the recent influx of refugees, many of these measures have been institutionalized long-term to help utilities cope with water scarcity and the pressures on municipal supply systems (EU Commission, 2014):

- Increased pumping from existing wells and drilling of new wells;
- Decreased operation time of the piped systems and non-piped distribution network;
- Re-allocation of water from irrigation, industrial and tourism to municipal supplies including the renting of privately owned agricultural wells;
- Distribution of water by tankers;
- Public awareness campaigns promoting water conservation; and
- Enforcement of water usage regulations (hosepipe bans, etc.)

The Ministry of Social Development's Takaful Social Assistance Programme works in partnership with the National Aid Fund to ensure food stability. It has served some 100,000 vulnerable Jordanian households through emergency cash assistance. The programme distributes e-cards credited with up to 100 JD/month for up to six months for food and essential non-food purchases. The cards can be used in markets (civil and military) across the country.

Feed subsidies and livestock

Drought and feed subsidy effects on the livestock sub-sector are difficult to disentangle. Through the mid-2000s, the increase in feed subsidies is identifiable in drought years when local feed production decreases significantly (MoA, 2014). From 1991-1996 feed subsidies cost $116 million, of which nearly half came from the drought year of 1996 (Hazell *et al.*, 2001). Feed subsidies were suspended between 1996-2000.

When they resumed in 2000, livestock feed subsidies cost $28.5 million (MoA, 2014), approximately 0.93% of total government spending that year (MoF, 2005). Largely as a result of global commodity price increases, feed subsidy costs more than doubled between 2006 and 2007 (a drought year) to reach $134 million, although local feed production was only 27% lower (MoA, 2014).

As shown in Figure 9, the removal of feed subsidies in 1997 and droughts in 1999-2001 contributed to a decline in sheep and goat populations by 1/3 from 1996 to 2000. However, the re-introduction of subsidies from 2000 to 2008 and the near tripling of feed imports in that period resulted in major herd expansion despite droughts. Subsidies were halted in 2009, which led to a herd size reduction of ~15%. Following the reinstatement of subsidies in 2010, herd size increased rapidly again (ibid).

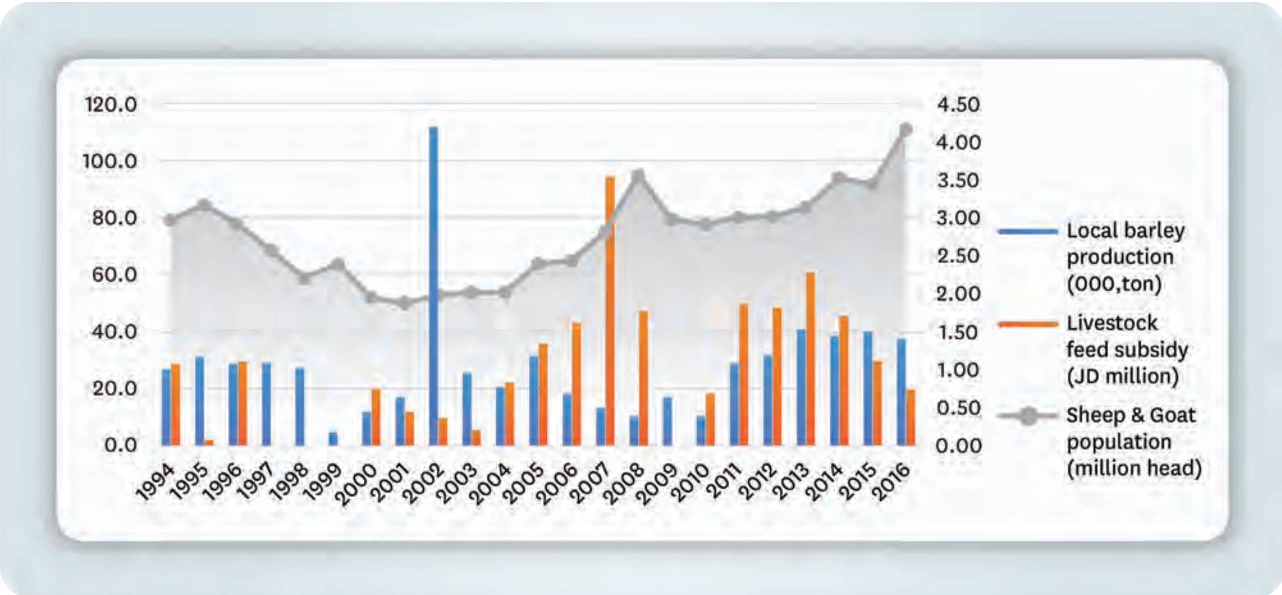

Figure 9. *Livestock population, feed subsidy costs, and local barley production 1994-2016.*

4.3 Adaptive capacity in the agriculture and water sectors

Below we describe a range of ongoing interventions to improve adaptive capacity in the agriculture and water sectors. Note that these do not reflect all stakeholder-identified needs, which we discuss more explicitly in Section 6.

Irrigation water supply and agricultural production

Stakeholders reported a range of ongoing measures to increase adaptive capacity. These connect to water supply- and demand-management as well as agricultural production systems.

Farmers increasingly use capital- and energy-intensive technologies to decrease sensitivity to drought impacts on water supply, temperature, and other ecosystem characteristics. Two primary technologies include small-scale desalination (reverse osmosis units) and greenhouse systems. Desalination is undertaken to improve water quality for irrigation purposes.

Managers of irrigation systems increasingly focus on reducing leakage and evaporation from distribution canals through lining and related measures. This focuses on increasing irrigation water delivery to farmers' pump networks or flood gates. However, it is worth pointing out that increasing evidence from the literature highlights that leakage from distribution infrastructure, particularly in agricultural areas that have intensive groundwater abstraction, are not "lost" to extractive use and rather are "re-appropriated" by other users through groundwater pumping (Lankford *et al.*, 2020). Indeed, the long-term reduction in groundwater discharges within the Jordan Valley would support this supposition.

Fossil groundwater use and over-abstraction are the most prevalent adaptive measures. For instance, to make up for increased wheat demand and irregular local production, the government has leased desert areas to agribusinesses to cultivate wheat using fossil aquifers and provided purchase price guarantees roughly double international market prices (Al-Karablieh, 2018). In this way, in some cases, adaptation measures can be at direct odds with long-term sustainability in relation to water resources and carbon intensity.

Other types of measures such as improving irrigation practices have been described in Section 3.2. Additionally, it is worth mentioning briefly the opportunities inherent in improving Jordan's placement in global food supply chains. A few examples include:

1. Improving internal market organisation to support exports of vegetables into high-value market chains;

2. Improving market intelligence, diversity of supply, and storage infrastructure for key staples such as wheat and rice to reduce exposure to global price and supply shocks; and

3. Encouraging the growth of key protein-rich staples (e.g. chickpeas and beans) and promoting contractual farming with the agrifood industry.

Water sector adaptive capacity

In addition to what has been described already in Section 3.1, adaptive capacity includes existing treaty agreements, inter-sectoral allocation arrangements, minimizing municipal network losses and non-revenue water, treated wastewater re-use, desalination, rainwater harvesting, and groundwater abstraction (Jemmali and Abu-Ghunmi, 2016).

Jordan's primary surface water bodies are subject to bilateral treaties and enter the territory from upstream controlling infrastructure: the Upper Jordan River from Lake Tiberius and the Yarmouk River from the Al-Wahda dam on the border with Syria. These treaties guarantee minimum flow delivery. However, in the case of Syria, there is no joint management plan for surface water or shared groundwater aquifers (Yorke, 2016).

Treated wastewater forms a critical part of Jordan's water security, particularly as it substitutes for surface water flows, which are increasingly diverted for municipal and industrial supply. Per Table C1, in 1990, only about 40% of treated wastewater was directly re-used (24.5MCM of 59.3MCM generated). By 2016, the proportion was 90%, and the volume treated went up more than two and a half times (to 151.4MCM, of which 136.3MCM were directly re-used).

The source of municipal water supply has an effect on overall basin flows when treated wastewater is incorporated; Amman is supplied by increasingly distant groundwater (some of which is fossil water), which ultimately makes its way to Jordan Valley irrigators via wastewater treatment. This is clearly illustrated in long-term increases in Zarqa river flows due to the addition of treated wastewater.

As of 2019, non-conventional water resources supply 185.01 MCM, of which 96.3% is from treated wastewater that is produced in 32 plants (MWI, 2019). Total utilization of treated wastewater reached 159.9 MCM and 50% of this is estimated to be lost to evaporation and infiltration to groundwater, which increases the risk of groundwater contamination (MWI, 2018a). The national rate of connection to sewerage networks is still only 67%. As such, the actual volume of treated wastewater represents 79.4% of the potential of treatment, which could contribute up to 21.1% of the total water demand (ibid).

About 115 MCM of treated wastewater is mixed with flash flood runoff and other freshwater streamflows and used for irrigating agricultural lands in the vicinity of treated wastewater plants, the Jordan Valley, and to a lesser extent, the Aqaba industrial area.

Desalination remains small-scale in Jordan, though the long-planned Red Sea-Dead Sea project would change that. Desalination of groundwater and, in Aqaba, seawater account for 3.69 and 3.12 MCM, respectively. Desalination was initiated in 2018 with a total capacity of 5 MCM/year to serve municipal systems (58% of produced water) and industry (42% of produced water). Rainwater harvesting, particularly at the agricultural rather than household level, is increasingly prominent. A recent FAO review showed ongoing works to increase small-scale water storage of this type by approximately 10% and planned works to increase by roughly a further 10% (FAO, 2016).

A few recent studies have assessed vulnerability spatially and quantitatively as a function of indicators of exposure, sensitivity, and coping mechanisms and/or adaptive capacity.

Al-Adaileh *et al.* (2019) examined groundwater vulnerability to drought. They assessed aspects of vulnerability by groundwater basin, through an impact chain framework, and with weighted values assigned according to various SES indicator categories such as groundwater safe yield, abstraction rates, effect of international treaties, presence of landfills, etc. They report that vulnerability is highest in the Zarqa and Dead Sea groundwater basins, and moderate in the Disi, Arab North, Yarmouk, and Sirhan basins. Interestingly, they report Jordan Valley and Side Valley aquifers to have lower vulnerability despite having among the highest depletion (over-abstraction) rates.

Al-Bakri *et al.* (2019) assess vulnerability at various administrative levels in relation to drought history; population and poverty; agricultural area, livestock herd, and forest or reserve area; and municipal water supply and groundwater wells. They find that vulnerability is highest in northern highlands governorates, moderate in Amman, Karak, and parts of Zarqa, and relatively low in other areas. They report that Badia, semi-arid and arid areas show up with little to no potential impact. This is likely due to their definition of indicators in relation to the spatial density of specific land uses (e.g. proportion of administrative unit as agricultural area). As a result, their mapping focuses on the concentration of populations and assets exposed more than potential magnitude of impacts per se.

4.4 Smallholder coping mechanisms and adaptive capacity – integrative case study from Azraq

Below we provide an integrative case study of farmers and herders in the Azraq region including their production systems, aspects of sensitivity, and the interactions of drought coping mechanisms and impacts.

This region was chosen because it includes fragile wetland and oasis ecosystems that are under national conservation protection and consideration for UNESCO World Heritage status, as well as bedouin rangelands, small-scale conventional integrated livestock farming, and medium to large-scale modern farms, as well as a new agribusiness industry. This region, therefore, has diversified agricultural activities, a multi-ethnic character and complex social dynamics. It is also subject to chronic water scarcity and substantive groundwater overdraft.

Azraq socio-environmental context and historical development

The Azraq region is in the heart of the *Badia* and is arid to hyperarid with an average annual rainfall of less than 200 mm/year. The rural center of Azraq is surrounded by plateaus, and it consists of the Azraq Qaa (depression) and the wetland. The basaltic plateaus are for pastoral purposes, while irrigated arable lands spread around the center and are composed of moderately fertile soils.

The Azraq plateau rangelands are culturally, economically, and ecologically important, and they have undergone major shifts in the past few decades from tribal pastoralism and sedentary peasantry schemes to intensive irrigation-based schemes. Even in years of mild to moderate drought, pastures can be severely affected and subject to the threats of overgrazing and brush fires. These threats are worsened in consecutive dry years when fluctuations in forage prices result in overgrazing and ecosystem degradation. Sedentary herders in Azraq have witnessed the gradual collapse of the sensitive Azraq oasis and significant decreases in the availability of biomass to support herds.

In the early 1970s, when the government started granting licenses for wells for farms spanning 10+ ha, the mean depth of wells was around 10m. The rural electrification policy, intended to limit rural out-migration, led to the transformation of open grazing land to irrigated fodder cultivation; rural tribal chiefs, originally the arbiters of open *Hima* transhumant practices, joined in the large-scale cultivation of olive trees to privatise land-holdings.

Private irrigation spread uncontrollably and began to compete with water utilities that supply the city of Amman and refugee settlements. Over-abstraction has caused rapid groundwater declines and has jeopardized subsistence agriculture. Nowadays, even large and modern farms are threatened by the impact of droughts that have grown more frequent and more intense.

Arable lands are continuously irrigated from aquifers with a thickness of 20-430m. This leads to increasing salinity, especially from the eastern part of the basin towards the west. This has accelerated due to the overexploitation of aquifers. The decline in the level of the wells, by an average of 10m in the last 10 years, has been associated with an increase in groundwater salinity. This exceeds 3,500 μS/cm in some wells, which is the upper limit for vegetables.

Irrigated agriculture in Azraq

Azraq's irrigated area is about 4,738 ha, predominantly olive groves (1,750 ha) as well as mixed alfalfa-olive crops and alfalfa in pure stands. New medium to large-sized farms dominate in the central part of the basin, east of the city of Azraq.

Irrigated agriculture remains an important domestic source of essential foodstuffs, especially fruits and vegetables, as per its role in foreign exchange earnings through exports, and its potential for direct and downstream employment. Irrigated agriculture is relatively less vulnerable to drought conditions than rainfed agriculture. While the irrigated area has further expanded by more than 50% over the last 20 years, groundwater is increasingly exploited intensively regardless of the low profitability of agriculture.

Livestock in Azraq

Azraq has 265 small integrated livestock farms (herd sizes ranging from a few small ruminants to about 350 heads) and 100 commercial farms that each cover over 20 ha, as well as a bedouin transhumant community with an average capital of approximately 200 small ruminants composed mostly of sheep and goats (Belhaj Fraj, 2018).

The average herd size of the farmers interviewed was slightly larger than average, between 300 and 400 sheep. Livestock supply chains are significantly shorter than those of small-scale growers. The livestock farmers interviewed often demonstrate vertical integration of different segments of the supply chain into the basic business practices of the family unit. This includes input sourcing, labour supply, logistics, value-added by-product processing (primarily dairy), and even direct sales and marketing.

Sensitivity for farmers - limitation of agricultural advisory services

For commercial farmers, the absence of agricultural advice from either the state or suppliers is one of the main obstacles to development under the constraints of drought and water scarcity. Farmers do not receive sufficient technical advice on water optimization, planting, and harvesting under drought conditions. Also, there is a lack of information on available financial aid or access to credit facilities for farmers facing cash flow difficulties. Farmers having more access to such advisors would increase long-term adaptation capacity, and it would also significantly help them to cope during drought more effectively.

Sensitivity for pastoralists - access to veterinarians and feed

A key factor for pastoralists to cope with drought is timely access to veterinary services, the absence of which all pastoralists agree is a significant threat. This is particularly true during the dry months when livestock are more likely to fall sick from thirst and hunger. As demand for such services increases during the dry months, there is a lack of access to veterinary experts to help provide advice on optimizing livestock feeding, watering, and medical support.

For small-scale pastoral operations to remain profitable, they now increasingly need to purchase water deliveries and manufactured feeds. The affordability and availability of fodder supplies are severely affected during droughts. Jordan imports about 80% of its fodder needs. This exposes the country's fodder markets to regional price volatility, which is further compounded by the increased reliance of livestock producers on imported fodder during droughts. During dry spells, traditional by-products of grain production, such as hay and bran, are bought and traded speculatively. Indeed, hay prices during dry months can be more lucrative when sold as fodder to smallholders than the grains themselves.

Although there are government subsidies for fodder, there are currently no strong government measures in place to regulate fodder import markets sustainably. Thus, poor small-scale livestock farmers are still dependent on rangelands, the carrying capacity of which is directly affected by droughts. Smallholder herds are often disproportionately exposed to impacts on local fodder availability, particularly in comparison to the large commercial operators that dominate the sub-sector in terms of market value and total livestock holdings.

Drought impacts on smallholder farmers

Subsistence farmers can suffer food production losses of around 50% during droughts. The most important losses are due to the lack of adequate storage or processing. The effects of drought-induced water stress and financial impacts can extend to subsequent years. For example, the impact on the productivity of olive trees continues through the following season as do financial hardships. This may be due to the desiccation of olive and fruit trees, deterioration of the soil, falling available capital and debts from the previous dry season, and the need to invest more in water infrastructure due to its deterioration.

Coping mechanisms of smallholders

Drought impacts hit poor growers in two forms: directly, through damage to assets and loss of productivity, and indirectly, through the coping mechanism of growing drought-tolerant but low-profit crops subsequently to reduce the financial risk implications of a possibly poor year. As such, even when weather is optimal for cultivation throughout a season, farm incomes can be reduced by such risk aversion, which leads to increased indebtedness as discussed in Section 3.4.

As incomes decline, farmers delay maintaining capital equipment and farm facilities. During droughts, farmers become more risk-averse when the prospects for a productive season are less likely; they prefer short-term measures to manage these risks. Reduced income also impacts the capacity to invest, as do problems accessing emergency credit during droughts.

The greater financial pressures that small and medium-sized farmers face during droughts lead to higher indebtedness and subsequently increased defaults. Creditors often include private sector suppliers of key inputs, including production and processing machinery, pesticides, fertilizers, and irrigation equipment.

Smallholder farmers emphasized that herbs and other fast-growing grasses, fodder crops such as alfalfa, and medicinal plants are fast-growing, high-value crops that are used to compensate for anticipated uncertainty about seasonal weather patterns.

In times of drought, greater collaboration and solidarity among neighbouring farmers emerge. Discussions among neighbouring farmers during drought periods focus on approaches, products, suppliers, and solutions to persisting or emerging problems. There is an interest in this exchange of information being officially promoted and seen as a potential mechanism to effectively convey difficult circumstances to cities and government as emphasized in the drought management needs described in Section 5.1.

Employment-related coping mechanisms

For smallholders, working as labourers on large farms is imperative. Olive picking is often the most profitable work because it is paid by yield rather than daily rates.

Rural households that depend on income from farm labour are increasingly pressured to push their children to work to meet household needs. They are suffering from falling labour opportunities in drought conditions, especially as they are in direct competition with Syrian refugees. The informal employment of Syrian refugees leads to the casualisation of the Jordanian labour force, which is paid increasingly less and allows the owners of medium and large farms to cut costs (mainly for weeding and harvesting).

Syrian refugee communities, which are often made up of female-headed households, often single parents, are mainly employed by these commercial farms. Against expectations, refugees in general (except for single female heads of household) are not the most vulnerable to drought impacts because they are supported by charity organizations.

