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Policy Brief

MENAdrought: Toward drought management in Morocco

Key messages

- Morocco is becoming more vulnerable to the impacts of drought due to climate change, which increases its frequency, extent and severity.
- The impacts of drought on rainfed agricultural and rangelands systems, and fragile agroecological areas, such as argan forests and oases, are particularly severe.
- The Directorate of Statistics and Strategy (DSS) within the Ministry of Agriculture has taken on a technical and operational coordination function for national drought monitoring.
- The MENAdrought project supported the DSS to develop, deploy, and validate an operational drought early warning system (DEWS) for monitoring rainfed systems, including rangelands, as well as test prototypes for seasonal rainfall forecasting and crop mapping.
- The MENAdrought project also supported the ABH Souss-Massa (river basin agency) to draft the outline of a Drought Action Plan (DAP) – focused on the critical groundwater aquifer in Chtouka – that includes actions for drought preparedness and mitigation, as well as incorporating outputs from the DEWS to trigger drought management responses.
- Now is the time to extend the utility of the DEWS through additional technical support to:
  - operationalize the seasonal rainfall forecasting and crop type mapping systems, which would enable anticipatory actions for drought risk mitigation by local government, development agencies, and public and private sector financiers; and
  - expand its focus to hydrological drought monitoring, and work with additional river basin agencies to support basin-level and cross-sector drought management and coordination.

Introduction

The series of deep droughts in Morocco since the 1980s is indicative of a long-term warming and drying trend that makes drought risk management increasingly important and urgent.

Morocco's economic and social development hinges on the agriculture sector. The agriculture sector directly contributes about 14–20% of Gross Domestic Product (GDP) and 40% of employment, hence, it is particularly important for the livelihoods of women and poorer households.

Since the early 1980s, when droughts devastated livestock herds and cereal crops, and contributed to poverty, the Government of Morocco launched numerous policy responses. In 2016, there was a legislative overhaul of water law and the passage of a new law on rangelands management, both have significant components related to drought management.

About MENAdrought

Launched in 2018, the MENAdrought project empowers the governments of Jordan, Lebanon and Morocco (countries in the Middle East and North Africa [MENA] region) with the tools to anticipate, prepare for, and mitigate the worst impacts of drought. The project is helping build self-reliance so the three countries can effectively manage the impacts that droughts have on water and food security, and in turn limit the social and economic damage resulting from drought.

Led by the International Water Management Institute (IWMI) with support from the United States Agency for International Development (USAID), MENAdrought pools the resources and expertise of global leaders in the field of drought monitoring, forecasting and management.

MENAdrought uses an approach based on three pillars to improve drought risk management. The pillars are: developing drought monitoring and early warning systems; conducting impact and vulnerability assessments; and drought mitigation, preparedness and response planning.

Assessing Morocco's needs to improve drought risk management

Within this context, the MENAdrought project assessed the needs of Moroccan stakeholders and then co-developed novel technical and policy tools for drought monitoring and management.

The needs assessment identified key knowledge and institutional gaps related to 1) drought definitions, information sharing, and inter-sectoral engagement (especially between farmers and government agencies); 2) tiered interventions and ease of political drought declaration; 3) addressing groundwater overdraft; and 4) developing ABHs' technical capacity and addressing the uneven integration of municipal supply and agricultural water management in management planning.

Addressing the needs

MENAdrought's work with national government officials focused primarily on development of drought early warning systems (DEWS) and improving intra-governmental communications to support national and local-level drought-related decision-making and wider policy implementation.

MENAdrought's work with the ABH Souss-Massa included development of a draft DAP that links DEWS information to response actions to reduce drought impacts on groundwater degradation in the critical Chtouka aquifer; it also included a wider range of preparedness, mitigation, and response actions that could be undertaken by other institutions, especially agriculture sector agencies and organizations.

Development of a Drought Early Warning System

The DEWS includes operational components for monitoring as well as prototype components for seasonal forecasting and crop mapping.

Monitoring

The map-based monitoring component uses an enhanced Composite Drought Indicator (eCDI) produced using remote sensing (satellite) and environmental modelling data to identify anomalies for each month relative to average conditions in that month since 2000. These anomalies include factors like precipitation, vegetation condition, soil moisture and a proxy for evapotranspiration.