Drought impacts on commercial farms

Drought primarily affects product quality and energy consumption for groundwater pumping and cooling systems for greenhouses and poultry. The costs of importing energy (90% of which is imported from GCC countries) are a financial burden on farmers and the national economy and foreign exchange reserves, and they represent more than 25% of GDP. These increased energy costs and drops in revenue due to product quality declines were unanimously cited as the most significant obstacle to the financial viability of farms during droughts.

The cost squeeze associated with drought affects the seasonal recruitment of unskilled labour among refugees and the supply of lower quality inputs and equipment. In the case of consecutive dry years, the major hardship is the seasonal deepening of wells, which is experienced as a recurring cost for the inter-annual maintenance of farming systems. This results in a long-term drain on income and holds back medium and long-term investment.

Drought impacts and coping mechanism of smallholder and transhumant pastoralists

Drought affects sedentary pastoralist smallholders and their business partners including input suppliers, labourers, other farmers, wholesalers, markets, and consumers. Drought impacts are partly influenced by the nature of these relationships, including issues of informality, family, community, and tribal relationships, and institutional dynamics related to the private and public sectors.

As with the bedouin, pastoralism is a family affair, and most livestock keepers resort to spending their savings and increasing debt to cope with the loss of sales revenue and rising input costs during droughts. Additionally, the sale of livestock to avoid losses and increased expenses, and provide some income during the drought period, has a major impact on capital retention and the speed with which post-drought recovery of herds can occur.

For settled pastoralists, production costs rise as more money has to be spent on fodder, transport, and water due to drought-related shortages. Increased production costs result in greater debt and also reduce investment in improving the productivity of their herds, as available capital and even credit are needed to cover pastoral and household costs.

Increasingly, drought years are pushing bedouin to buy water and fodder for their animals. Water purchases are becoming necessary either because the state is closing illegal wells, or because of widespread pollution of groundwater in water harvesting infrastructure and shallow wells due to the injection of semi-treated wastewater into the aquifers. This is a common practice visible to rural people.

Thus, traditional pastoral practices are becoming less profitable, leading to uncontrolled changes in land use, with the conversion of rangelands into irrigated agricultural production. In addition to increasing unauthorized groundwater withdrawals, this endangers the long-term stability of these ecosystems and their ability to support pastoral activities and local communities.

Pastoralists - and particularly bedouin households - interviewed also demonstrated a clear lack of information about available financial support or access to credit. In all pastoralist families, droughts were associated with increased tensions within the household and disruptions in access to health and education services for children.

Food security for farming households

Smallholder pastoralists react to increased risks of growing fodder costs by selling off male, elderly and sick livestock. The sudden oversupply in the market firstly reduces prices with local meat becoming – even if momentarily – more affordable to poorer households. However, prices increase again as prolonged drought increases reliance on imported grains for feed. Nonetheless, larger farmers and crop-livestock integrators experience less disruption to the variety and quantities of food access, noting that increased debt repayments and loss of earnings only marginally influence their families' patterns of food consumption.

Adaptation options for smallholders

The major concern of smallholder farmers during drought is to support household consumption. The most diligent are integrating fish farming (see Corner *et al.*, 2020) and trying to modulate volatile production patterns. In addition, traditional household dairy processing, mainly by women and older children, adds value and provides a source of food security, nutritious substitutes for store-bought items, and a diversified source of household income. These could be supported more formally by the state but are currently undertaken by pioneer farmers.

From a market perspective, some farmers focus more on raising *Awissi* sheep. Under optimal production and market conditions, the rich and distinctive flavour of *Awissi* lamb brings in nearly twice the price of imported meat, at about JD 300 per head.

However, the market for *Awissi* can be volatile. With the initial onset of drought, local meat prices drop dramatically below those of imported meat due to the sudden oversupply. Later in the drought period, local meat prices rise sharply again due to lack of supply as small-scale farmers have already sold off much of their livestock. In contrast, imported meat shows greater price stability, making it more desirable to consumers during droughts, as the majority of imported livestock is managed by a handful of large domestic traders and slaughterhouses.

Coping mechanisms - coordination among pastoralists

Information for market coordination is weak and is most degraded under drought conditions in relation to tracking of price volatility. When the ongoing costs of fodder and water purchases, and veterinary services - even if subsidized - become unsustainable during droughts, some herders resign themselves to selling or prematurely slaughtering part of their herd. Doing so before they reach full maturity, and therefore optimal weight and market value, represents a significant loss of income that can jeapordize the economic viability of the whole year. The pastoralists sold the older male sheep first, trying to keep the females to allow for faster herd repopulation when possible.

Interestingly, according to pastoralists, periods of drought are often marked by greater tribal coordination to manage access to pasture. The bedouin often agree on grazing locations in advance to avoid unnecessary conflict. If disputes arise, they discuss the sharing of land and the avoidance of overgrazed areas together. This *Hima* customary scheme, however, could be formally supported to include stewardship of the agro-pastoral ecosystem.

Coping mechanism - Syrian Bedouin refugee skillsets

Since the arrival of Syrian refugees, many herders employ younger Syrian men to help manage the flocks. The maturity of the pastoral sector in Syria means that in addition to providing a vital source of income for Syrian workers, local pastoralists have access to experienced labour to help manage the increasing difficulties associated with increased movement of herds required during droughts (2-3 times per month).

Still, the demand for livestock labour falls during droughts. All of the herd owners interviewed lay off hired labour during prolonged droughts to reduce overhead costs. Instead, family members - including children - would be required to work with the herds whenever possible. For poorer pastoralists who struggle to manage the increased overhead costs during drought periods, this could mean taking their children out of school to help.

4.5 Section summary

We provide a conceptual typology of drought management mechanisms including post-impact interventions, pre-impact programmes for mitigation, and development of policies and preparedness plans. These, in sequence, range from coping to adaptation mechanisms.

In the agriculture sector, individuals, communities, and the government have a range of short-term coping mechanisms to reduce exposure and sensitivity. These include short-term water demand reduction (annual crop types, season, use restrictions/incentives, and irrigation practices); water supply increase (groundwater abstraction and blending of treated wastewater); technologies and practices related to salinity; feed subsidies; agricultural planning guidance; and monetary relief.

Long-term adaptive mechanisms include capital and energy-intensive technologies (e.g., small-scale desalination, greenhouses, and increasing and improving wastewater treatment capacity and network infrastructure); reduction of leakage in irrigation networks; shifts in crop-seasons, crop types, and crop varieties; improvements to irrigation practice; and, most prevalently, groundwater over-abstraction (including fossil groundwater).

In the water sector, utilities and the wider government take a range of short-term coping measures: increasing supply through groundwater over-abstraction, re-allocation from agriculture and other sectors, and purchase from the private sector, as well as reducing demand within the infrastructure network and from the public through rules and information campaigns.

Long-term adaptive capacity is related to treaty agreements and integration in global market chains, inter-sectoral allocation arrangements, minimizing municipal non-revenue water, treated wastewater re-use, desalination, rainwater harvesting, and groundwater abstraction.

The integrative case study assessed how drought exposure, sensitivity, and coping mechanisms interact with drought impacts on both growers and herders in Azraq. Primary aspects of exposure relate to the large area of irrigated farms and livestock herds reliant on rangelands, integrated cropping systems, and imported feed. Aspects of sensitivity pertain to access to advisory services and veterinarians; price increases of energy (for farmers) and feed and water purchases (for herders); groundwater pollution and drawdown; food insecurity; and casualization and reduction of employment on commercial farms.

During droughts, smallholder farmers can suffer production losses of around 50%. This is primarily due to the lack of adequate storage or processing. Drought impacts hit poor growers in two forms: directly, through damage to assets and loss of productivity; and indirectly, through the coping mechanism of growing drought-tolerant but low-profit crops in subsequent years to reduce the financial risk implications of a possibly poor year. Thus, some coping mechanisms can contribute to longer-term declines in income and indebtedness. However, during periods of drought, communities report greater collaboration and solidarity.

During droughts, settled and transhumant pastoralists run family affairs, and most livestock keepers resort to spending their savings and increasing debt to cope with the loss of sales revenue and rising input costs. The sale of livestock to avoid losses and increased expenses, and provide some income during the drought period, has a major impact on capital retention and the speed with which post-drought recovery of herds can occur. Traditional pastoral practices are becoming less profitable, leading to uncontrolled changes in land use, with the conversion of rangelands into irrigated agricultural production. During droughts, coordination amongst pastoralists increases, and some aspects of the *Hima* system, including the communal agreement on herd movements, help communities cope.

5. Informing drought risk management

Here we describe drought management needs as articulated by stakeholders and prioritised by government officials. We then provide a brief description of the Drought Action Plan (DAP) and its recommended actions for preparing for and mitigating drought impacts and responding during drought events. Then we “map” those DAP components and MENAdrought activities to vulnerabilities identified in the agriculture sector, rural communities, and the water sector. Lastly, we reflect on findings to date and identify additional research for development opportunities to inform and embed drought risk management approaches in Jordan.

5.1 Drought management planning – early identification of stakeholder-needs and government priorities

Stakeholder needs to improve drought management

During the 2015-2016 needs assessment, Jordanian stakeholders articulated needs related to drought monitoring and management in Jordan. These are described in full in Appendix E. In summary, the top need was for an official drought policy and clear drought declaration procedures linked to robust monitoring data. Other predominant themes included improved communication and interaction amongst state agencies and then between the state, civil society, and farmers. These stated needs broadly reflect factors that are logical starting points for assessing and analysing drought management systems generally: policy settings, financial systems, institutional coordination mechanisms, drought management plans, and institutional capacity to deliver them, extension services and crop planning, and water management regimes.

In relation to drought management planning in particular, stakeholders expressed a desire to incorporate a range of impacts into plans and ensure that adequate “bottom-up” information and ground-truthing feeds into drought monitoring information that is produced at the central government level. Also, they strongly desire the monitoring information to feed into management plans and especially financial relief measures.

Government priorities

To support the development of a national Drought Action Plan (DAP) in 2019, we assessed the priorities of government stakeholders for a drought management system.

Since the 2015-2016 needs assessment, the Ministry of Water and Irrigation (MWI) published the Water Sector Policy for Drought Management (2018c) and established a Drought Management Unit (DMU). The 2018 drought policy provided for a National Drought Management Committee (NDMC), an inter-agency decision-making body of ministerial executives, supported by an interagency Drought Technical Committee (DTC)[15].

Both the DTC and NDMC are convened by MWI, but until 2019 neither had been activated. Another national agency, the National Centre for Security and Crisis Management (NCSCM), not explicitly covered by the 2018 drought policy, had a mandate for mobilising additional resources and coordinating responses to drought crises. However, the thresholds for the declaration of national drought crises were unclear, although understood to be exacting, and no drought plan from the NSCSM was available.

The 2019 assessment, endorsed by the Secretary-General of the MWI, concluded that the DTC, led by the DMU, was the appropriate forum for formulating a DAP that identified and proposed actions to reduce drought risk. This proposed DAP would then be endorsed by the NDMC. The assessment also concluded that the DAP and supporting processes should work with the grain (see Booth, 2012) of nascent drought management institutions and reflect the limited resources available for implementing drought mitigation and response actions. The assessment recommended that initial iterations of the DAP focus on a limited subset of drought impacts reflecting the current membership of the DTC. The expectation is that future iterations of the DAP will expand in scope to include a wider range of impacts and engaged agencies.

[15] Comprising officers from the ministries of Water and Irrigation, Agriculture, Health, and Environment, the Jordanian Metrological Department, the National Agricultural Research Centre, and the Department for Statistics.

During the inaugural workshop of the DTC in 2019, supported and facilitated by MENAdrought researchers, Committee members shortlisted the following drought impacts as focus areas for the first iteration of the DAP:

- Water resource degradation;
- Declining quality of drinking water services;
- Production losses in irrigated agriculture;
- Production losses in rainfed agriculture;
- Production losses in livestock;
- Rangeland degradation;
- Forest degradation; and
- Increasing incidence of diarrhoeal disease.

This prioritisation concentrates attention and resources on a subset of critical impacts. These shortlisted impacts largely reflect the priorities of stakeholders identified earlier in the project (see section 2.7), although economic, labour, and some social issues were not included. Two other issues on the DTC's longlist did not make the short-list: high food prices, and the intensification of poverty during drought. After consideration, the DTC decided not to include a specific focus on these issues, as the main policy and intervention areas lay outside the mandates of the agencies and ministries currently represented on the DTC.

5.2 Drought Action Plan

The 2018 Water Sector Policy for Drought Management (MWI, 2018c) sets out two components for proactive drought management: implementation of Drought Early Warning Systems, and development of an action plan stipulating measures to mitigate and respond to drought impacts. MENAdrought's primary activities in Jordan have been to support these two components. The first component has supported improvements to the eCDI and its use by the DMU and Jordanian Meteorological Department. The second component has supported the DMU and DTC in developing a DAP. The DAP also links these two components, as it links response actions to indicators of emerging drought conditions monitored through the eCDI.

In 2021, the most updated DAP (V1.2) was accepted by the inter-agency DTC for recommendation to, and endorsement by, the NDMC. The Executive Summary of the Drought Action Plan is shown in Appendix E.

Drought Action Plan measures to reduce drought risk

The DAP identified actions to reduce drought risk through a process of mapping and analyzing the proximal and root causes of specific drought impacts. Investments to prepare for and mitigate drought impacts are generally less expensive and more effective at reducing the costs of drought impacts when compared to drought response actions. They tend to focus on measures to reduce sensitivity and build coping and adaptive capacity. However, some causes of drought impacts cannot be effectively mitigated because they emerge during the drought event itself. These need to be addressed through response actions and coping strategies such as reallocating or providing resources to alleviate temporary types of vulnerability. Impact pathways that cannot be addressed within existing frameworks and resources were framed as 'accepted risks'.

The DAP includes a series of 14 "preparedness actions" to strengthen the institutional capability for drought management, and 84 "mitigation actions" to increase adaptive capacity as well as reduce exposure and sensitivity to priority drought impacts (as shown in Section 5.1). The full lists are shown in Tables E2 and E3, and, in summary, they include the following components:

- Institutional development, including the formulation of legislation, policies, strategies, plans, instruments and budgets;

- Improving underlying data and information sharing, including public awareness-raising, in relation to managing drought risks;
- Monitoring and analysis, to support drought early warning and the design, timing, targeting, and evaluation of drought actions; and
- Resilience strengthening (e.g. investing in public infrastructure).

The Drought Action Plan also includes 67 recommended response actions to implement when drought occurs. Specific response actions are "triggered" by levels of drought conditions, which are derived from the eCDI and potentially other sources including seasonal forecasts, raw data from weather stations, groundwater monitoring stations, and river and reservoir gauges, and any reports of drought impacts. These levels include the following:

- Watch: normal conditions - no drought detected, monitoring continues.
- Alert: moderate drought detected - responses focus on keeping stakeholders informed as drought conditions evolve.
- Emergency: drought likely to have significant impacts on people, the economy and the environment - responses actions rely on reallocating available resources.
- Crisis: drought likely to have very negative impacts on people, the economy and the environment - response actions will need additional resources, and responsibility for coordinating drought responses moves from the National Drought Management Committee to the National Centre for Security and Crisis Management.

The full list of recommended response actions is shown in Table E4. It includes response actions dependent on impact category and magnitude and identifies the responsible organisation. In summary, the types of responses can be categorised as follows:

Alert:

1. Provide warnings, information, and updates to relevant agencies, including likely drought locations and impacts;
2. issue public notices (various channels and recipients) and encourage water demand reduction; and
3. some agencies to check preparedness of contingency response capability.

Emergency:

4. Consider and/or initiate water re-allocation measures;
5. Consider permitting additional pumping in reserve areas and initiate rationing and water trucking in some areas;
6. Initiate and enforce restrictions (water, agriculture and livestock, forestry);
7. Provide information to the public: expected shortages and periods of service, demand management methods and advice (water and agriculture), restrictions, government aid programmes;
8. Initiate survey of impacts;
9. Alert donors and relief agencies;
10. Use Drought Contingency Fund to ensure minimum income (or compensation for losses) targeted at poorest rainfed farmers and pastoralists;

11. Intervene in feed markets to regulate prices and prioritise feed subsidy areas;

12. Increase monitoring and testing (fires, standards for treated wastewater, surface and groundwater quality, and food); and

13. Distribute emergency equipment and redeploy expert staff (human health, livestock).

Crisis:

14. Additional water re-allocation and restrictions (water, agriculture and livestock, forestry);

15. Mobilise strategic water reserves, allow additional groundwater pumping for set priorities, and increase tanker trucking;

16. Cash transfers/subsidies for affected areas and vulnerable households (water costs, agricultural impacts);

17. Emergency food, seed, and feed procurement and subsidised provision;

18. Public works schemes to provide rural employment; and

19. Conduct readiness drills.

5.3 Synthesis – Drought Action Plan links to stakeholder vulnerability needs

We match Drought Action Plan preparedness and mitigation actions, as well as response measures, with the primary aspects of drought exposure and sensitivity as articulated in Sections 3 and 4. Further, we show how MENAdrought activities relate to specific aspects of vulnerability. We do this for the agriculture sector and rural communities in Table 4 and the water sector (encompassing water resources as well as municipal supply and sewerage) in Table 5.

In other words, we show which specific components of vulnerability would be addressed by undertaking identified actions and responses. This analysis feeds into our future research for development opportunities.

Agriculture and rural communities

In terms of drought impacts and vulnerability in the agriculture sector and rural communities, the DAP specifically addresses impacts on productive losses in livestock production and irrigated and rainfed agriculture. Proposed actions include a mix of coping responses during drought and preparedness and mitigation elements.

For instance, drought conditions exacerbate soil degradation, but soil resources are also under stress from a wide range of factors under non-drought conditions. The DAP includes proactive measures to encourage the adoption of soil fertility management, soil-water management, and soil conservation, no-till agriculture, and regulatory and community protection for fragile soil resources. All these actions provide positive outcomes in their own right, with co-benefits for enhanced resilience of soil resources during drought conditions. Response actions during drought conditions, such as limiting and controlling herd movements in vulnerable areas, help reduce the potential impacts of higher temperatures and aridity on soil degradation.

Depending on which additional drought impacts are included in the widening scope of future iterations of the DAP, other vulnerabilities affecting the agriculture sector and rural communities may also be incorporated. For example, engagement of new agencies in the DAP could bring the institutional expertise and mandates to develop work on financial risk mitigation tools, which are comparatively under-emphasised in the initial iteration of the DAP.

Table 4. *Aspects of vulnerability, Drought Action Plan mitigation and response actions, and MENAdrought activities.*

Aspect of agriculture sector vulnerability and/or identified management need	Drought Action Plan preparedness and mitigation actions as described in full in Tables E2 & E3	Drought Action Plan response actions as described in full in Table E4)	Response connected with MENAdrought
Prevalence of high-water demanding crops & low use of drought-tolerant crop/livestock types	M5; M8; M23-24; M40; M51	R5; R7; R27-28	Related via farm audit
Water quality and soil degradation (agriculture, rangelands, and forests)	P13; M7; M28; 38; M42; M44; M56; M58-61; M63-64; M70; M74-76; M78	R49-50; R53-54; R60; R62-67	Related through impact evaluation and farm audit
Inter-sectoral water management	P4-5; M2; M4; M9-11; M19; M21; M55; M72; M74-76	R2-5; R7; R16; R22; R27; R41-42	Related via drought action planning
Groundwater overdraft	P4; M3; M4; M6; M7; M10-11; M26-27; M37; M54; M62	R4; R6; R8; R22; R27	Tangentially related via impact assessment
Lack of guidance / information provision from government	P7-8; P10-13; M32-35; M38-40; M45-48; M66-69	R1; R11-12; R20-21; R23; R25; R28; R35-37; R48; R51; R59; R61	Core component – support for Drought Technical Committee
Access to & uptake of support services, practices, and technology (e.g. vets and irrigation)	P14; M23-25; M29; M34-35; M38-39; M48; M63-64	R38; R44; R56-58	Related via farm audit
Low access to credit and financial risk management tools	P6; M30-31; M43; M56; M57	R26; R30-33; R39-40; R43; R45-47	Related via financial risk management mechanisms review and impacts studies
Rural debt and poverty	P6; P14; M31; M36; M50; M52-53; M57; M71	R15; R18-19; R24; R29-34; R39-40; R43; R45-47; R52; R56-58	Tangentially related – issues and needs identified
Food insecurity	M65	R24; R29-30; R33-34; R45; R46-47; R55	Tangentially related – issues and needs identified
Refugees and labour markets	M52-53	R29; R34	Tangentially related – issues and needs identified

Water sector

Regarding the water sector, the DAP specifically addresses the impacts of drought on water resources degradation and the declining quality of drinking water services. Several actions addressing other impacts covered by the DAP also contribute to positive outcomes for the water sector. As for agricultural water use, a mixture of mitigation and response actions are identified.

Table 5. *Aspects of vulnerability, Drought Action Plan mitigation and response actions, and MENAdrought activities related to water sector vulnerability.*

Aspect of water sector vulnerability	Drought Action Plan mitigation actions (Adaptive Capacity building - Tables E2 & E3)	Drought Action Plan response actions (Coping Mechanisms – Table E4)	Response connected with MENAdrought
Underlying water scarcity & environmental monitoring	P1; P6; P9-14 M3; M4; M8; M9; M10; M11; M12-13; M19; M21	R2-R8; R16-17; R22; R53-54	Related but not core component (supports understanding and targeting of support)
Economy-wide water use efficiency	M5; M8; M13	sR2; R14; R22	Tangentially related through impacts evaluation
Inter-agency coordination	P1-3; P6; P9-11; P14; M5; M12; M23-25; M27-28; M30; M44-45; M54-56; M61; M70; M72; M74-76	R1; R9-10; R20; R23-24; R35-36; R48; R51; R59	Core component – Drought Action Plan
Water supply infrastructure	M1; M10; ; M11; M17; M19; M69	R6; R8; R15-18	Tangentially related through impacts assessment
Non-revenue water	M2; M20	R19	None
Water quality challenges (groundwater, TWW, and household storage)	M7; M21; M28; M69-70; M72; M74-76	R52-54	Tangentially related through impacts assessment
Groundwater overdraft	M3; M7; M25; M27	R4-5;	Tangentially related through impacts assessment
Identification of illegal wells and regulatory enforcement	P4; M3; M6; M26	R4-5	None (note – this is the topic of a project currently underway by the World Bank and ACTJ)
Weak information-sharing with community	P7-8; M14-16; M18; M68	R1; R11-13; R21-23; R25	Related via Drought Action Plan and inter-sectoral engagement.

Notably, there is a significant concentration of actions for improving inter-agency coordination. These particularly focus on enhanced information sharing and upgrading and enforcing multi-agency policies and regulations over agricultural water use, such as restricting illegal wells and groundwater abstraction. This reflects the strategic vulnerability resulting from the over-withdrawal of water resources, the dominance of agricultural water use, and the need for agencies to pool capacities to solve complex governance challenges.

Two aspects of vulnerability in the water sector are comparatively lightly addressed in the plan: economy-wide water use efficiency, and non-revenue water. These are addressed in other government policy initiatives: non-revenue water is at the heart of the Water Sector Strategy 2016-2025 and is a major theme for international donor aid and technical cooperation such as through USAID's Non-Revenue Water Program[16]. These aspects may be more fully incorporated in future iterations of the DAP, depending on which impacts are included in a widening scope.

Commentary on Drought Action Plan in relation to wider stakeholder-identified needs

The drought impact priorities and management needs shown in Sections 2.7 and 5.1 came from a wide range of stakeholders beyond government officials. It is therefore useful to assess the extent to which the DAP's proposed actions address these issues. The primary components are front and centre in the DAP, which is very encouraging and highlights the concordance between government officials' and other stakeholders' views on core drought problems.

In particular, the environmental monitoring to inform recommendations of drought declaration, and the institutional processes to do so, are clearly articulated in the DAP. Likewise, it provides clear direction on inter-agency data- and information-sharing, coordination, and detailed management planning directives. It also incorporates several key components of financial and other relief measures and provides direction to enable this financial relief to be prioritised for the poorest communities rather than those who have the most assets exposed (who by definition are wealthier), and for the other relief to be targeted at hardest-hit areas generally.

A revised version of the DAP (V1.2) elaborated in 2021 with MENAdrought support also includes a framework for monitoring and ground-truthing of social, economic, and environmental conditions, a key need identified by stakeholders. It draws on statistical information regularly collected by agencies engaged in the DTC and disaggregated at the district level to inform specific monthly, mid-season, and yearly indicators for the different impact areas covered by the DAP.

The DAP is modular and flexible, allowing iterative development of different components with experience and as and when additional resources become available. For example, one key need identified by non-governmental stakeholders was for "bottom-up" public-private engagement, i.e. information flowing from farmers and the private sector to government officials rather than from government officials to the private sector. Such a system is not well defined in the current situation of the DAP, as resources do not exist to support it. Similarly, the DAP calls for cycles of vulnerability assessment and performance evaluation to improve future iterations of the DAP, although resources are not currently available. However, these aspirations are included and can be incorporated as and when resources become available.

It is also important to note that the DTC and NDMC are implementation bodies, but they have advisory and coordination functions; actions are to be implemented by specific agencies with appropriate mandates and resources. Most recommended mitigation and response actions are therefore framed in terms of objectives rather than specific implementation measures. This allows for flexible implementation according to local and institutional contexts.

For instance, M58 is for the Ministry of the Environment "to develop rangeland drought management plans based on localised drought risk assessment and studies of sustainable production". The development of these plans could be undertaken in a top-down technocratic way or in a more participatory manner including public-private engagement. Stakeholders clearly prefer the latter approach, and the MENAdrought research to date (Fragaszy *et al.*, 2020; Jedd *et al.*, 2020) highlights how participatory approaches can lead to improved drought risk management as well as wider governance benefits. However, the Ministry of the Environment will adopt an approach for implementing M58 depending on available resources and programmes.

In sum, like with most policies, the manner in which the DAP's recommendations are implemented will shape the extent to which they meet expressed stakeholder needs. The means of implementation will vary according to the engaged agencies' capacities and the priority they give to drought risk reduction.

[16] As above, see USAID's NRW activity in Jordan.

5.4 Future research for development

Here, we suggest several potential future research for development opportunities based on the information produced above and knowledge we have gained through the MENAdrought project. These relate to cross-cutting Drought Action Plan components and some aspects of vulnerability not as thoroughly covered in the Drought Action Plan. Table 6 below provides a summary description, relation to Drought Action Plan components, methods that could be used, the type of output that could be produced, and the potential scale of the undertaking.

5.5 Section summary

Early work in the MENAdrought programme identified stakeholder needs to improve drought risk management. These related to a range of themes, with the top need being for an official drought policy and clear drought declaration procedures linked to robust monitoring data and management plan responses. To develop the DAP, government stakeholders prioritised impacts they wished to address in the first iteration. They chose to focus on water resource degradation, drinking water service quality, livestock and agriculture sector production, human health, and protection of key natural resources.

The DAP preparedness, mitigation actions, and response measures have components that explicitly address all of the identified aspects of vulnerability for rural communities as well as the agriculture and water sectors. Almost all aspects are covered through several responses in this Drought Action Plan or other government planning documents. The few aspects of vulnerability not covered extensively relate to financial risk management mechanisms and refugee and labour market dynamics, and there is scope for these to be incorporated in future iterations of the DAP.

The Drought Action Plan also explicitly addresses most of the stakeholder-identified drought monitoring and management needs. However, It remains unclear to what extent it will meet the stakeholder needs for bottom-up public-private engagement. Whether and to what extent it will meet stakeholder needs and significantly contribute to the reduction fo drought risk depends on how the plan is operationalised, especially the future theme- and sector-specific risk management plans. There is a major opportunity for that planning to occur in a participatory and collaborative fashion.

Finally, we identify a range of research for development opportunities to support the implementation of the Drought Action Plan and reduce Jordan's vulnerability to primary drought impacts. These cover a range of themes including:

1. Support for farmers;
2. Public-private engagement;
3. Policy and governance; and
4. Underpinning information and technical tools.

Table 6. *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	Drought Action Plan components (From Tables E2-E4)	Methods to use	Output	Scale
Support institutionalisation of the Drought Action Plan: work with the Drought Technical Committee to obtain National Drought Management Committee endorsement of the Drought Action Plan, encourage political prioritisation for drought risk reduction, and support "downstream" activities across agencies. !	P1; P3; M1; M17; M24; (support detailed planning of response actions).	Collaborate with Drought Technical Committee lead and SG of WMI to convene National Drought Management Committee, and hold pre-engagement meetings with implicated agencies, to obtain high-level official endorsement of the Drought Action Plan. Provide follow-up support for inter-agency collaboration and planning processes on interventions requiring multi-agency implementation. Provide dedicated technical and policy support for agencies developing sector-specific drought plans. Engage with other stakeholders in Government (e.g. Cabinet, National Centre for Security and Crisis Management) to support awareness and political prioritisation of drought risk management.	Political buy-in for the Drought Action Plan, which leads to cross-agency implementation mandate.	Central government agencies and local representatives (for implementation).
Support regional drought monitoring and impact data collection 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. * + # + ^ + !	P14; M34-35; M46-48; R20; R23; R26; R28; R35.	Linking local officials and stakeholders to drought monitoring unit; Training in the application of validation and impact assessment methods; Develop and disseminate guidance.	Improvements to eCDI (and potentially seasonal forecasting) over time; Improved collaboration between agencies, local representatives, and stakeholders; Impacts data collection and register.	Could be national or targeted to the specific region and/or farming communities.
Develop rangelands-specific drought monitoring products and linked biomass modeling, and support associated drought planning (building on outputs and learning from MENAdrought efforts in Morocco). ^ + ! + #	M55; M58-60; R49-50;	Refine eCDI to focus on rangelands condition and link to vegetation productivity modeling; incorporate participatory approaches for planning components.	Refined drought monitoring product and vegetation model, and training for local staff to use them; Draft drought management plan for rangelands.	Specific to rangelands areas, and could focus specifically on *Badia* or cover all rangelands types.
Continue development of seasonal forecasting to support Drought Technical Committee and integrate it into hydrological models. ^	P2; M1; M9; R1	Further refinement of artificial intelligence methods and application focused on Jordan; Training of Jordanian stakeholders on seasonal forecasting application and its integration into hydrological models.	Technology transfer - potential to develop data and modeling framework, and train agency staff in their use.	National with potential to focus validation on one or more regions or agro-ecological settings.
Support agencies to undertake spatial and community-focused vulnerability mapping building on methods and results to date, and link to drought management planning. This would require collating and harmonising spatial environmental, socioeconomic, and market indicators related to water and food security. ^ + !	M16; M36; M50; R14; R24; R36	Co-develop methods and application software, collate and harmonise data, and train local staff in their use; link to policy planning.	Spatial vulnerability maps targeted to specific sub-sectors or communities to inform policy planning.	Targeted to specific regions, sub-sectors, and/or communities.
Support expansion of hydrological, soil moisture, and precipitation network to improve integrated modeling capabilities including for eCDI validation. ^	P10-13 (would improve the efficacy of mitigation and response actions)	Spatial optimisation of monitoring network for model validation purposes as well as IT infrastructure to ease data sharing and model integration.	Improved monitoring networks and modeling capabilities.	National, though with local focus areas (e.g. specific soil types or key surface water basins).

Summary description	Drought Action Plan components (From Tables E2-4)	Methods to use	Output	Scale
Develop workflows for identification of illegal wells and estimation of water abstraction from them to support policy implementation and regulatory enforcement. ^	M6; M26; M37 (supports planning of response actions)	Develop remote-sensing and machine learning workflows for the identification of wells, and couple them with models to estimate groundwater abstraction.	Technology transfer - potential to develop data and modeling framework, and train agency staff in their use.	Either national or targeted to specific areas of interest (e.g. Azraq) as a pilot.
Support development of drought financial risk management mechanisms. * + # + ^	P6; M30-31; M57-58; R19; R30-31; R43; R45-46;	Detailed analysis of potential financial risk mechanisms and threshold development process to pitch a business case to government, private sector, and/or international institution stakeholders; If successful, progress pilot development of financial product and related monitoring/ modeling 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/modeling system.	Likely regional (e.g. northern highlands or *Badia*) or sub-sector specific, dependent on initial scoping exercise and business case.
Continue supporting the adoption of efficient irrigation and water conservation technologies and practices as well as drought-resilient agriculture[17] through a Market System Development (MSD) approach that considers institutional supporting functions for practice change and incentives. * + #	M5; M23; M29; M38-40; M51; (support detailed planning of response actions)	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. Support the GoJ in developing incentives (certified water audited farms) and water/ energy tariffs in groundwater-based systems
Technical support for the planning of surface and groundwater protection zones.	P1; P5; M3; M6-7; M28; R4; R42	Surface and groundwater modeling linked to discharge/recharge zones and land use activities.	Draft geospatial layers for protection zones that can be incorporated into policy/action plans	Either national or regional focus areas.

[17] For example, USAID Jordan Water Innovation Technologies Project: 2017-2022.

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Appendix A – Detailed content from Section 1: Introduction

National context

Here we describe summary information on Jordan's water availability, national water supply and demand, and the agriculture sector to contextualize the evaluation of drought impacts, vulnerability, and management.

Jordanian water availability in a global context

Jordan faces structural water scarcity. According to the World Resources Institute's Water Stress Ranking, which compares the amount of water withdrawals to the amount of available flows for current and future projections, Jordan is one of the most water-stressed countries at the global level (Luo *et al.*, 2015). The country's industrial, domestic, and agricultural sectors as a whole receive a "highly stressed" description, with a score of 4.86 out of 5 (ibid).

The Water Poverty Index (WPI) is a measure of the amount of adequate and sufficient water supplies and is based on five indicator components: resources, access, capacity, use, and the environment (Sullivan, 2002). In a global study (Lawrence *et al.*, 2002), Jordan received a moderate score of 46.3, whereas a modified WPI evaluation focused solely on Jordan and undertaken at the governorate scale (Jemmali and Ghunmi, 2016) shows a lower average – 39.77 – across governorates. They showed that the component indicators have remarkably wide differences across governorates indicating significant differences in environmental, economic, and infrastructural aspects of water availability in Jordan.

The stark difference in Jordan's Water Stress Ranking and WPI stems from their focus themes. Whereas the Water Stress Ranking captures water supply features, the WPI is designed to measure both the supply and availability of water resources, as well as people's access to them and capacity to use them. These latter characteristics reflect general socio-economic features and so track the Human Development Index (ibid).

National water supply and irrigation demand

In 2017, estimated water usage was approximately 545 MCM for irrigation and livestock, 470 MCM for municipal supplies, and 32MCM for industry (MWI, 2018a). Irrigated area continues to expand with limited options to increase the adoption of water-saving technologies (Belhaj Fraj, 2018). Municipal water demand includes approximately 50% of lost and non-revenue water caused by leakages in distribution networks, faulty metering systems, and illegal connections (MWI, 2018a).

Jordan's primary surface water bodies are subject to bilateral treaties and enter the territory from upstream controlling infrastructure: the Upper Jordan River from Lake Tiberius and the Yarmouk River from the Al-Wahda dam on the border with Syria. In the case of Syria, there is no joint management plan for surface water or shared groundwater aquifers (Yorke, 2016).

About 80% of the population lives in the Amman-Zarqa basin and Yarmouk sub-catchments. These basins supply most of the nation's surface water for domestic and industrial use, and they also provide 146.7 MCM/year of treated wastewater for irrigation to the Jordan Valley, much of it through the King Talal Dam that controls the Zarqa river (MWI, 2017).

Agriculture sector

Agricultural exports have a value of $0.7 billion while national food imports – including 100% of sugar and rice, 95% of cereals, 80% of animal feed, 50% of dairy, and 30% of red meat – resulted in a net food deficit of approximately $1 billion in 2017 (DOS, 2018a). As such, the country is highly exposed to price fluctuations of food staples and basic commodities.

While Jordan's primary agricultural production is a small proportion of GDP (under 5%), its total economy-wide impact is greater: indirect contributions through value chains reach 26-28% of GDP, agricultural exports by value can approach 25% of Jordan's total exports (Netherlands Enterprise Agency, 2016) and it is important for social stability and rural livelihoods.