Data generated for these factors is used to produce an eCDI value for each 5x5 km area in the country. This allows policymakers to categorize different regions of Morocco into one of four drought levels simply, effectively, and quickly: no drought, moderate drought, severe drought or extreme drought.

Furthermore, eCDI results were assessed and validated by experts from regional departments of agriculture who work in rangelands that cover nearly 2 million hectares, and analyzed statistically to produce potential 'trigger' thresholds for drought management actions. The triggers reflect relationships between annual rainfed staple crop production and yields, and historical drought severity, longevity, and extent. There are two types of triggers in the outline Souss-Massa DAP: triggers that reflect recent months' conditions, and a trigger that reflects a 'cumulative eCDI' that reflect eCDI values from the months of December and March, which are critical for rainfed agricultural production and rangelands.

The eCDI outputs are communicated through a straightforward web interface and the maps are published on Google Maps in due course (see https://bit.ly/3BtKxk5). This enables visualization of drought conditions at various administrative levels and over time, and it eases comparison of drought events across the country and in relation to past events. With this system, Morocco has a powerful tool for early detection of the impacts of drought, and Moroccan officials are eager to improve the accuracy of the eCDI, particularly for rangelands.

Seasonal forecasting prototype

The seasonal forecasting tools developed through MENAdrought use convolutional neural network (CNN) models, an artificial intelligence technique, to provide information on predicted precipitation up to three months in advance. The CNN models use precipitation forecast data produced by global centers to predict precipitation in Morocco according to five climate regions.

The CNN-based system implemented by MENAdrought has been shown to accurately predict rainfall with a two-month lead time in sub-humid and semi-arid areas of Morocco. In arid areas, the predictive accuracy was significantly lower, in part due to rare precipitation events.

This approach has enabled high accuracy, precision forecasts, including for the severe drought in winter 2021/spring 2022 and wet winter 2022, that will support the DSS and ABHs in their efforts to prepare for, and mitigate, drought impacts by providing advanced warning of drought occurrence.

Figure 1 shows the predicted monthly rainfall anomaly for all of February 2023. The figure was produced in early January. Thus, it forecasts with 'two months lead-time'. It shows the percent of rainfall above and below normal. Dark blue areas, are predicted to have 60% rainfall above average for the month of February, compared to all Februaries in 2000-present year, and dark brown areas are expected to have 60% less rainfall than average for the month of February.

Crop type mapping prototype

MENAdrought developed a prototype operational software for crop-type mapping that is intended to be easily usable by staff of the Moroccan Ministry of Agriculture in applications to:

- increase the accuracy of annual crop-failure statistics;

- support decision-making on drought management response measures in major rainfed and irrigated cropping systems;
- direct ground-truthing teams to survey the damage caused to cereal crops as a result of drought, together with the insurance firm Mutual Moroccan Agricultural Insurance Company (MAMDA) and the agricultural bank Crédit Agricole du Maroc; and
- to enable future development of the DEWS including thematic drought risk mapping and yield forecasting for staple crops.

With these monitoring, forecasting, and crop mapping tools on the table, MENAdrought provides: early detection of the impact of drought on different agricultural systems and even crop types in Morocco, and a tool for seasonal precipitation forecasting. Moroccan agencies now seek to use this forecast precipitation data in hydrological models to predict streamflow or, in combination with crop mapping tools, in agricultural models to predict crop yield and production.

Drought history and hazard mapping

Analysis using the eCDI shows two major drought periods between 2001 and 2022: the first in 2001, which was an extension of a dry period that began in 1998, and the second occurring during 2018–2020 (Figure 2). These were primarily years of creeping drought in which there is a continual and gradual increase in intensity and extent, or late-onset droughts that begin after winter. In 2007 and 2008, drought was interspersed over the year. In 2005, 2012 and 2016, there were quick-onset and intense droughts that, though relatively quick to subside, still had significant impacts.

Areas with consistently higher climatological drought hazard predominantly include the densely populated Atlantic coastal plains from Tangiers to Souss-Massa and Figuig province. Areas with consistently lower climatological drought hazard include the Atlas and Anti-Atlas Mountains, as well as Taounate and Fes in the Rif, and Tan-Tan province.

Drought impacts

MENAdrought's early work identified agriculture and water supply as the two most impacted and vulnerable sectors, and subsequent work focused on agriculture given the focus of the DEWS on agricultural drought impacts.

> The MENAdrought team estimated the costs of drought from 1980–2015 using information on livestock losses and damages from the national cereal deficit (the difference of national cereal supply and demand). Livestock impacts likely reached $2.22 billion[1], with more than 1/3 of all losses from 1982 alone. The cereals deficit equaled about $16.37 billion, with impacts more evenly distributed – the year with the single largest cost was less than 11% of total losses – and significantly affected by international commodity market prices.
>
> [1]base 2021, estimates ranging $0.82 billion to $4.99 billion.

Drought reduces national and agriculture sector GDP, and the government expends significant resources on intervention programs. For example, the drought of 2000 caused a 31.5% reduction in agriculture sector GDP and a corresponding 7.5% reduction in national GDP compared to 1998. Furthermore, government expenditure on relief programs during the 1999–2001 drought reached $318 million. This was equivalent to 2.3% of total government expenditure from the fiscal year 1999–2000. Labor market effects are severe as well – during the 1992–1993 season, job losses were estimated at 60 million

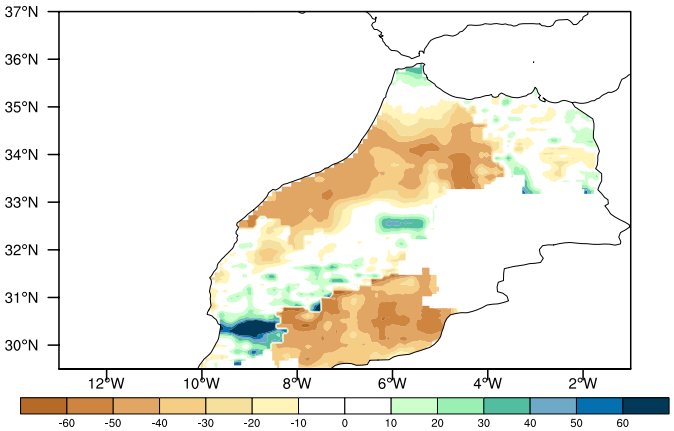

Figure 1. February 2023 rainfall anomaly (% of precipitation above or below the normal from the year 2000 onwards) as predicted with a lead time of two months.

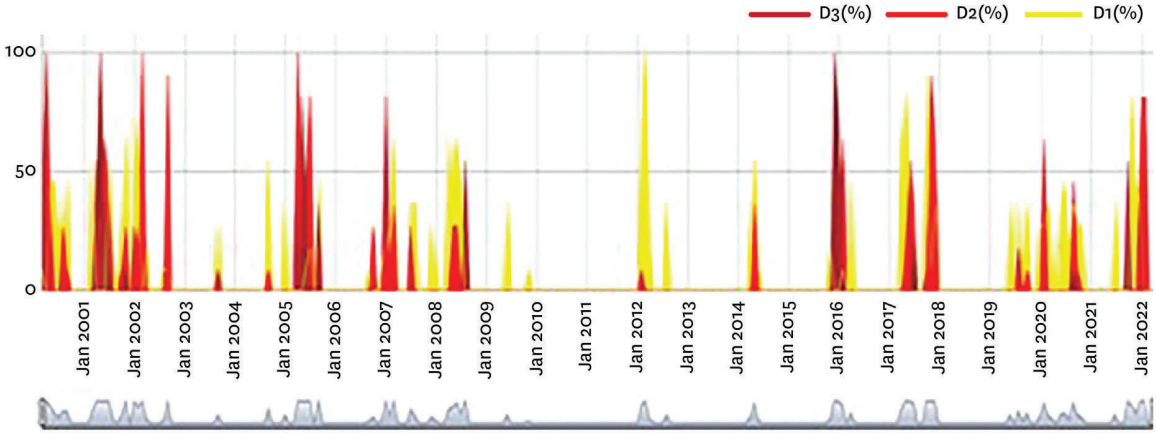

Figure 2. Drought severity in Morocco during the period 2000–2022.