Horticulture, livestock, rangelands, and forests

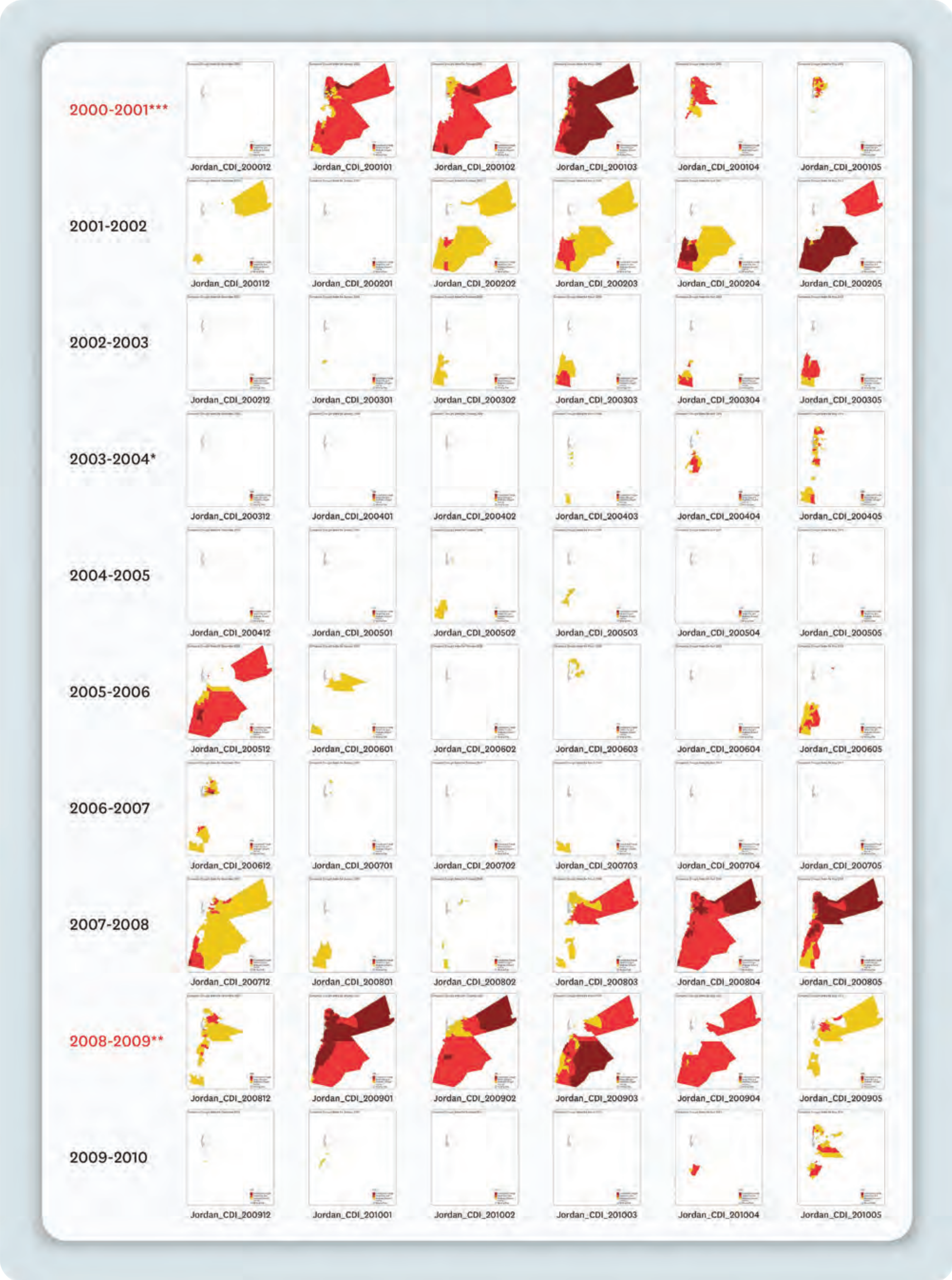
Total arable lands cover 258,000 ha, with 98,000ha irrigated as shown in Figure 1 (DOS, 2018). Irrigated agriculture provides 90% of the sector's total value. Rainfed production consists of about 55,000 ha in olives and the remaining in cereals in highlands and central west mountains (Irbid, Madaba, Karak, Tafileh, and Shoubak governorates). Cereals production is on average 0.08 Mt while imports are 1.2-1.4 Mt (ibid).

Livestock includes 4.2 million small ruminants and 75,000 cattle. The cattle and 3.2 million sheep are mostly reliant on feed imports – irrigated fodder constitutes only 7,000 ha – and about half of sheep are raised in arid *Badia* areas (pre-desert arid lands). Exceptions include the high-quality *Awassi* breed, in addition to the 35% of sheep flock raised under relatively favorable agro-ecological zones of the highlands, mountains, and the Jordan Valley. The 1 million goats cover national demand and do not rely on feed imports. The livestock production sector provides income for about 25,000 to 30,000 farming families (ibid).

Jordanian officials consider there to be about 7 million ha of rangelands. Most of this is in arid areas with average productivity of 40 kg/ha, and the FAO estimates economically viable rangelands to cover only 0.8M ha (FAO website, 2021).

Forests cover 96,000 ha including 51,000 ha of remnant trees and shrubs and 45,000 ha of forests planted for soil conservation and other purposes. Key natural reserves are in Azraq and Fifa (ibid).

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



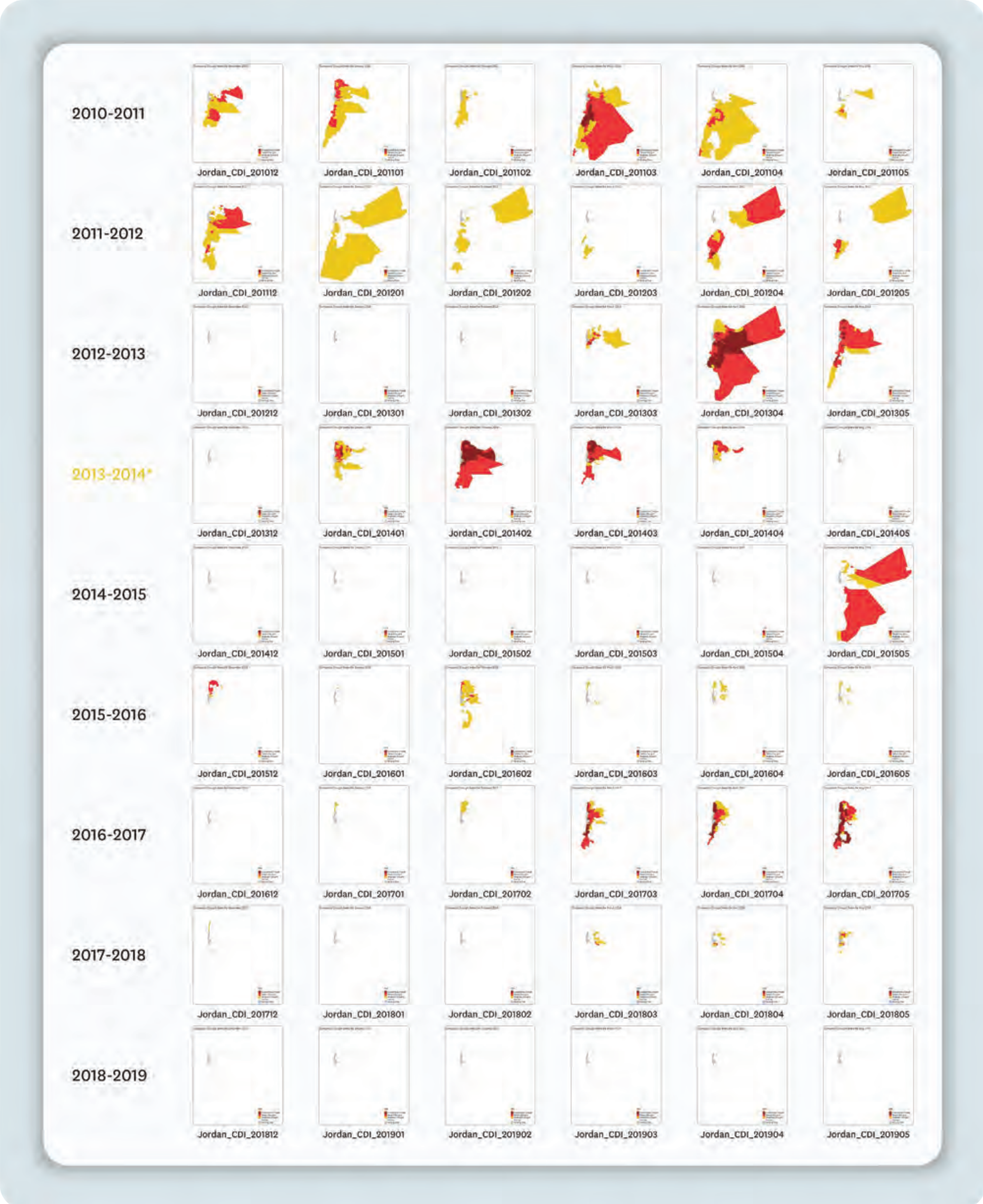


Figure B1. *eCDI-based assessment of drought in the 2000-2019 period from December (first image on left) to May (last image on right) of each year. Years in red are national/major droughts, years in yellow had a "flash drought", purple are creeping and late spring droughts. Moderately dry years are in orange, and wet years are in black. In the maps themselves, extreme drought (D3) is shown as dark red, severe drought (D2) is orange, moderate drought (D1) is yellow.*

Drought hazard from precipitation data

Jordan Meteorological Department (JMD) data (MWI, 2018b) on drought intensity and extent across regions from 1980-2017 (reported as annual SPI data in Figure B2 below) show that moderately dry years can have locally severe precipitation deficits, but spatially wide and severe droughts are rare. The 1998-2000 period is by far the deepest and longest drought in this period.

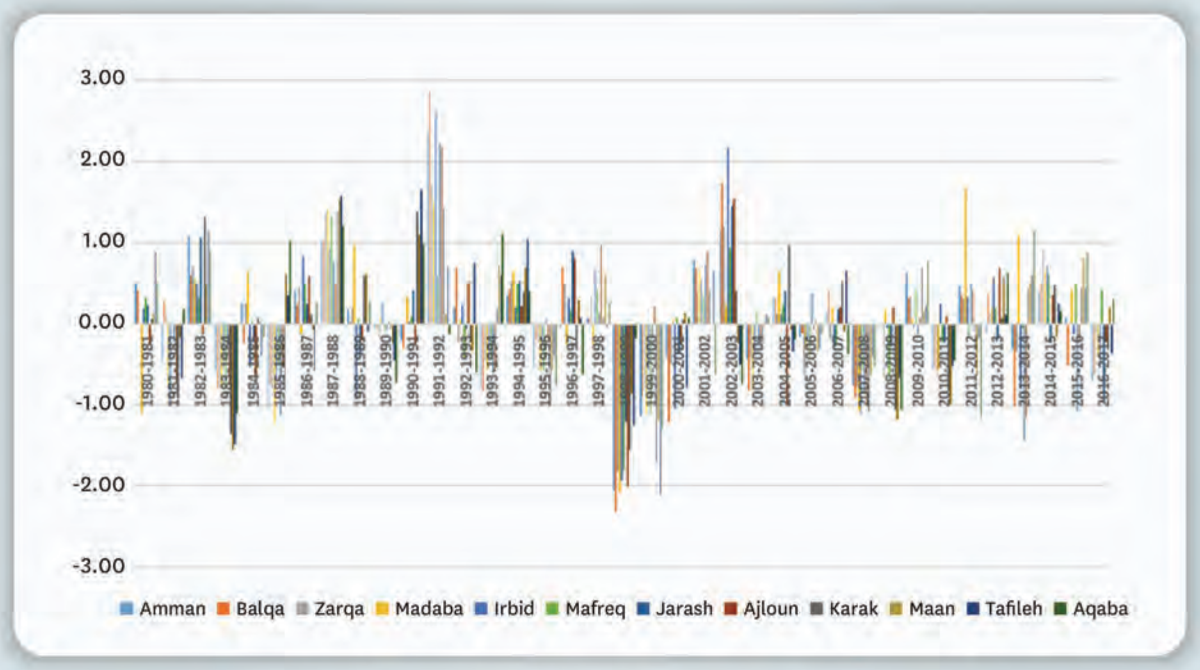


Figure B2. *SPI values per governorate, 1980-2017.*

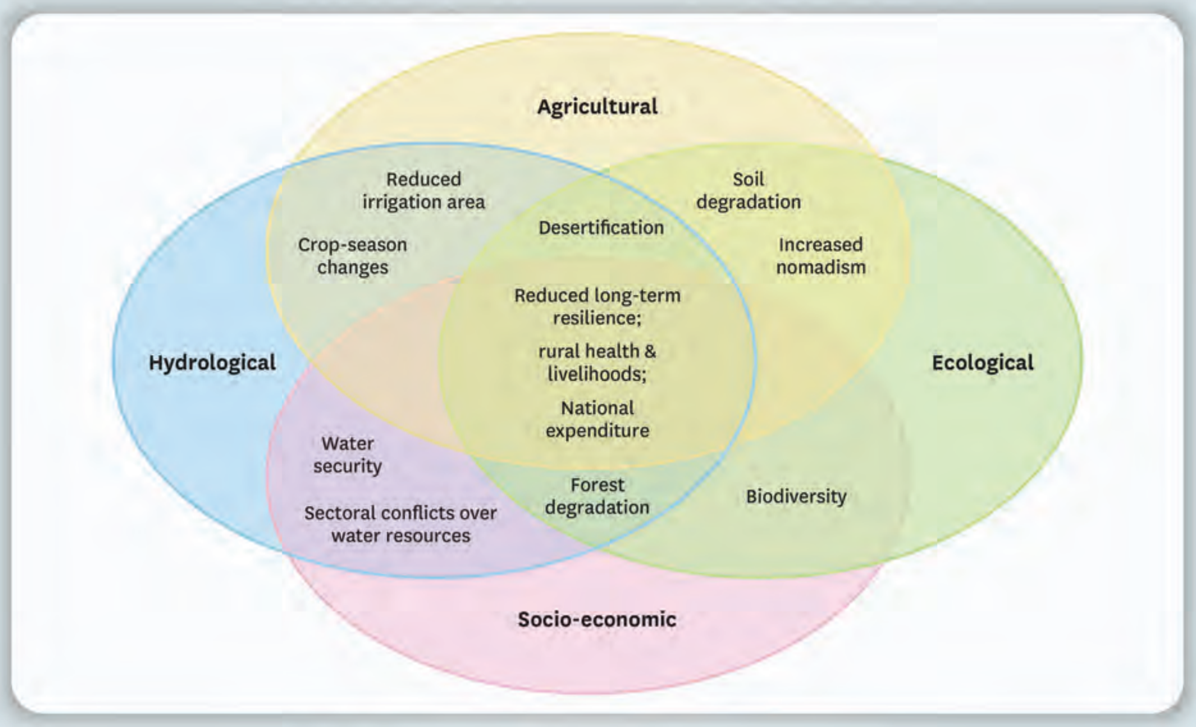


Figure B3. *Conceptual figure highlighting drought impacts on various SES and their interactions.*

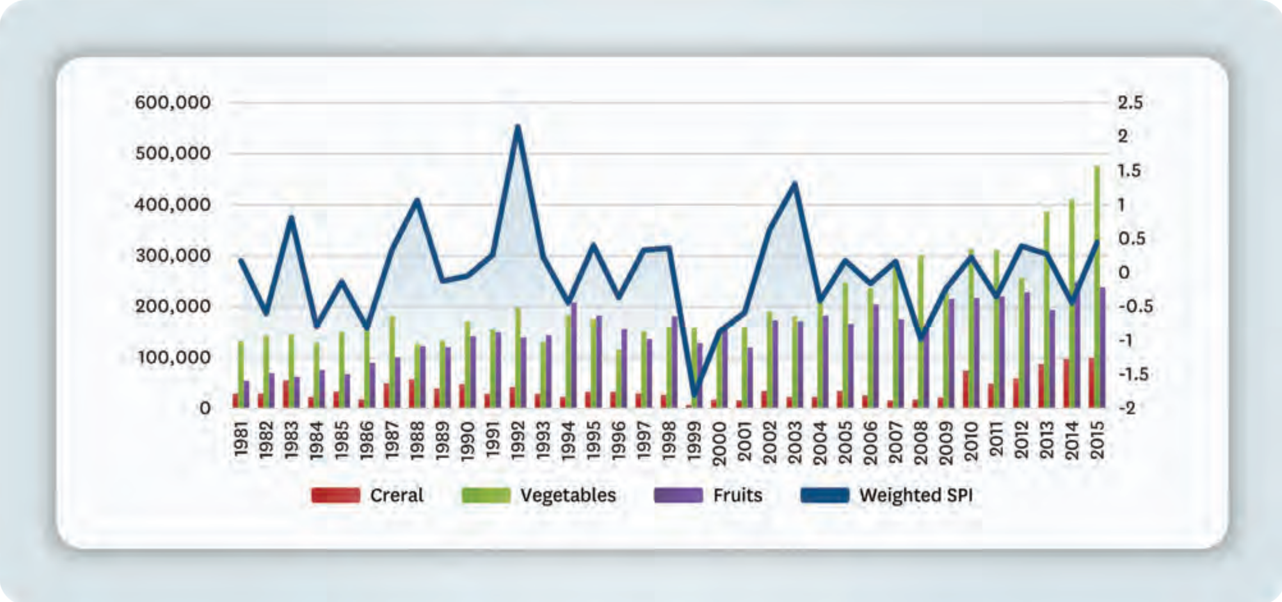


Figure B4. *Agricultural production (Y-axis, left side, million JD at constant 2015 prices) and precipitation 1981-2015 (Y-axis, right side, weighted SPI).*

Loss of field crop production	H=Historical	C=Current	P=Potential	Total Scores
Low productivity of the crop (yield tons/acres)	5	10	11	26
Changing cropping pattern in subsequent years	3	6	8	17
Damage to the crop quality	2	10	4	16
Reduced acreage in subsequent years	2	6	6	14
diffusion of agricultural pests	2	4	8	14
Leaving the land fallow	3	4	6	13
Decrease the amount of harvest residues Hays	2	8	2	12
Minimize the use of production inputs (such as fertilizers, employment, etc.)	1	6	5	12
Appending wildlife crop damage (for example, mice, rats)	1	4	1	6
Eliminating indigenous breeds		3	1	4
Eliminate Small grain farmers			1	1

Figure B5. *Priority impacts – Field crops.*

Crop losses and standing trees	H=Historical	C=Current	P=Potential	Total Scores
Low productivity of the crop (yield: tons/acres)	5	9	10	24
Damage to the quality and size of the fruit	6	7	11	24
Following supplementary irrigation and additional cost	2	10	10	22
widespread of agricultural pests	4	4	3	11
Appending wildlife crop damage (for example, mice, etc.)		6	2	8

Figure B6. *Priority impacts – Crops and trees.*

Crop losses of seasonal vegetables	H=Historical	C=Current	P=Potential	Total Scores
Changing cropping patterns	6	7	6	19
Low productivity of the crop (yield: tons/dunam)	4	7	7	18
Outbreaks of insects and flies, vectors	3	7	7	17
Leave a piece of land without cultivation	5	7	3	15
widespread of agricultural pests	4	5	5	14
Damage to the crop quality	2	7	3	12
Appending wildlife crop damage (for example, mice, etc.)		3	2	5

Figure B7. *Priority impacts – Vegetables.*

Loss of timber production and forest	H=Historical	C=Current	P=Potential	Total Scores
Increase in forest and rangeland areas	3	8	9	20
Increase forest trespass and cutting forests	8	7	4	19
Failures in replanting of forest	1	7	9	17
Widespread of agricultural pests	3	6	7	16
The erosion of productive forest land	5	5	5	15

Figure B8. *Priority impacts – Forestry.*

Loss of income for farmers and other directly affected and overall economic impact	H=Historical	C=Current	P=Potential	Total Scores
Unemployment caused by a decline in production related to the drought.	4	9	6	19
Farmers' loss resulting from bankruptcy.	7	6	5	18
Reduce seasonal employment and spinoffs	3	8	5	16
Laying off permanent employment	2	7	4	13
Increasing demand for drought-related energy	2	5	3	10
Loss of related activities that depend Directly dependent on agricultural production and food manufacturing	1	5	4	10
Loss of recreational and tourism industry and restaurants	2	5	2	9
Increase in food prices	4	8	5	17
Low economic development	4	9	4	17
Reduced agricultural exports	3	6	5	14
Overruling in grain supplies and basic food	4	7	2	13
A decrease in food production/food supply failure	3	6	3	12
The rising cost of living	2	7	3	12
Increasing food imports (higher costs)	1	6	3	10
Lower land prices		1	3	4
Increasing unemployment			1	1
An increase in poverty			1	1