BOX 1. Souss-Massa Drought Impacts and Vulnerability Case Study

Agriculture is core to Souss-Massa's economy. It generates more than 15% of regional GDP, and 90% of production value is from citrus, tomatoes, and vegetables primarily destined for export. Irrigation is groundwater-dependent, and there is more than 275 MCM/year of groundwater overdraft. The region is primarily semi-arid and on the climatological edge for cereal growth, so even relatively moderate drought years result in significant drops in cereal production, which affects food security.

MENAdrought assessed drought history using the eCDI and found that 40% of the years between 2000–2020 exhibited one of the four drought typologies, with the most impactful type, creeping drought, occurring in 2000 and 2020.

Assessments of agricultural drought since 1969 indicate that Sidi Ifni, the High Massa, and High Souss areas have the highest climatological drought hazard.

Exposure and sensitivity to drought impacts vary by agroecological zones:

- The coastal zone is highly exposed to groundwater quality degradation due to seawater intrusion, and exposure mostly relates to urban communities and the tourist sector.
- The plains are highly exposed in relation to agricultural production, though somewhat less sensitive due to the high reliance on pumped groundwater for irrigation.
- High Atlas and Anti-Atlas zones have high drought hazard and are highly sensitive due to limited water infrastructure, precarity of rangelands, and poorer socio-economic status.
- The pre-Saharan zone is highly sensitive because of its reliance on traditional water supply networks, prominence of drought-sensitive crop species, frequent presence of crop diseases and pests, and environmental degradation in oases.

Across zones, accelerated erosion increases sensitivity to drought impacts, particularly as it can lead to major long-term declines in productivity and/or lead to desertification. Also, overgrazing pressure on rangelands, especially in silvo-pastoral landscapes like argan forests, is exacerbated by pastoralists from other regions who frequently bring their herds, especially camels from southern provinces, into Souss-Massa.

Coping and adaptation mechanisms focus on supply-side interventions. For example, Agadir hosts one of the largest desalination plants in the world, and the first to provide irrigation water as a major component of intended production. Demand management efforts focus on improvements in irrigation efficiency.

workdays, or the equivalent of 300,000 full time jobs.

Drought causes major social disruption and exacerbates desertification and related environmental degradation including, in recent years, through the transformation of transhumance to uncontrolled nomadism. Still, the relationship between drought and migration is complex; the limited data point primarily to labor and economic 'push' and 'pull' factors that relate to climate and natural hazards as part of wider socio-environmental systems in change. However, considering the characteristics of migrants and the Moroccan economy, one can infer that drought's highly negative effects on productive assets will translate into increased rural outmigration.

Drought vulnerability – exposure, sensitivity, and coping and adaptive capacity

Drought vulnerability is a feature of exposure (presence of people, assets, etc., in drought-affected areas), sensitivity (the drought severity required to cause negative impacts), and coping and/or adaptive capacity (respectively, the ability to withstand impacts and the ability to change systems to fit new conditions).

Water resources

People experience challenges to water access during droughts due to availability problems and water quality degradation. In drought years, water availability can fall below the UN's 'absolute water scarcity' threshold of 500 m^3/year/capita and inflows to reservoirs can fall below 30% of an average year.

The population's exposure to drought impacts on water resources has increased in recent years because the proportional availability and absolute quality of water has declined, while per capita demand has increased. Also, the 126 major aquifers face structural over-abstraction: intensive irrigation areas can face drawdown greater than 2 m/year. Groundwater resources' exposure and sensitivity to drought impacts are much higher now than in the past due to the massive increase in groundwater-dependent irrigation over the past several decades.

However, communities' sensitivity to health-related drought impacts, which stem from effects on water resources, has reduced significantly in recent years. This is primarily because of improved municipal water and sewerage infrastructure built since the early 1990s. Still, drought can intensify drinking water contamination via multiple pathways. The World Bank estimated that the cost impacts of water-related disease burden represented 0.33% of GDP in 2014, a significant reduction from 1.1% in 2000.