Figure B9. *Priority impacts – Primary production labour, economic, and value chain effects.*

Disruption in water supply	H=Historical	C=Current	P=Potential	Total Scores
Shortage of water supply for agriculture	4	9	12	25
Decline Groundwater level	6	10	9	25
Shortage of water supply for drinking.	5	9	10	24
Increased cost increase groundwater extraction	4	9	10	23
Decrease the flows of Rivers and Streams	5	10	8	23
Increase the amount of water is the accountant and illegal use	4	10	8	22
The increase in the cost of finding new water resources or complementary	5	8	8	21
Reduced flow of springs	5	9	7	21
Change the quality of groundwater (salinity, carious tooth)	7	3	10	20
Low water levels in dams and reservoirs And Lakes	4	8	7	19
The high cost of obtaining water from alternative sources	1	6	10	17
Shortage of water supply for industry and economic activities	3	5	8	16
Low water supply companies income	2	5	6	13
Increased spending on buying bottled water	1	5	6	12
Increase the proportion of water lost in networks-physical losses	3	4	5	12
Increased subsidence phenomenon and increase drilling	1	3	5	9
Loss of revenue to the Government) by shrinking tax base)		5	3	8
Service institutions stress (and increase the fiscal deficit)	3	3	1	7
Low per capita water			1	1

Figure B10. *Priority impacts – water supply sector.*

Potential health effects	H=Historical	C=Current	P=Potential	Total Scores
Increase in diseases associated with lack of water	3	7	4	14
Spread of insects and disease vectors	3	6	4	13
Increased respiratory diseases	1	6	6	13
Increasing water pollution related diseases	1	6	4	11
The spread of diseases associated with malnutrition.	1	5	4	10
Demerit decreases in nutrition) mthlaalamrad relevant nutritional stress(	1	4	2	7
Mental and physical stress) for example, anxiety, depression, loss of sense of security, and domestic violence (	1	3	2	6
Loss of human life), for example due to thermal stress, suicides (		2	2	4

Figure B11. *Priority impacts - Human health.*

Potential health effects	H=Historical	C=Current	P=Potential	Total Scores
Increasing conflicts between water users	1	6	5	12
Public safety is affected by forest and grassland fires	1	6	4	11
Public dissatisfaction with the Government on tackling the drought		5	6	11
Resort to borrowing from different sources.		5	6	11
Not recognizing the institutional limitations on water use		3	7	10
Reliance on family and family social solidarity		5	5	10
Increasing conflicts between community members		2	7	9
Increased social and regional conflicts		3	6	9
Rely on social charity and social solidarity		4	5	9
An imbalance in cultural belief systems), for example, religious and scientific views on natural hazards and water uses (		3	5	8
Increased activity of charity campaigns		3	5	8
Inequitable distribution of drought relief		2	4	6
Reduction or modification of recreational activities		1	4	5

Figure B12. *Priority impacts – Social cohesion, conflict, and security.*

Reduced quality of life, and changes in lifestyle	H=Historical	C=Current	P=Potential	Total Scores
Depopulation), for example, from rural to urban (	1	3	1	5
In rural areas	1	3	2	6
In specific urban areas		4	2	6
Growing poverty in General		2	4	6

Figure B13. *Priority impacts – Rural-urban migration and poverty.*

In assessing the effects of the drought on the basis of:	H=Historical	C=Current	P=Potential	Total Scores
Differentiation by socio-economic class		3	2	5
Differentiation of ethnicity		2	1	3
Age (children and adolescents)		1	2	3
Discrimination Against older		2	1	3
Discrimination by sex		1	1	2

Figure B14. *Priority impacts – Disaggregation within social structure.*

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

Water stress

We calculate the water stress indicator using three components, as described below:

1. Total renewable freshwater resources (TRWR). This includes:

    a. Internal renewable water resources - the long-term average annual flow of rivers and recharge of groundwater for a given country generated from endogenous precipitation.

    b. External renewable water resources – the flows of water entering the country, taking into consideration the quantity of flows reserved upstream and for downstream countries through agreements or treaties (and, where available, the reduction of flow due to upstream withdrawal).

2. Total freshwater withdrawal (TWW). This is the volume of freshwater extracted from sources (rivers, lakes, aquifers) for agriculture, industries, and municipalities. It is estimated at the country level for the following three main sectors: agriculture, municipalities (including domestic water withdrawal), and industries (including cooling of thermoelectric plants).

    Freshwater withdrawal includes primary freshwater (water not withdrawn before), secondary freshwater (water previously withdrawn and returned to rivers and groundwater, such as discharged treated wastewater and discharged agricultural drainage water), and fossil groundwater.

    It does not include direct use of non-conventional water, i.e. direct use of treated wastewater, direct use of agricultural drainage water, and desalinated water. TWW is calculated as the sum of total water withdrawal by sector minus direct use of wastewater, direct use of agricultural drainage water, and use of desalinated water.

3. Environmental flow requirements (EFR). This is the quantity of water required to sustain freshwater and estuarine ecosystems. For the sake of simplicity, water quality and also the resulting ecosystem services are excluded from this formulation, which is confined to water volumes. Methods of computation of EFR are extremely variable and range from global estimates to comprehensive assessments for river reaches. For the purpose of the Water Stress indicator, water volumes can be expressed in the same units as the TWW, and then as percentages of the available water resources.

    Using these three components, we calculate water stress (%) as follows:

    $$\text{Water Stress (\%)} = \frac{TWW}{TWW/(TRWW\text{-}EFR)} * 100$$

    where:

    TWW = Total freshwater withdrawn, where year to which it refers will be provided

    TRWR = Total renewable freshwater resources

    EFR = Environmental flow requirements

    The data tables supporting this calculation and the production of Figure 7 in Section 3.1 are below.

Energy subsidies

Energy imports are a financial burden on the national economy and constitute about 25% of its GDP. Domestic natural gas covers only 4% of the Kingdom's energy needs. The 2010 energy law is intended to increase renewable energy generation, achieve safe supply, and promote investment in the sector.

The objectives of the energy subsidy include supporting the poor and improving equity, achieving energy security, correcting for externalities, and supporting domestic economic production and the associated employment.

There are cross-subsidies between high- and low-volume consumers and sectors through a differential block tariff system. The government currently subsidizes households that consume 600kW per month and less at a total cost of JD 500 million.

In August 2013, the government applied a new tariff system with a 15% increase on all economic sectors, except for agriculture, which was exempted from the hike. The current agriculture electricity tariff is 60 fils/kWh and for water pumping a flat rate price of 94 fils/kWh, whereas household consumers with a block of 601 to 750 kWh pay a tariff of 158 fils/kWh[18].

The increasing cost of power generation as reported by the government, (up to 184 fils per kilowatt-hour that is equivalent to USD 0.26/kWh) was due to the disruption of cheap Egyptian gas supplies. The cost of power generation for the National Electricity Production Company has steadily increased from a low of approximately 5-7 USD cents/kWh (for baseload gas generation) and a blended cost of generation of 10 USD cents/kWh in 2010, to today's high of 25 USD cents/kWh. Part of this increase has been passed on to the consumer due to socio-economic pressures (Greenpeace, 2013).

Rangeland degradation effects during recent droughts

During the 1998-2000 drought, natural ranges in the Eastern and Southern governorates - the major fodder source for about 70% of the nation's livestock - were estimated at 10% of normal productivity. Only 3 of the MOA's 24 rangeland reserves were opened due to a lack of fodder. Rangeland degradation resulted in major flock liquidations, increasing import of fodder, and gradual westward movement of herders towards more productive regions, which has caused social strife. Total estimated losses in terms of forage production in that drought were JD 44.8 million (~$USD 63.4 million), of which JD 31.5 million (~$USD 44.6 million) came from the *Badia* (EU Commission, 2014).

Disaster risk finance mechanisms

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

Government agencies typically face difficulties funding pre-impact programmes for mitigation as well as the development of preparedness policies and plans. Because drought impacts are rarely defined fully in economic terms and due to 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 (Figure C1). In MENA countries, as well as 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.

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.

Figure C1. *Public sector responsibility in managing catastrophe risk (Source: Kron for Munich Re, 2017)*

[18] From National Electric Power Company's Electricity Tariff in Jordan webpage. Available online.

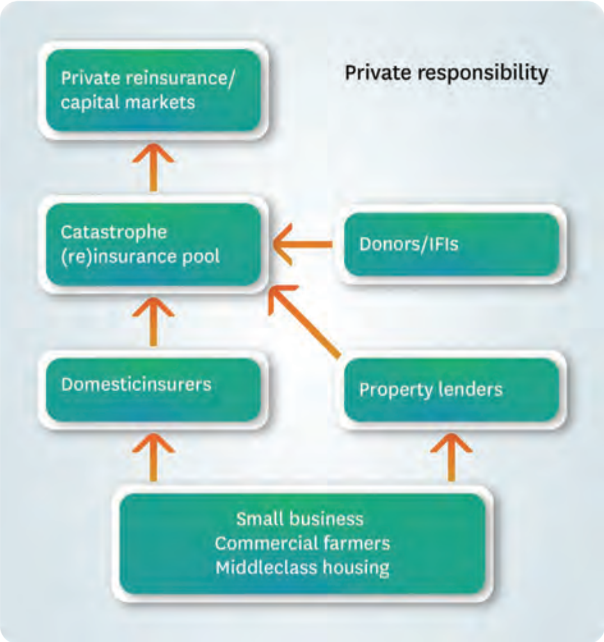


Figure C2. *Private sector financial responsibilities in drought relief support. (Source: Kron for Munich Re 2017).*

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 economy recover and re-establish themselves more quickly (Overseas Development Institute, 2017). In an ideal world, this would be the safety net of last resort and would be part of an integrated approach to drought risk management (Munich Climate Insurance Initiative, 2017). However, until there is greater adoption of adaptation measures, undertaken 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.

Figure C3 below provides summary analysis of the strengths, weaknesses, opportunities, and threats (risks) associated with different types of drought insurance products.

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	Smoothing farmer's income between seasons
Long-term social impact	Smoothing farmer's income between seasons	Named-peril insurance
Smoothing farmer's income between seasons	Traditional products for insurance forms	Smoothing farmer's income between seasons
Promising market for insurance companies	Smoothing farmer's income between seasons	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

Figure C3. *SWOT analysis of financial risk management products*

Given Jordan's relatively extensive and dense meteorological and hydrological monitoring networks in core areas and relatively rich agricultural production datasets, there is likely an adequate base of data on which to generate payout thresholds. These could be focused on specific crops or areas such as the Jordan Valley or northern Highlands, and they could potentially also include risk transfer mechanisms associated with production losses at the macro-economic level rather than at the producer level.

Long-term challenges to resilience: groundwater over-abstraction practices and reliance on fossil water cannot last long-term

Access to groundwater has always been a source of drought resilience in Jordan, but modern abstraction practices threaten its capacity to buffer drought impacts and the long-term sustainability of aquifer usage. As reported in Section 3.2.1 and examined further by Al-Karablieh and Salman (2016), groundwater levels are dropping rapidly in all major aquifers.

However, determining whether and how structural over-abstraction affects drought resilience is not straightforward. Hornbeck and Keskin (2014) evaluated how rapid shifts to groundwater-dependent irrigation – in many cases precipitated by drought – affected drought resilience in areas of the United States underlain by the Ogallala Aquifer. They compared long-term economic trends in rainfed and groundwater-dependent areas and showed that groundwater resource depletion resulted in increased vulnerability to drought impacts including earnings fluctuation, crop yield, and land prices.

In contrast, rainfed areas had more predictable land values, crop yields, and drought sensitivity in the period under study. In that example, groundwater use reduced drought vulnerability for a short time period until farmers had shifted practices to rely on it entirely, after which groundwater was mined for rapid wealth extraction until the resource collapsed.

Whether the accumulated capital allowed them to weather future droughts more effectively overall from a wider socio-economic or community perspective is another question. The Ogallala example and subsequent question highlight the difficulty in disentangling linkages between resilience-building and long-term sustainable resource management.

Given that socioeconomic status is one of the most important factors in disaster resilience at the national, community, and household level (see, for example, Kamali *et al.*, 2019; Nelson *et al.*, 2007; SAMHSA, 2017), it is worth considering the following question: does it make sense, from a political economy perspective, to allow rapid groundwater mining? In the abstract, one could conclude that if the expected wealth accumulation would buffer the population from future drought impacts by providing adequate replacement income flows, that would be a sensible choice.

Until the 1990s, the GOJ was providing major direct incentives for groundwater abstraction and running state-owned agribusinesses dependent on fossil groundwater. Currently, electricity subsidies and other indirect subsidies incentivize groundwater abstraction (Al-Karablieh and Salman, 2016).

However, more recent GOJ actions indicate that it does not consider groundwater mining to be an acceptable outcome writ large, and particularly in several key areas such as the highlands and the Azraq basin. For instance, Molle *et al.* (2017) describe how the GOJ has vigorously attempted to slow groundwater declines in the Azraq basin and expended considerable political capital in doing so. Likewise, Al-Karablieh and Salman (2016) show how the GOJ has worked to reduce irrigation in the Disi basin since the late 1990s.

Political dynamics, particularly the government's willingness to constrain economic activities, will continue to shape these outcomes over time (Molle and Closas, 2020). Groundwater-dependent farms primarily serve export markets, so one could reasonably expect the balance of trade and internal political considerations to drive these future decisions more than considerations of whether capital accumulation will be adequate and appropriately distributed, to offset future drought impacts. However, the distributional effects of groundwater resource degradation, and the attendant social impacts of increased drought vulnerability, will likely be core in that decision-making calculus and thus vital to consider in relation to drought risk management policies.

Table C1. *Water resources in Jordan over the period (1990-2016) in Million Cubic Meter (mcm) (MWI, 2018b).*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Rainfall volume (mcm)	8379.0	10529.0	5898.0	8439.7	8439.7	8524.0	6046.0	8676.0	9110.0	2972.8	3651.1	7376.0	6517.9	9708.0	6951.0
Evaporation Volume (mcm)	7836.5	9425.0	5482.9	7913.5	7921.5	7858.3	5573.8	8141.6	8606.2	2919.9	3473.9	6978.6	6003.3	9026.2	6550.3
Floods Volume (mcm)	245.1	438.3	136.6	168.7	171.4	290.7	206.2	226.1	255.3	10.0	75.1	136.2	150.9	274.4	134.4
Recharge Volume (mcm)	297.3	665.7	278.5	357.5	346.9	375.1	266.0	308.4	248.5	42.9	102.1	261.1	363.7	407.4	266.3
1. Total Surface Water Resources (A+B+C)	645.0	857.2	621.4	547.7	602.5	762.9	629.7	688.2	720.1	430.3	498.7	490.7	516.0	720.3	588.3
A. Total Surface Water Resources within the Country	520.1	733.3	424.5	390.5	449.0	575.7	437.2	478.1	490.3	238.5	300.2	313.5	355.6	556.9	376.1
Floods	245.1	438.3	136.6	168.7	171.0	290.7	206.2	226.1	255.3	10.3	75.2	148.4	127.0	276.1	134.3
Base Discharge and Spring	275	295	287.903	221.859	278	285	231	252	235	228.18	225.027	165.064	228.56	280.798	241.794
B. Total External Water Resources	98.4	95.5	165.0	118.5	99.2	129.8	131.6	146.9	156.3	118.1	122.5	98.8	82.1	82.1	118.3
a. Yarmouk river	98.36	95.50	165.00	118.50	99.20	108.00	100.80	99.50	100.40	87.76	92.15	68.06	59.56	59.56	85.35
b. Tibaria Transfer	0	0	0	0	0	21.79	30.831	47.414	55.927	30.35	30.31	30.739	22.507	22.507	32.954
C. Non-Conventional Water Resources	26.5	28.4	31.8	38.7	54.3	57.5	60.9	63.2	73.5	73.7	76.0	78.4	78.4	81.4	93.9
1. Treated Wastewater used	24.5	26.22	29.44	36.06	51.496	54.985	58.946	61	70.989	69.724	72.033	73.438	72.365	75.396	86.422
2. Desalination	2	2.2	2.4	2.6	2.8	2.5	2	2.2	2.5	4	4	5	6	6	7.5
1. Total Conventional Surface Water Resources (A+B)	618.5	828.8	589.5	509.0	548.2	705.5	568.8	625.0	646.6	356.6	422.6	412.3	437.7	638.9	494.4
Total Surface Water Utilized (from WB)	340.2	314.6	424.6	449.0	350.5	324.8	313.7	328.5	341.4	249.8	271.5	242.5	215.4	214.7	278.5
c.Total Surfcae Water lost by Uncontrol Floods, Evaporation	278.3	514.2	164.9	60.0	197.7	380.7	255.1	296.5	305.3	106.8	151.1	169.8	222.3	424.2	215.9
Percent of Total Surface Water Utilized	55%	38%	72%	88%	64%	46%	55%	53%	53%	70%	64%	59%	49%	34%	56%
2. Total Groundwater Resources	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0
a. Renewable Groundwater	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0
b. Non-Renewable Groundwater	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0
3. Treated Wastewater generated	59.3	59.3	59.3	59.3	59.3	60.7	65.1	67.4	78.4	77.0	79.6	81.1	80.0	83.3	95.0
3.1 Treated Wastewater used	24.5	26.2	29.4	36.1	53.7	55.0	58.9	61.0	71.0	69.7	72.0	73.4	72.4	75.4	86.4
a. Treated Wastewater Blended in Jordan Valley (KTD+etc)	22.4	24.1	27.3	33.9	51.5	51.9	55.6	57.3	66.0	64.7	66.9	73.4	65.4	67.4	65.4
b. Direct Use of Treated Wastewater from source, highland	2.1	2.1	2.1	2.2	2.2	3.1	3.3	3.7	5.0	5.0	5.1	6.2	7.0	8.0	21.0
4. Desalination	2.000	2.200	2.400	2.600	2.800	2.500	2.000	2.200	2.500	4.000	4.000	5.000	6.000	6.000	7.500
Total Water Resources (1+2+3+4)	1,098	1,308	1,069	989	1,028	1,187	1,054	1,113	1,146	856	924	916	942	1,146	1,015

Table C1 Continued. *Water Resources in Jordan over the period (1990-2016) in Million Cubic Meter (mcm) (MWI, 2018b).*