Agriculture sector

Overall, farmers and the agriculture sector are highly exposed and sensitive to drought impacts. Farming households are disproportionately poorer than others and the small, traditional farms that predominate are rainfed. Irrigation covers 15% of agricultural land, but the irrigated sub-sector provides about 45% of the sector's total added value and 75% of the sector's exports (which increases in drought years).

Livestock and cereals are the most exposed and sensitive sub-sectors to drought impacts, though there is variation between agroecological zones. Horticulture and orchard crops are the least sensitive because they are primarily irrigated (Figure 3). Since the late 1990s, the livestock sector's sensitivity to drought has decreased because of trade policy reforms and more direct government interventions, though longer term, it faces threats from rangelands degradation and desertification (Figure 4).

Agricultural sub-sectors now have markedly different profiles for drought exposure and sensitivity than even two decades ago due to government policies that have enabled irrigation-based intensification, improved water supplies, developed financial risk management products, and supported water demand management. Still, groundwater degradation in major productive basins such as Souss-Massa poses a long-term risk to agriculture within Morocco's overall political economy.

Opportunities remain to improve adaptation through human and social capital development, particularly through education; technical knowledge; and improving linkages throughout agricultural value chains.

Rural communities and women

Morocco's rural communities generally have low adaptive capacity because of rural areas' limited economic resources, and health and education characteristics. However, significant gains have been made in recent years through the Moroccan Green Plan and social policies. As a result, their sensitivity to drought impacts has likely decreased in recent years.

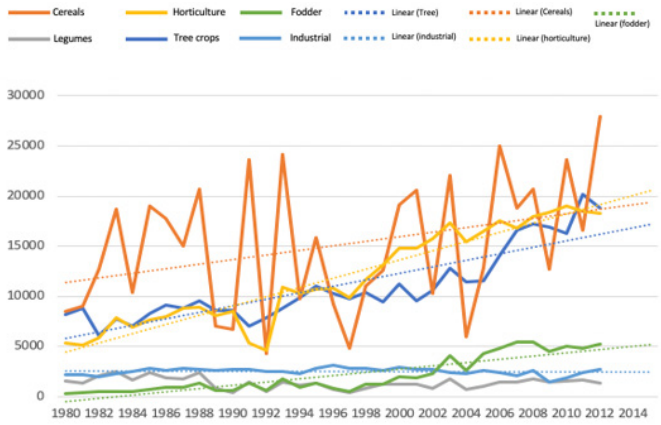

Figure 3. Value of crop production by crop type (Year 2000 constant prices; thousands of Moroccan dirhams). Source: Authors using High Commission for Planning of Morocco (HCP) data.

The MAMDA multi-risk insurance product, primarily for rainfed cereals and highly subsidized by the central government, is a core pillar of Morocco's drought coping and adaptation strategy. It has proven effective and provided pay-outs to farmers quickly during two drought years since 2015 (speed of pay-out provision is critical to ensure recovery the following season).

Fragile ecosystems – argan forests, oases, and rangelands prone to desertification

Moroccan stakeholders describe fragile ecosystems including argan forests, oases, and rangelands prone to desertification as a significant source of vulnerability to drought. Argan forests are highly sensitive to drought impacts from natural and anthropogenic pressures. In oases, the pest-related decimation of date plantations and shifts to water-intensive market crops, rather than integrated farming systems, have contributed to widespread water resource and soil degradation in oasis systems. Coupled with drought, this has created several negative feedback loops that can lead to significant land abandonment, rapid groundwater depletion, and ultimately outmigration.

Drought's relationship with desertification is complex. While drought causes loss of biodiversity and productivity, which is exacerbated by overgrazing and mechanized nomadism (whereby larger herds are transported over larger areas with trucks), there is ample evidence that both recover when precipitation returns to more normal levels in the absence of other pressures. Endemic species are drought tolerant. However, prolonged drought can lead to reduced seed propagation, and other pressures (such as land clearance and overgrazing) can greatly exacerbate erosion and/or encroachment of sand. Recent policy shifts have incentivized planting of rainfed tree crops (like olives) and shifted away from cereals cultivation on fragile soils.