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Rainfall volume (mcm)	9304.4	6258.0	7684.0	5194.0	6376.0	8728.0	6476.6	5942.6	8120.6	7228.2	8884.8	9482.8
Evaporation Volume (mcm)	8670.4	5812.7	7194.4	4869.7	5924.5	8092.8	6072.4	5533.8	7688.9	6816.9	8154.1	8771.9
Floods Volume (mcm)	269.8	156.6	167.3	115.2	194.1	210.1	119.0	139.1	187.1	180.5	245.3	266.0
Recharge Volume (mcm)	364.2	288.8	322.3	209.1	257.4	425.1	285.2	269.7	244.6	230.8	485.4	444.9
1. Total Surface Water Resources (A+B+C)	694.0	554.1	584.5	490.2	521.0	593.5	497.1	562.7	651.8	653.1	742.0	727.6
A. Total Surface Water Resources within the Country	508.5	392.4	422.8	313.3	313.7	418.7	328.8	373.5	449.5	405.0	495.0	477.7
Floods	269.7	156.6	194.5	115.3	126.8	210.2	119.0	139.2	187.1	180.0	245.0	265.9
Base Discharge and Spring	238.82	235.8	228.33	197.91	186.92	208.575	209.774	234.3	262.32	225	250	211.8
B. Total External Water Resources	92.2	68.2	59.5	64.2	94.8	58.8	56.4	74.7	81.1	112.6	108.0	109.4
a. Yarmouk river	43.96	17.70	15.99	18.20	52.19	13.50	12.64	18.52	28.23	57.40	60.00	57.40
b. Tibaria Transfer	48.22	50.45	43.48	46	42.64	45.3	43.73	56.2	52.91	55.2	48	52
C. Non-Conventional Water Resources	93.3	93.5	102.2	112.7	112.5	115.9	111.9	114.5	121.2	135.5	139.0	140.5
1. Treated Wastewater used	83.545	83.545	90.997	101	102.4	102.84	102.994	101.3	109.1	125.3	133	136.34
2. Desalination	9.797	10	11.181	11.7	10.1	13.1	8.935	13.15	12.1	10.2	6	4.2
1. Total Conventional Surface Water Resources (A+B)	600.7	460.5	482.3	377.5	408.5	477.5	385.1	448.2	530.6	517.6	603.0	587.1
Total Surface Water Utilized (from WB)	351.4	365.3	344.9	335.8	341.3	279.1	286.8	239.0	252.7	258.0	274.2	288.8
c. Total Surfcae Water lost by Uncontrol Floods, Evaporation	249.3	95.2	137.4	41.6	67.2	198.5	98.3	209.2	277.9	259.6	328.8	298.4
Percent of Total Surface Water Utilized	58%	79%	72%	89%	84%	58%	74%	53%	48%	50%	45%	49%
2. Total Groundwater Resources	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0	418.0
a. Renewable Groundwater	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0	275.0
b. Non-Renewable Groundwater	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0	143.0
3. Treated Wastewater generated	99.0	86.5	97.9	108.8	110.1	112.7	115.8	111.3	110.3	137.0	147.0	151.4
3.1 Treated Wastewater used	83.5	80.3	91.0	101.0	102.4	102.8	103.0	101.3	109.1	125.3	133.0	136.3
a. Treated Wastewater Blended in Jordan Valley (KTD+etc)	59.8	58.8	65.9	54.3	62.8	64.0	60.9	52.3	58.4	83.0	90.0	101.1
b. Direct Use of Treated Wastewater from source, highland	23.8	21.5	25.1	46.8	39.6	38.8	42.1	49.6	50.7	42.3	42.5	35.2
4. Desalination	9.797	10.000	11.181	11.681	10.100	13.100	8.935	13.600	12.100	10.200	10.000	7.800
Total Water Resources (1+2+3+4)	1,127	975	1,009	916	947	1,021	928	991	1,071	1,083	1,178	1,164

Table C2. *Non-revenue water per governorate (1995 to 2016; inclusive of physical losses and administrative losses) (MWI, 2018b)*

Year	Amman	Balqa	Zarqa	Madaba	Irbid	Mafraq	Jerash	Ajloun	Karak	Tafela	Maan	Aqaba	Non Revenue Water(%)
1995	54.40%	62.20%	55.10%	54.40%	55.00%	76.20%	55.00%	55.00%	53.60%	53.80%	53.80%	53.60%	55.50%
1996	50.30%	59.60%	54.30%	67.20%	49.60%	68.70%	50.20%	57.80%	50.20%	52.70%	56.70%	49.60%	53.80%
1997	48.50%	61.20%	54.20%	77.30%	49.50%	78.90%	47.40%	60.00%	57.10%	44.80%	65.80%	44.80%	54.10%
1998	49.50%	62.10%	56.40%	86.10%	48.90%	78.50%	60.10%	60.30%	59.40%	43.90%	67.30%	43.90%	55.90%
1999	50.00%	56.10%	55.30%	75.00%	45.70%	76.40%	42.90%	48.00%	56.80%	47.50%	62.30%	42.90%	54.20%
2000	50.30%	54.70%	54.80%	58.20%	44.30%	74.60%	44.70%	44.70%	56.40%	41.30%	59.90%	41.60%	52.00%
2001	52.90%	46.80%	55.00%	58.30%	41.90%	74.30%	33.60%	37.20%	56.60%	38.50%	53.50%	40.60%	50.80%
2002	47.50%	53.90%	55.80%	50.00%	42.20%	70.60%	37.20%	40.60%	51.90%	44.60%	52.30%	31.50%	49.10%
2003	48.50%	51.60%	51.50%	46.50%	39.60%	68.20%	23.80%	37.40%	47.50%	43.10%	46.80%	30.80%	49.40%
2004	44.60%	54.10%	51.80%	45.30%	36.50%	64.60%	30.40%	26.60%	46.50%	40.60%	43.10%	29.90%	46.50%
2005	42.50%	53.60%	52.10%	45.10%	37.80%	61.50%	24.20%	32.40%	44.90%	43.80%	42.10%	27.00%	45.50%
2006	39.60%	53.20%	50.90%	40.40%	37.90%	59.60%	22.80%	34.00%	55.40%	42.20%	45.60%	24.60%	43.00%
2007	35.80%	50.80%	53.10%	45.80%	36.10%	58.70%	19.60%	33.20%	60.60%	46.30%	55.00%	25.40%	43.00%
2008	37.90%	51.90%	55.60%	49.20%	38.40%	59.80%	30.60%	35.00%	61.30%	51.60%	57.40%	21.60%	44.00%
2009	37.70%	52.20%	54.40%	49.60%	33.10%	63.50%	30.20%	34.00%	58.80%	49.70%	54.80%	21.00%	44.00%
2010	35.30%	51.90%	51.90%	49.20%	38.40%	59.80%	30.60%	35.00%	61.30%	52.00%	57.40%	23.60%	43.00%
2011	33.90%	49.80%	49.80%	47.20%	36.90%	57.40%	29.70%	33.60%	58.90%	49.90%	55.10%	22.90%	42.00%
2012	37.40%	59.30%	49.40%	37.70%	34.20%	47.70%	43.00%	43.80%	40.20%	46.20%	78.10%	25.90%	47.00%
2013	34.90%	62.30%	58.20%	61.90%	33.60%	52.00%	41.40%	41.60%	58.30%	40.30%	66.60%	25.80%	48.00%
2014	37.60%	68.30%	65.00%	34.50%	38.60%	68.00%	45.00%	42.00%	69.00%	57.00%	73.20%	28.00%	52.00%
2015	36.60%	68.30%	65.20%	36.20%	38.60%	69.50%	45.10%	42.20%	69.20%	57.20%	73.20%	28.20%	51.30%
2016	37.00%	62.20%	59.50%	61.90%	35.80%	66.70%	41.50%	41.10%	58.30%	40.00%	66.80%	24.00%	50.00%

Poverty by region

Table C3 below reports official 2010 figures for poverty by governorate (Table 8; DOS, 2010) and a recently-published estimate in the academic literature for 2017 figures (Al-Jaloudi, 2020). Although the highest 2010 poverty rate was seen in the governorate of Ma'an (26.6%), the highest total number of poor households was in Amman (about 37,000 households). The data indicate that while there is a higher incidence of poverty in rural areas (16.8%) compared to urban areas (13.9%), far more urban households are poor.

The poverty gap is a measure of how far, on average, households are from the absolute poverty line. The poverty gap is also more significant in rural areas than urban areas, which means that, on average, poor households in rural areas are poorer than poor households in urban areas. Between 2010 and 2017, Al-jaloudi (ibid) estimates poverty has increased significantly throughout the country, but most especially in Amman, Al-Zarqa, Al-Karak, and Al-Mafraq governorates.

Table C3. *Poverty indicators (in %) in Jordan in 2010 and estimated for 2018 (Al-Jaloudi, 2020) using the consumer price index.*

Indicators	Poverty Rate (2010)	Estimated poverty Rate (2017)	Poverty Gap Ratio (2010)
Amman	11.4	21.6	2.7
Balqa	20.9	24.1	5.9
Zarqa	14.1	24.6	3.4
Madaba	15.1	22.7	3.7
Irbid	15	22.1	3.6
Mafraq	19.2	20.2	5.6
Jerash	20.3	27.1	1.2
Ajloun	25.6	26.5	6.3
Kerak	13.4	24.8	3.7
Tafileh	17.2	21.9	3.5
Maan	26.6	20.1	8.3
Aqaba	19.2	24.8	4.3
Kingdom	14.4	22.2	3.6

In 2010, 27 "rural poverty pockets" existed, areas in which more than 25% of the population was in poverty, as shown in Figure C4 below.

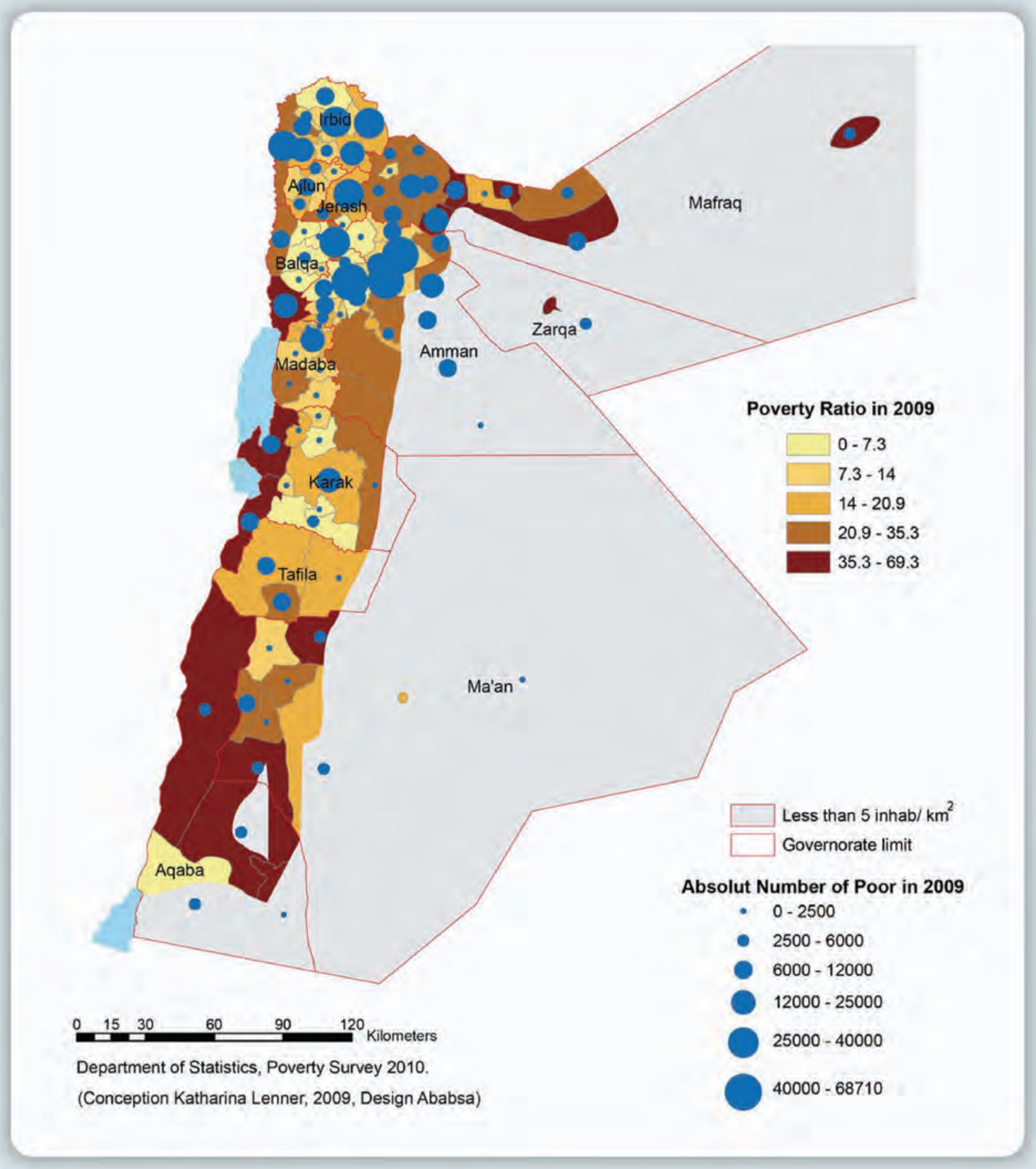


Figure C4. *Proportion and absolute number of poor households by sub-district (from Katharina Lenner's chapter in Ababsa (ed.) Atlas of Jordan: History, Territories and Society).*

Access to finance and debt

Here we provide more extensive detail on farmers' and herders' access to credit according to wealth hierarchies as this is the primary determinant of farmers' finance and debt characteristics. The growing frequency of drought conditions increases the importance of timely and affordable access to credit as a critical success factor for farmers and herders to weather dry periods. Increased costs for inputs put pressure on all farmers and herders. The lack of access to short-term credit facilities to perform routine 'maintenance' to work vehicles, for veterinary services, or for fodder or well operations often make these operations financially unsustainable.

Access to finance and debt for commercial farms (medium and large size)

For medium- and large-sized farms (over 20ha), the state-owned Agricultural Credit Corporation (ACC) is a valuable option for accessing finance. ACC offers seasonal-, short-, medium- and long-term loans to around 7,000 beneficiary projects annually across the country (ACC webpage, 2021).

In the case study described in Section 4.4, larger farmers felt that debt-related challenges were more related to repayment than access in the first instance. Only 11% of farm owners had borrowed in the past from the ACC, and the reimbursement schedule was 300-500 JD/month; only 6% had conducted feasibility studies to ensure return on investment was possible. Only 2% of these farmers continue to borrow regularly from the ACC.

For farmers that usually access credit, they prefer to make purchases through selected credit commissioners that are typically also agricultural input suppliers. Belhaj Fraj (2018) interviewed commercial farms in the Azraq area and found that beyond the farmers who access the ACC, only 35% of owners of medium to large farms declared that they took credit from commissioners or benefited from gradual repayment to equipment suppliers.

In the case of loans for farm establishment, including equipping a full irrigation system, farmers need at least 3.5 years to pay back the initial investment. Most of the farmers declared that they paid back the entirety of their loans within a maximum of 8 years. Most farmers (65%) rely on savings to invest as farming is their main source of income. Large farms have three months of positive cash flow: December, July, and August. 35% of large farm owners rely on trade, services, and other industrial activities as their main source of income.

Interest rates from commissioners are typically 20% per year, which is financially predatory. The creditors from input and equipment retailers are more flexible with the owners of large farms, and they primarily offer low-quality products at low prices. This is partly due to the lack of public support, such as for the palm weevil that ravages date palms. Medium-sized farm owners saddled with debt are discouraged from investing in timely and routine repair and maintenance of equipment and machinery. Medium-sized farms are also likely to experience a higher turnover in staff compared to larger farms, which usually implies further losses in terms of knowledge and capability.

This credit market and operational environment are unconducive to medium-sized farmers, who are more likely to go bankrupt than large farms. The deterioration of productivity and product quality in a situation of price volatility, lack of integration in value chains, and continuous increase in costs due to irrigation requirements to address water and thermal stresses can make these operations unviable in the medium and long term. They are bought up by wholesale market traders and opportunists, not necessarily people with a professional agricultural vocation, or by wealthy people looking for a second home and a hobby farm.

Even large farm owners are worried about the debt required to invest in expansion or diversification. Farmers are aware of challenges with loan repayments, high interest rates, and having to divert funds to cover unexpected input cost increases rather than investments in, for instance, processing or cooling. When loan repayments start in the season following a drought period, the costs of restarting agricultural activities usually increase.

The productivity of drought-affected olive trees among farmers in *Azraq* was said to take more than one season to recover. In addition to these initial labour costs and reduced productivity, loan repayments can push many farms to the limits of financial viability. In seasons following drought years, labourers perceived that farmers were often slower in starting to employ seasonal farm labourers. This was seen as resulting either from delayed harvest periods because there was less to pick and process, or because of increased caution among farmers when restarting cultivation. There are also greater delays in farmers paying labourers during such a season, which further interferes with labourers' abilities to manage expenses and debts in a timely fashion. The additional pressure of debts even in non-drought years can continue to push farmers towards making compromising decisions around inputs. The only investment they are convinced of is that in water- and energy-efficient hardware.

Commercial farms and market chains

Commercial farmers mainly sold their produce to the local market with wholesale markets being 30% and commissioners and cooperatives being 25%. Only 20% of farmers target export markets, which contrasts strongly with neighbouring countries. Farmers relying on traders and the internet to market their products do not exceed 5%.

20% of farmers find new customers in exhibitions, through associations, cooperatives, unions, and commissioners. To improve their marketing, most of the pioneer farmers (10%) belong to AAPMO (Association of Azraq for Production and Marketing of Olives), in addition to other minor NGOs such as Olives Producer Society (OPS), Association of Azraq to Save the Water Oasis (AASWO), Sahara Farmers to Save the Oasis (SFSO), Reservoir Savers (#RS), and Azraq Reservoir Association (ARA). The preferred professional networks of farmers are associations, projects, and cooperatives. The engaged farmers rely mainly on associations to get technical advisory services and discounts on agricultural equipment and inputs. Farming businesses are still profitable, as 85% of the farmers are going to hand over their profession to the next generation. However, they think that it will be challenging for the next generation to stay profitable.

Access to finance and debt for smallholder farms (under 2ha)

Smallholder farmers' expenses and losses are seasonal, but earnings and household expenditure need to last the whole year, so farmers can become overwhelmed with managing their own financial performance. Financial literacy plays an important role in farmers' abilities to make informed decisions around the sustainable and effective financing of farm and household overheads. There was a paucity of literature on available financial support, crop insurance, or access to credit facilities for farmers facing financial difficulties, and the information presented in this report, therefore, stems from interviews and focus groups.

For farm labourers among smallholder farmers, debts were most often accrued to cover general household costs, rather than for any agricultural activities. Farm labourers most frequently relied on personal networks for raising capital for household and work-related expenditure. All-female farm labourers interviewed were familiar with and had accessed credit from the Jordanian Micro-fund for Women (MFW).

Access to finance and debt for large pastoralists

Among livestock producers, credit options depend very much on the scale of the operation and the grazing system operated. Larger crop-livestock integrated operations would typically rely on the ACC for loans and, less frequently, on commercial banks or private lenders. The need to source affordable, reliable inputs in times of price fluctuations and scarcity was achieved by maintaining solid relationships with partners along the supply chain. Several respondents highlighted input providers as a source of financial stability when droughts impact capital availability.

Access to finance and debt for smaller pastoralists

This category– with a herd size of between 100 – 200 sheep or goats – report relying on informal sources of credit, such as family or tribal networks. Money is typically borrowed from friends and family at the beginning of the dry season to cover unanticipated increases in household and pastoral expenditure and paid back at the end of the season. While informal, the inability to repay loans would have different consequences for this latter group and was often discussed as a source of personal concern and household tension, as suggested in this quotation:

"We try to rely exclusively on family support when I get stuck, but my losses are my own and I must make up for them as a matter of honour."