Drought risk management policies and planning

Over the past 40 years, the Government of Morocco has progressively advanced drought risk management. The most calamitous effects of the early 1980s drought (for example,

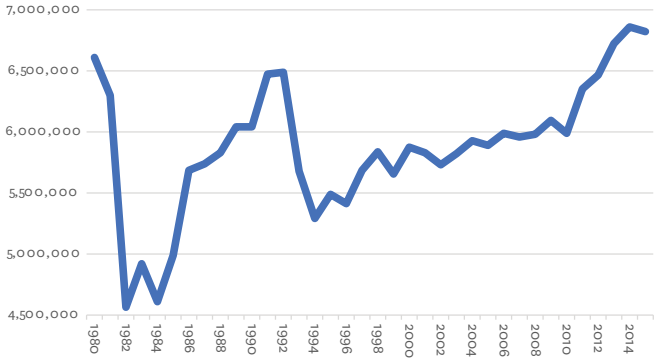

Figure 4. National herd in livestock units from 1980-2015. Source: HCP data.

livestock herd collapse) were avoided in the intense early 1990s drought. Following the early 1990s drought, government responses targeted the next 'tier' of drought impacts and management issues (for example, rainfed cereals financial risk management), and so on.

The new legislative frameworks provided by Water Law 36-15 and the Rangelands Law 113-13, both from 2016, delegate drought planning to basin agencies and local government offices. They structure drought management decision-making processes and determine which agencies and other stakeholders, including civil society and private sector actors, must coordinate. This long-term progression in drought management policy influenced Morocco's wider disaster risk policy, including its creation of a Disaster Risk Management Directorate within the Ministry of Interior and issuance in 2021 of a government-wide Disaster Risk Management Strategy.

Now central government agencies are focused on embedding drought risk management through governance frameworks, management plans, and the information products that support them (such as drought monitoring tools). But the development of detailed management plans happens at the local/regional (rather than the national) and the scope of management plans is not mandated; for instance, there is not a requirement to integrate planning of irrigation, hydropower production and municipal supply in any specific way. As a result, management planning differs across ABHs depending on capability, capacity, and stakeholder-driven factors. MENAdrought's efforts focused on collaboration with ABH Souss-Massa to address these issues.

Summary of the outline Drought Action Plan for the ABH Souss-Massa

Priority impact and its relation to preparedness and mitigation actions

The outline DAP developed by the ABH Souss-Massa includes measures to *prepare* for and *mitigate* drought risks proactively before drought occurs, as well as *response* actions once it begins.

ABH officials prioritized addressing the degradation of groundwater in the Chtouka Ait Baha aquifer in the DAP's first iteration. The prescribed preparedness, mitigation and response actions are limited to those directly within the ABH's control, but it includes other potential actions (e.g., those related to wider agricultural water management) outside of its mandate. Thus, it provides the foundation for more wide-ranging societal drought management policy planning and governance.

The prescribed preparedness and mitigation measures (those within the ABH's perceived remit) focus heavily on regulatory enforcement and associated social norms, primarily related to groundwater abstraction. Other preparedness and mitigation actions outside of the ABH's perceived remit relate to capability building, information-sharing and supporting engagement across sectors, and creating inter-sectoral contingency plans.

Response measures and drought impact monitoring

The DAP outline includes 34 drought response actions, of which the ABH has the mandate to undertake 18. These actions escalate according to drought severity, beginning with information sharing and awareness raising and increasing to supply-side interventions, allocation regimes, and demand management and control. Other actions they don't have the mandate to undertake relate to creation of infrastructure, controlling land use and farming practices, and general agricultural water management regimes.

The Souss-Massa DAP includes the development of impact monitoring indicators as an action to be undertaken in the near future.

Recommendations for future work

MENAdrought's recommendations address all aspects of the drought effect chain through suggested future work on policies and governance, development of technical tools, and generation, sharing, and application of usable information from those tools (Table 1).

Conclusion

With climate change, Morocco will face increasingly severe droughts and greater water scarcity. The MENAdrought project helped the Moroccan government establish, validate, and share information from a drought early warning system that enables drought risk management and supports wider implementation of water and rangelands policy.

In the Souss-Massa region, the project also supported the basin agency (ABH Souss-Massa) to develop the outline of an inter-sectoral DAP that includes preparedness and mitigation measures as well as incorporates robust outputs from the early warning system to trigger drought management response actions. When drought first appears, responses focus on communications and preparations with various stakeholders about how to respond if the situation deteriorates. If the drought worsens, the plan guides decision-making and specific interventions.

Now other basin agencies are prepared to develop inter-sectoral drought action plans, and the Moroccan government needs support to capitalize on the early warning system as well as the prototype seasonal forecasting and crop mapping system. Agencies are well placed to operationalize these tools, link them with wider crop and hydrological modelling systems, and expand information sharing platforms. Such monitoring and forecasting capacity would be a powerful tool to support effective climate change adaptation.

TABLE 1. Recommendations to meet drought monitoring and management needs.

Need type	Specific need	MENAdrought work to address need	Recommendations for future work
Drought-specific policy, governance, and institutional arrangements	Embed DAP components and inter-agency cooperation at watershed/region level Improve public – private engagement on drought monitoring and management issues	Working with the ABH to develop the outline DAP eCDI validation across rangelands and development of drought management triggers	Support implementation of the Rangelands Law through creation of a Drought Impact Reporters network Support additional ABHs in the development of cross-sector DAPs that embed DEWS components
Technical information tools	Ongoing improvement of the DEWS	Development of the eCDI and seasonal precipitation forecasting systems as well as tools to support their use (e.g., web interface)	Support operationalization of the seasonal forecasting and crop type mapping systems Link the DEWS and forecasting components to crop production models for crop yield forecasting Anticipation of cereals import requirements using coupled seasonal forecasting and crop models
	Develop hydrological drought monitoring and forecasting capabilities using DEWS inputs	Not a focus for MENAdrought	Support development of hydrological modelling capabilities to improve central government and/or ABH ability to monitor and forecast hydrological drought Develop an eCDI proxy for hydrological drought to support cross-sector drought management planning Anticipation of dam inflows and levels using coupled seasonal forecasting and hydrological models
	Improve regulatory enforcement	The DAP specifies the regulations that should be targeted	Support the relevant ministry and/or ABH with development and deployment of information and tools to facilitate regulatory enforcement, especially in relation to groundwater abstraction
Information translation and sharing	Identify regions at highest risk of drought impacts to target interventions	Developed a drought hazard (climatological risk) map that shows where drought is most frequent and severe. Produced information on exposure, sensitivity, and adaptive capacity in various communities and economic sub-sectors	Create thematic drought monitoring and forecasting maps per crop type/land cover to support anticipatory actions
	Engage with intended audiences to create usable information products and stable information sharing networks	Validation of the eCDI with rangelands monitoring experts from the Regional Departments of Agriculture Supported DSS to share the eCDI publicly and through the web interface	Support the activities of a Drought Impact Reporters network Engage with governmental, farming, agribusiness, agri-finance, and applied research organizations to develop targeted information and/or advisory products based on the DEWS
Drought-related financial risk management	Need for drought-relevant financial risk management products	Engaged with financial institutions on the utilization of a hazard map for premium determination, and the eCDI for establishing the strike level	Support additional development of seasonal forecasting capacity and crop mapping to help target impact monitoring and intervention programs
Drought-related agricultural practice improvements	Understand the drought-crop connection: offer irrigation and planting guidance	Development of the drought mitigation compendium	Support governmental and private sector agricultural extension services actors to increase uptake of conservation agriculture and efficient water and nutrient conservation technologies and practices building on past market system development work in Morocco

Additional reading

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Partners

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National partners: Hassan II Institute of Agronomy and Veterinary Medicine; Ministry of Equipment, Transport, Logistics and Water; National Department of Meteorology (DMN); various regional directorates of agriculture (DRA); various river basin agencies (ABH); and various regional offices for agricultural development (OMRVA).

Contact details

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