As a result, smaller pastoralists preferred to rely on more regular migration and more stringent minimising of household expenditure (and expectations), rather than increased borrowing. Although all livestock producers benefitted from subsidized fodder, especially when droughts affected pastoralists who depend on rangelands, the costs of even subsidized fodder remained prohibitive for shepherds with smaller flocks. Pastoralists were not aware of any government aid (other than subsidized fodder) or relief programmes that could help them manage the increasing threats and costs of droughts.

A general challenge facing livestock producers when recovering from drought relates to sourcing the funding to cover the additional costs of returning to former levels of productivity. Even when a year's rains are good and rangelands are rich in biomass, many livestock producers find themselves poorly placed to take full advantage of conditions. This is not only due to their having sold off much of their herd at suboptimal prices during the former dry year but also because of the additional costs and challenges of paying back debts accrued during that period. All pastoralists felt that more structured financial help was necessary to support the recovery of flock and herd numbers when drought events resulted in reductions in herd size.

Appendix D – Detailed content and figures from Section 4: coping mechanisms

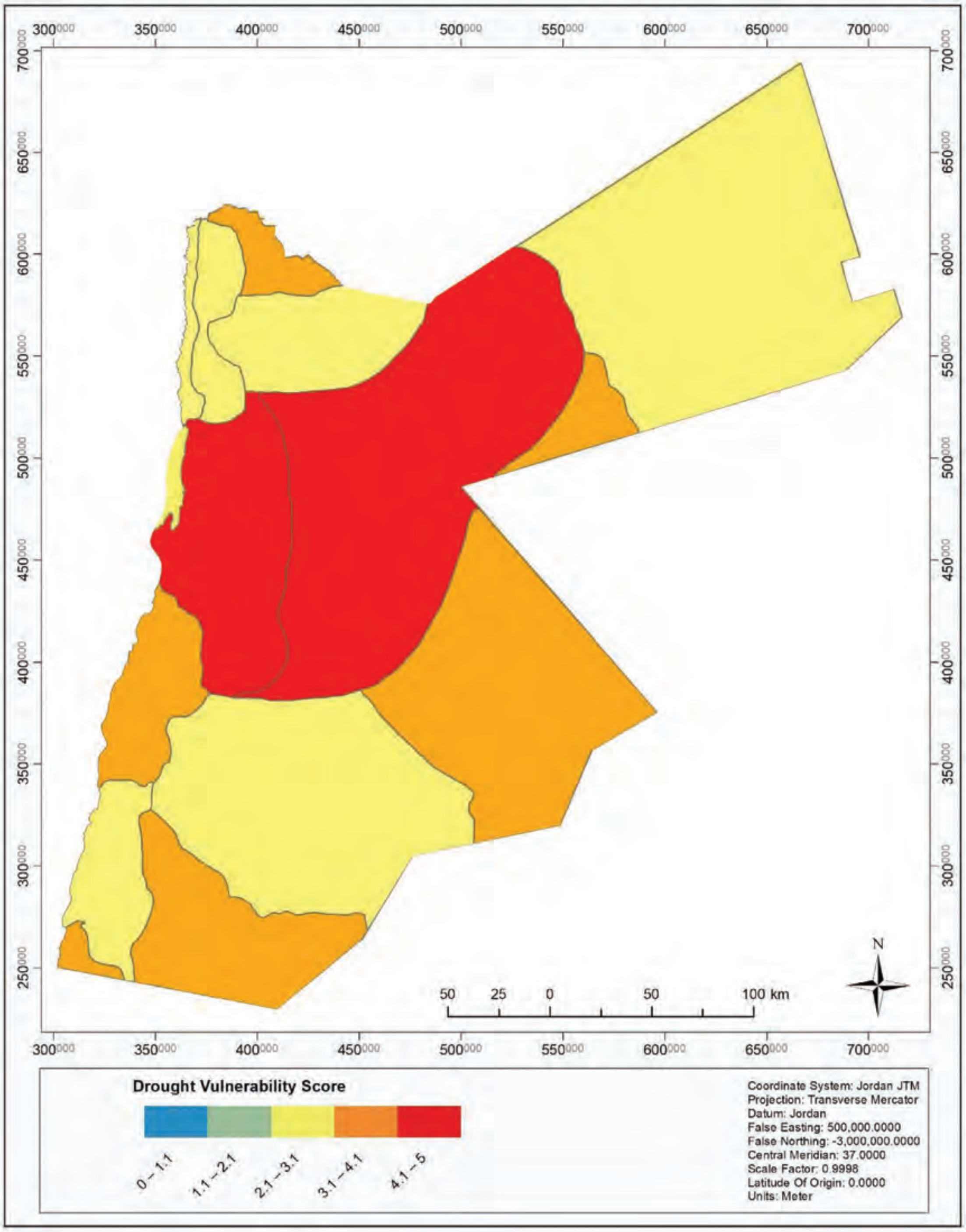


Figure D1. *Groundwater drought vulnerability in Jordan (Al-Adailah et al., 2019).*

Appendix E – Detailed content and figures from Section 5: Informing drought risk management

Table E1. *Identified drought monitoring needs (2015) in rank order.*

Need	Description
Detailed technical training	*Improved technical training for engineers and officers.*
Data sharing	*Formalize the data sharing exchange program; create a permanent network with regular meetings.*
Drought declaration	*Create clear mechanisms for defining a drought and/or making a declaration.*
Interagency buy-in	*Create a cooperative environment with open communication between agencies, and buy-in amongst them.*
Civil society involvement	*Involve farmers, non-governmental organizations, and the public in monitoring; use their input, and make products accessible to them.*
Scientific consensus	*Use a single indicator, or agree on the multiple inputs.*
Reliability	*Use of reliable data sources; engage field validation efforts.*
Drought committee	*Appoint a national committee to coordinate stakeholders with the authority to declare drought.*
Include groundwater	*Link drought with groundwater resources and water balance modeling.*
Crop guidance	*Develop the capacity to provide crop planting advice related to timing and irrigation.*
Regional connection	*Link up with regional monitoring initiatives.*
Proper time scale	*Produce monitoring products on a frequent and tailored (downscaled) basis; understand the time-scale involved in processes related to drought.*
Local vulnerability	*Work with local offices and vulnerable areas.*
Open data	*Use openly available data and make the outputs readily accessible.*
Simple training	*Simplified training for political users.*
Data platform	*Have a data repository for ease of use.*
Connect other issues	*Understand how drought fits in with other domains, such as climate and finance.*
Ease of use	*Create a simple, easy-to-use early warning system.*
Water markets	*Understand how to inform water pricing programs.*

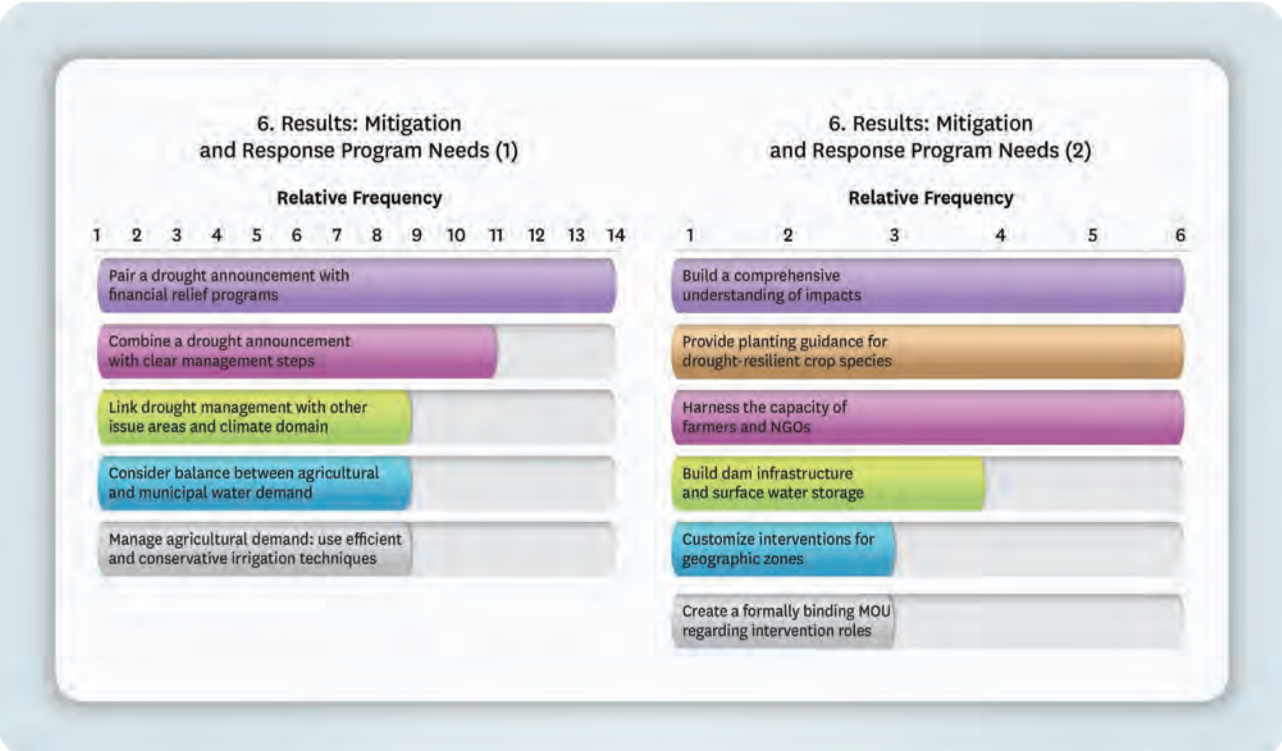


Figure E1. *Ranked drought mitigation and response needs (2015), listed in order of their prevalence.*

Explanation of top-ranked drought management needs

Pair a drought announcement with financial relief programs.

Stakeholders see a need for financial support for farmers when drought occurs through subsidies for livestock feed or to delay loan repayment when farmers cannot make payments due to drought. Stakeholders want a connection between drought monitoring and monetary relief for losses associated with drought at the national level to help bridge the current gap between drought information and drought intervention. Implementing financial relief programs would require skills and capacity building for the agriculture staff who monitor drought. Also, connecting financial mechanisms to drought monitoring may improve the clarity of roles and responsibilities and lead to a clearer articulation of how the drought information can be used. At present farmers do not have access to drought insurance products for financial risk management.

Financial measures and interventions, according to participants, must be pre-prepared to ease drought declaration processes and interventions themselves. Financial relief programs represent a significant departure from current operating procedures; at present, according to participants, crisis management is lacking, and "there's no preparation and preparedness".

Stakeholders are concerned that drought 'payouts' in the past have only been for irrigated agriculture and not rainfed systems, and they hope that a well-designed drought map tool would equalize relief efforts.

Control and enforce well drilling operations; government-based accounting for existing wells.

Stakeholder comments regarding water management begin with the observation that limiting agricultural expansion would reduce water consumption, especially in groundwater-dependent areas. These conversations inevitably shift to the monitoring and control of well drilling operations. Participants are particularly concerned with the levels of policing and what they view as more favourable treatment of particular groups. Controlling illegal wells is viewed as key to effective water management, but groundwater governance is not effective even though a regulatory framework is in place. Participants wanted more active coordination with the Ministry of Interior and Ministry of Defence to enforce groundwater regulations.

Participants noted a connection between illegal well drilling and land speculation and believe that it is the government's duty to manage both activities. Inconsistency regarding enforcement signals to illegal well owners and diggers that they should simply "wait a while and then pick up like normal." This has become a key source of tension between legal well owners and illegal well owners. Farmers who have legal wells are often left on their own to pressure illegal well-owners. Under-reporting of well location contributes to the overall number of illegal wells. Engaged citizens and farmers could be potential actors in a future action plan to deal with illegal drilling. GPS tagging and reporting is a good idea for creating a database of well locations, but stakeholders expressly reiterated the core problem is lack of enforcement at present.

Combine monitoring and a drought announcement/declaration with clearly defined management steps.

Stakeholders report that the MOA needs clear mechanisms to declare drought. This would allow monitoring information to reach relevant users once the thresholds for monitoring are reached, which can be the basis for drought intervention policies. As it stands, the government avoids drought declaration because they view it as having severe financial implications (e.g. feed subsidy and compensation for yield reduction). Clarifying the mechanisms of drought declaration would reduce the uncertainty regarding agency roles and reliance on foreign donors. As one stakeholder put it, "this monitoring information must connect with an actual strategy and action plan for managing drought". Participants think that monitoring capacity within government agencies is strong, but they desire capacity building for staff to create drought management strategies with outside stakeholders. For example, the meteorological department sends good information, and pairing this with analysis of drought mitigation measures would be complementary to the monitoring information. Also, establishing a drought unit or committee with political decision-making power would help to meet the need for clear definitions and management steps for drought.

Link drought management with other issue areas (frost, water supply and scarcity, desertification, poverty, zoning regulations) and the climate domain.

Connecting the drought management system with climate change issues was reported as a need. Stakeholders know that water scarcity is increasing in Jordan as a result of population growth and declining long-term precipitation trends. This makes drought management and climate change adaptation similar in many ways. Connections between drought monitoring and other programs (e.g. frost) were offered as potential models to follow in which remediation actions are paired with monitoring tools. Stakeholders also want to connect drought management to long-term municipal water supply programs. They describe the Wadi Araba project as complementary to the Red Sea - Dead Sea connection. Using surface water canal systems and pumping stations would provide governorates with supplementary municipal supplies. Understanding how climate change will affect this infrastructure is critical and is also connected with desertification and social vulnerability trends.

Lastly, stakeholders described the need for zoning regulation enforcement to slow down rapid land-use change. As parcels are converted from rangelands and fields to housing, vulnerable populations are removed from former grazing lands considered 'unused', though they are cultivated on a small scale. Drought mapping that is cognizant of land use and zoning regulations would accommodate the needs of these impoverished communities.

Consider the balance between water demands in municipal and agricultural supply.

Stakeholders describe the need to understand more thoroughly how demand shifts in urban and agricultural settings. Since drought impacts extend beyond agriculture, stakeholders request strategic preparations for drought in connection with municipal water supply. As saline water utilization grows, blending water for municipalities and agricultural communities becomes increasingly viable, and stakeholders want to engage in careful planning to manage between these competing needs.

Participants said additional staff upskilling in ET/crop mapping would build management capacity in the agricultural sector because it would help agencies conduct regional water demand and efficiency balances that can feed into sectoral arbitration frameworks. Since there is no clear law or regulation for water use in agriculture at present, it is difficult to understand how it connects with municipal needs. Participants do not think that drinking water is presently threatened, but they are concerned that it is a long-term challenge that will require pre-planning.

Manage agricultural water demand by using efficient, innovative, conservative, and seasonally appropriate irrigation practices.

Beyond having drought planning in place in advance, participants say there is a major role for demand management. Smallholders in the Jordan Valley recognize that a range of cropping and irrigation systems create unique needs and constraints throughout the valley. The drought management system, therefore, must work to include monitoring and expanding good irrigation practices, timing, and other measures. To facilitate additional water efficiency improvements, participants want agencies to raise awareness in local communities about efficiency and conservation strategies.

It was suggested that government oversight would aid in the efficient coordination and functioning of well-fields beyond that which is currently in place by individual farmers who informally link up. Another avenue to improve is through using technological treatments and conservation practices such as saline irrigation and low tillage to reduce water consumption and soil erosion. These practices could be coordinated to achieve the targets of soil improvement and better soil moisture retention. In tree-based farming in particular, there is a need for training, equipment, and flexibility to adopt new practices. Reducing water consumption at the level of irrigation practices would decrease pressures on groundwater systems in particular.

Build on a comprehensive understanding of impacts to inform cross-sector management.

To manage the effects of drought, participants wanted an improved understanding of drought impacts. Extension services led by agencies and research groups would play a key role in collecting this information. It is an important endeavour for Jordanians because they want to understand how societal and industrial entities are affected by changes in precipitation. To be comprehensive, the assessment must aim to uncover cross-cutting issues that are faced by multiple sectors.

Stakeholders see the potential for extension programs to facilitate interaction and technical cooperation between the agencies to develop integrated management strategies. Minimal coordination amongst stakeholders in multiple sectors is one of the biggest gaps identified in current management practices. Going forward, better research on drought impacts from key agencies about the basic ways that drought impacts society is seen as an important need.

Harness the capacities of farmers and non-government actors for monitoring and enforcement.

A drought map would increase cooperation between government stakeholders and ensure that government agencies can exchange experiences with non-government stakeholders. Farmers are used to dealing with water scarcity and can be key information leaders in monitoring water availability. They can also monitor and improve the enforcement of management practices and regulations regarding usage and consumption. As program development and funding moves, "marginal" (saline and treated wastewater) water usage, irrigation efficiency, and a very precise determining of minimum crop water needs will all be critical. One commenter noted that "highly qualified" water engineers join the private sector or go abroad, rather than the government. One way to fill this governmental human resources gap is to connect agencies more closely with farmers in order to build the relationships necessary for proper drought management system enforcement. Farmers can be conduits for building trust amongst citizens and agencies.

Executive Summary of the Drought Action Plan (2021)

The purpose of the Drought Action Plan is to manage drought risk. The Drought Action Plan takes an integrated approach to drought risk management using three components: preparedness, mitigation, and response.

Preparedness ensures that institutional and operational mechanisms are established in advance, saving time with detecting and responding promptly to drought. Mitigation actions reduce vulnerabilities to and impacts of drought in advance. Response actions are taken during drought events to limit the impacts of drought and promote swift recovery. Together, drought preparedness, mitigation, and response actions reduce the costs of drought impacts compared to the significantly high costs of inaction. Likewise, effective preparedness and mitigation reduce the costs of response actions.

Chronic water stress makes Jordan extremely vulnerable to drought. While widespread drought affecting the whole country is rare, localised droughts are becoming more frequent and can be very severe. Public authorities face challenging conditions in meeting social and economic needs for water under normal conditions; thus, drought could lead to crisis situations. The Government of Jordan has therefore taken steps to address drought risks. The National Water Strategy 2016-2025 (MWI, 2016) and Water Sector Policy for Drought Management (MWI, 2018c) have established the mandate and institutional framework for drought management, while the National Centre for Security and Crisis Management has a mandate for coordinating responses to drought crisis after an official declaration of extreme drought.

The Drought Action Plan defines an operational framework of roles and responsibilities for the different institutions engaged in implementation of the plan, including the National Drought Management Committee and the Drought Technical Committee. It also describes funding and resourcing arrangements. Building capabilities for monitoring, evaluation, research and learning is crucial for effective drought risk management operations. The Drought Action Plan describes needs for assessing vulnerabilities, drought monitoring and early warning, reporting impacts, learning from experience, and adapting the Drought Action Plan to incorporate lessons learned.

The Drought Action Plan identifies actions that prepare for, mitigate and respond to drought impacts in eight priority sectors: water resources, drinking water services, irrigated and rainfed agriculture, livestock, rangeland sustainability, forest sustainability, and diarrhoeal disease. Further sectors and actions may be added to future iterations of the Drought Action Plan. Drought preparedness and mitigation actions are taken before drought events occur and reduce the costs of relief efforts and drought impacts on people, the economy, and the environment. Drought response actions are taken during drought events, and are tailored to the severity, location, timing, and duration of drought impacts in the eight priority sectors.

The Drought Action Plan supports the Water Sector Policy for Drought Management (MWI, 2018c). It identifies actions that prepare for and mitigate drought impacts. The Drought Action Plan is a living document for which the Drought Technical Committee has mandated responsbility. The Committee will keep the Drought Action Plan updated as drought challenges and response capacities evolve, and as lessons are learned during drought events.

Table E2. *Drought preparedness actions from the Drought Action Plan.*

	Drought Preparedness
P1	MWI to continue to develop the DTC with rehearsals and contingency planning for drought events.
P2	MWI to keep drought policies and Drought Action Plan updated to reflect new knowledge and changes in economic, institutional and environmental contexts.
P3	MWI to convene Higher Drought Committee yearly to review progress with mitigation measures and response preparations.
P4	MWI to upgrade laws and regulations to ensure water sector has appropriate powers for responding to drought emergencies.
P5	MWI to develop drought water resource contingency plans and incorporate drought risk management into strategic and operational planning of water sector, including mobilisation of supply and allocations during drought conditions.
P6	NDMC to work with the Ministry of Finance, Cabinet and other relevant authorities to develop a Drought Contingency Fund for resourcing emergency relief efforts.
P7	MWI to maintain information sharing and contact lists for dissemination of drought information.
P8	MWI to develop list of media contacts for sharing public information during drought emergencies.
P9	MWI to coordinate GIS and remote sensing capabilities between agencies for drought risk management.
P10	MWI, JMD and NARC to extend and network automated weather stations operating in Jordan to support drought early warning systems.
P11	MWI, MoA and MoEnv to establish a soil moisture monitoring network to support drought early warning systems.
P12	MWI to improve data and monitoring systems for climate, surface water and groundwater, and upgrade process and systems for sharing datasets.
P13	MoEnv to improve data and monitoring systems for climate, surface water and groundwater quality, and upgrade process and systems for sharing datasets.
P14	MWI, MoA and DoS to compile a list of potential drought reporting indicators relevant to priority sectors.

Table E3. *Mitigation action and responsible organisation from the Drought Action Plan.*

	Water Resources (MWI, WAJ, JVA, MoA)
M1	MWI to incorporate drought risk management into strategic and operational planning of water sector, including mobilisation of supply and allocations.
M2	MWI to develop proposals for drought risk mitigation (adaptation) in the water sector for financing from international climate change adaptation funds.
M3	MWI to identify and designate appropriate aquifers as strategic reserves for use only in national emergencies, and strictly enforce zero-abstraction in these zones.
M4	MWI to pursue the strategic objective of reducing Jordan's strategic water imbalance to net zero.
M5	MWI to work with other government departments to introduce economic and regulatory incentives for reducing water use in all sectors.
M6	MWI to introduce and enforce regulations and directives to keep groundwater abstraction within sustainable limits and prevent the depletion of aquifers.
M7	MWI to implement and enforce measures for protecting water resources quality, e.g. by updating and enforcing protection zones.
M8	MWI to ensure technologies for water efficiency are deployed only when accompanied by appropriate regulations that ensure they reduce absolute levels of water consumption.
M9	Where possible, strengthen transboundary water resources management and regional cooperation to preserve Jordan's rights to international waters.
M10	MWI to enhance surface- and ground- water storage to reduce water stress during drought periods.
M11	MWI to develop alternative sources of water supply including desalination, rainwater harvesting in both rural and urban areas, treated wastewater, and brackish groundwater.
M12	MWI and MoEnv to include messages about water conservation and drought management in public awareness campaigns.
	Drinking Water Services (MWI, WAJ, Utilities)
M13	MWI and Water Authority to implement policies that reduce water demand and incentivise private water conservation.
M14	Water Authority to provide training to utility customer service teams on managing expectations during drought periods.
M15	Water Authority and utilities to upgrade customer service policies for water providers.
M16	MWI and Water Authority to update water rationing procedures during drought to ensure social and economic equity.
M17	Water Authority to support utilities prepare drought management plans.
M18	Water Authority to develop a process and contact list for sharing drought warnings with utilities, local authorities and appropriate media (e.g. radio and newspapers) in affected areas.
M19	MWI and Water Authority to develop infrastructure and increase network coverage allowing re-allocation from multiple sources.
M20	Water Authority and utilities to increase investment on network maintenance/rehabilitation to reduce non-revenue water network losses.
M21	MWI to increase water supply from large-scale desalination.
M22	Water Authority and utilities to prepare stockpiles of any necessary equipment.

Irrigated and Rainfed Agriculture (MoA, MWI, MoLA)	
M23	MoA, NARC and MWI to introduce, implement and enforce policies incentivising $ per drop from agriculture, encouraging irrigation farmers to prioritise crops with significant economic and food security value per unit water.
M24	MoA, NARC and MWI to develop, integrate and enforce policies for agricultural water management responses to drought in different areas depending on irrigation technology (including supplementary irrigation), water source, crop type and agricultural technique.
M25	MoA and MWI to enact regulations and legislation requiring that farmers accept groundwater abstraction limits if adopting drip irrigation, other 'water efficiency' technologies, and other soil-water management techniques (e.g. zero-tillage, mulching, etc).
M26	MWI to strengthen regulations, controls and enforcement governing unregulated and illegal wells.
M27	MoA and MWI to strengthen regulations, controls and enforcement to limit groundwater abstractions for irrigation.
M28	MoA, MWI and Ministry of Local Administration to upgrade and implement regulations, including for land-use zoning, to protect productive rainfed areas from pollution and land-use change, especially urbanisation.
M29	MoA to provide incentives for farmer adoption of technical measures for soil fertility and soil-water management (e.g. conservation agriculture).
M30	MoA and MWI to develop and promote drought insurance schemes.
M31	MoA to explore options with donors for developing financial services for small farmers, including debt-management advice, and access to micro-credit and rain-insurance schemes, perhaps based on frost insurance schemes.
M32	MoA to clarify a process and contact list for sharing early warnings of agricultural drought within Ministry of Agriculture, as well as between Department of Extension and farmers.
M33	MoA, MWI and NARC to consider developing mobile/social media applications to inform farmers in affected areas about impending drought.
M34	MoA and NARC to provide training and resources for agricultural extension staff to raise awareness and preparedness of farmers.
M35	MoA and NARC to consider options for training private sector agriculture dealers on supporting farmers in drought conditions.
M36	MoA to prepare lists and vulnerability maps identifying poorer farmers most likely to be affected by drought in each district to help target and speed up response measures.
M37	MoA and MWI to explore with donors options for technology transfer and capacity building for a remote sensing system for surveillance of groundwater irrigation perimeters and monitoring of crop water use.
M38	MoA to provide incentives for farmer adoption of technical measures for soil fertility and soil-water management (e.g. conservation agriculture).
M39	MoA Extension Department and NARC to provide farmers with technical advice on locally appropriate drought resilient agriculture.
M40	MoA and NARC to improve farmers' access to drought tolerant varieties and incentivise their adoption.
M41	MoA and MWI to expand water-harvesting and waste-water treatment schemes.
M42	MoA and MWI to continue evaluating rain enhancement (ionisation) programmes and developing thibased on success.
Livestock (MoA, MoEnv, MWI)	
M43	MoA to enhance information flow between farmers/pastoralists, government, business, and sources of credit.
M44	MoA, MoEnv and NARC to work with community-based organisations to promote rangeland conservation programmes and support conflict resolution.
M45	MoA and MoEnv to clarify a process and contact list for sharing early warnings of agricultural drought within Ministry of Agriculture, and between Department of Extension and pastoralists.
M46	MoA and MoEnv to develop a strategy for communicating drought risk and condition to livestock farmers and pastoralists.
M47	MoA to consider developing a mobile/social media application to inform pastoralists in affected areas about impending drought.
M48	MoA to provide training and resources for agricultural extension staff to raise awareness and preparedness of pastoralists.
M49	MoA and to conduct annual census on stocking.
M50	MoA to prepare lists of the most vulnerable/poor pastoralists most likely to be affected by drought in each district to help target timely response measures.
M51	MoA and NARC to provide technical assistance to farmers in the implementation of field trials for heat, drought and salinity tolerant crops and livestock species.
M52	MoA and NARC to encourage diversification of production among pastoralists.
M53	MoA to and MoLA to develop programmes for off-farm job creation to diversify household incomes, especially for women.
M54	MWI, MoEnv and MoA to expand groundwater recharge schemes.
M55	MoA and MWI to plan an emergency water-hauling scheme for livestock.
M56	MoA and MoEnv to improve targeting of subsidies to ensure stocking of rangelands is kept within sustainable limits.
M57	MoA to design an effective emergency compensation scheme to support recovery of small livestock producers.
Rangelands (MoEnv, MoA, MoLA)	
M58	MoEnv to develop rangeland drought management plans based on localised drought risk assessment and studies of sustainable production.
M59	MoEnv to strengthen stewardship institutions for sustainable co-management of rangeland areas, with agreements on sustainable limits of livestock grazing and the allocation of grazing rights.
M60	MoEnv and RSCN to establish set-aside protected areas to allow over-grazed areas to recover.
M61	MoEnv, MoA and MoLA to regulate land-use changes to limit conversion to agricultural land in sensitive areas.
M62	MoEnv and MWI to restrict and monitor groundwater abstraction in rangeland areas.
M63	MoEnv to implement soil conservation measures in at-risk areas.
M64	MoA to promote no-till agriculture in cropping areas.

Diarrhoeal Disease (MoH, MWI, MoEnv, MoA)	
M65	MoEnv and MoH to work with other authorities to enhance regulations and standards for and monitoring of food quality standards during droughts and heat extremes.
M66	MoH to raise awareness of local health officials and develop contingency and response plans at appropriate levels.
M67	MoH to clarify internal processes and contact list for sharing drought warnings.
M68	MoH to include messages about increased risk during drought and heat waves in public hygiene awareness campaigns.
M69	Water Authority and MoH to include messages about design and practice for safe household water storage in public awareness campaigns.
M70	MoEnv, MoH and MWI to cooperate on monitoring groundwater and surface water quality, including rivers, dams, canals, streams and water bodies.
M71	MoH to strengthen systems for monitoring and reporting diarrhoeal disease during drought.
M72	MoEnv, MoA, MWI and MoH to cooperate on upgrading capacity for monitoring treated wastewater used in irrigation.
M73	MoH to stockpile diarrheal disease treatment kits and emergency hygiene kits.
M74	MoEnv, MoH and MWI to upgrade operating guidelines on water use and treatment from polluted and contaminated sources during drought periods.
M75	MoEnv, MoH and MWI to upgrade operating guidelines for the use and treatment of water, particularly from polluted and contaminated sources, during drought periods.
M76	MoEnv, MoA, MoH and MWI to upgrade operating guidelines for use of treated wastewater in irrigation during drought periods and heat extremes.
Forests (MoEnv, Civil Defence)	
M77	MoEnv to introduce stricter regulations and penalties governing illegal activities in forest areas.
M78	MoEnv to invest in resources for enforcing and prosecuting the regulations, especially for charcoal production, illegal logging, grazing, and conversion of forests to agricultural land.
M79	MoA and MoEnv to invest in forest rehabilitation, replanting and reforestation.
M80	MoA and MoEnv to legislate for heavy fines and penalties for arson in natural areas.
M81	MoA and MoEnv to develop and implement forests fire risk management plans.
M82	MoA and MoEnv to prepare public awareness campaigns about fire risks in forest areas.
M83	MoA and MoEnv to invest in plans, equipment and training for fighting forest fires.
M84	MoA and MoEnv to develop fire-watch systems with forest rangers and local communities during periods of heightened fire risk.

Table E4. *Drought response actions from the Drought Action Plan*

Water Resources (MWI, WAJ, JVA, MoA)		
Impact condition	**Drought level**	**Recommended response actions**
All	Alert+	R1. Share drought warnings and updates on evolution of the drought season within MWI, Water Authority and Jordan Valley Authority.
Increasing water stress	Emergency+	R2. Ensure water allocations meet agreed priorities; R3. Consider restrictions /withdrawing allocations to water-intense uses; R4. Enforce restrictions on groundwater pumping in designated areas; R5. Enforce restrictions on irrigation in affected areas depending on crop types and source of irrigation water (different areas may require different interventions); R6. Consider permitting additional pumping in designated areas where reserves permit.
	Crisis	R7. Enforce stricter restrictions on irrigation in affected areas depending on crop types and source of irrigation water (different areas may require different interventions); R8. Mobilise strategic water reserves and allow additional pumping for drinking water and other agreed priorities.
Drinking Water Services (MWI, WAJ, Water Utilities)		
Impact condition	**Drought level**	**Recommended response actions**
All	Alert+	R9. Issue drought early warnings and monthly updates to senior Water Authority of Jordan officials; R10. Issue drought advisories to water utilities; R11. Issue public drought notices through appropriate media (e.g. radio and newspapers) encouraging reduced water demand.
Declining customer satisfaction	Emergency+	R12. Keep public in affected areas notified about expected shortages and periods of service; R13. Hire / reallocate temporary to customer satisfaction teams in utilities.
Loss of universal / equitable access	Emergency+	R14. Implement a socially fair rationing system; R15. Provide emergency supplies using tanker trucks.
	Crisis	R16. Reallocate supplies from less affected areas and other uses (e.g. irrigation) to ensure supplies of drinking water; R17. Mobilise additional water supplies for affected areas, sinking emergency boreholes if necessary; R18. Provide emergency supplies using tanker trucks R19. NCSCM to provide cash transfers/subsidies for affected areas and poor / vulnerable households to offset higher water costs.

Irrigated Agriculture (MoA, MWI)		
Impact condition	**Drought level**	**Recommended response actions**
All	Alert+	R20. Share drought early warning outputs through the drought information systems with Ministry of Agriculture, agricultural extension system, private inputs dealers, and farmers in affected areas;
	Emergency+	R21. Public information and awareness campaigns about drought conditions and restrictions on irrigation in affected areas;
Production / yield losses	Emergency+	R22. Consider permissions for additional abstractions in affected areas depending on crop types and source of irrigation water, and subject to ability to meet needs of higher priority water users (different areas may require different interventions).
Rainfed Agriculture (MoA, MWI)		
Impact condition	**Drought level**	**Recommended response actions**
All	Alert+	R23. Share drought early warning outputs within Ministry of Agriculture, agricultural extension system and farmers; R24. Provide Ministry of Local Administration and Ministry of Social Development with information about likely drought locations and possible impacts.
	Emergency+	R25. Public information campaigns in affected areas to raise awareness about recommended farmer responses to drought conditions; R26. Conduct survey of drought impacts on production.
Production / yield losses	Emergency+	R27. Consider permitting supplementary irrigation in appropriate areas with sufficient irrigation areas; R28. Issue timely advice over planting appropriate crops, particularly vegetable crops.
Increasing poverty of farmers	Emergency+	R29. Alert international donors and relief agencies to heightened risks; R30. Use Drought Contingency Fund to ensure minimum income (or, where possible, compensate for crop losses), targeted at poorest rainfed farmers.
	Crisis	R31. NCSCM coordinate implementation of emergency drought recovery fund targeted at the poorest farmers, so they don't have to sell crucial assets to survive the drought R32. Initiate procurement and subsidy programmes for seed stock and cereal seeds to help affected farmers recover production quickly. R33. Emergency food program to ensure food security of poorest farming households and reducing price/supply volatility in local food markets; R34. Implement public works/infrastructure schemes to provide rural employment opportunities and improve water harvesting, drainage and logistics performance.
Livestock (MoA, MoEnv)		
Impact condition	**Drought level**	**Recommended response actions**
All	Alert+	R35. Share drought early warning forecasts through the drought information systems with Ministry of Agriculture, agricultural extension system and pastoralists; R36. Provide Ministry of Local Administration and Ministry of Social Development with information about likely drought locations and possible impacts.
	Emergency+	R37. Public information campaign.
Production / yield losses	Emergency+	R38. Reallocate veterinary care resources to livestock in affected areas prioritising Mafraq, Irbid and Karak; R39. Reallocate / prioritise feed subsidies to affected areas; R40. Intervene to regulate prices in feed market.
	Crisis	R41. Implement emergency water-hauling scheme for livestock in affected areas; R42. Issue emergency water pumping permits in affected areas; R43. Implement emergency livestock feed provision scheme for livestock in affected areas.
Increasing poverty of pastoralists	Emergency+	R44. Make pastoralists aware of government aid programmes; R45. Use Drought Contingency Fund to compensate poorest pastoralists for livestock losses.
	Crisis	R46. NCSCM implement an Emergency Drought Recovery Fund targeted at the poorest pastoralists, so they don't have to sell crucial assets to survive the drought; R47. Emergency food program to ensure food security of poorest pastoralist households.
Rangeland degradation (MoEnv)		
Impact condition	**Drought level**	**Recommended response actions**
Risks of over-exploitation	Alert+	R48. Share drought early warning forecasts with Ministry of Environment, protected areas, pastoralists and NGOs and community groups.
	Emergency+	R49. Implement rangeland drought management plans where available.
	Crisis	R50. Limiting and controlling herd movements in sensitive areas.

Diarrhoeal disease (MoH, MWI, MoEnv)		
Impact condition	**Drought level**	**Recommended response actions**
Risks of over-exploitation	Alert+	R51. Share drought alerts with Ministry of Health departments and local health officials in affected areas; R52. Ministry of Health to check preparedness of contingency and response capability.
Higher levels of pathogens in water and food	Emergency+	R53. MWI, MoH & MoEnv to implement standards for using and monitoring treated wastewater quality during droughts; R54. MWI & MoEnv to implement standards for using and monitoring groundwater quality during droughts; R55. MoH, & MoEnv to implement standards for food quality testing during droughts.
Health impacts on children	Emergency+	R56. Ministry of Health to distribute diarrhoea disease treatment kits to affected areas if necessary; R57. Ministry of Health to distribute emergency hygiene kits to affected areas if necessary; R58. Ministry of Health to redeploy equipment, staff and materials, including mobile care facilities, to affected areas.
Forests (MoEnv, Civil Defence)		
Impact condition	**Drought level**	**Recommended response actions**
All	Alert+	R59. Share drought early warning outputs with Ministry of Environment, protected areas, civil defence, Royal Society for the Conservation of Nature.
Forest fires	Emergency+	R60. Implement fire-watch systems in affected areas; R61. Implement public awareness campaigns with media (radio, newspapers, etc.); R62. Enforce bans on smoking and open fires in forests; R63. Consider bans on recreational visits to forests; R64. Conduct readiness drills for fire-fighting responses.
	Crisis	R65. Ban recreational visits to forest areas; R66. Conduct readiness drills for fire-fighting responses with armed forces / civil defence.
Forest degradation	Emergency+	R67. Zero-tolerance policy towards cutting and grazing in forests.

Photo: Seersa Abaza / IWMI

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