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MENAdrought

Baseline Assessment

Morocco

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Background

Fluctuations in water availability caused both by drought events and inadequacies in preparedness generate a plethora of challenges for a variety of stakeholders. Abilities to mitigate and adequately adapt to these challenges are greatly influenced by factors often excluded from national data on economic performance.

Among the major limitations to Morocco's response to drought events are shortcomings in the operational drought monitoring system in the country; the absence of appropriate tools and/or frameworks for assessing drought impacts; and the absence of a comprehensive drought vulnerability mapping system. At the institutional level, there is also a need for greater coordination for the effective management of drought events. This would require improvements in the associated supporting legislation, drought planning and decision-making frameworks.

The purpose of this document is to establish a baseline to inform future drought impact mitigation and vulnerability monitoring, analysis and reporting, specifically devised for at-risk sectors, households and elements of the economy.

This baseline assessment includes findings taken from previous vulnerability and needs assessments, and meetings conducted with key stakeholders to date as part of the USAID-funded MENAdrought project. It builds on Phase 1 MENA-RDMS with the ambition of improving the following key project focal areas:

i. Advancing **drought monitoring and seasonal forecasting** through improved and locally validated CDIs

ii. **Socio-economic assessments of drought impacts** to both highlight the costs of past droughts and support policy initiatives.

iii. Develop **water accounting** which will act as the base for water re-allocation planning during drought events, and to support initiatives for improved water management

iv. Developing agriculture, water productivity, non-conventional water **technology packages to support drought resilience** building

v. Assess potential role of **drought insurance** in mitigation initiatives

vi. Develop **policies and plans for drought management**

The MENA-RDMS project used the methodological approach of the Integrated Drought Management Plan, based on three interconnected pillars.[1] Accordingly, this baseline assessment is structured around those three pillars, by first assessing *drought monitoring and early warning*; then looking at *vulnerability and risk assessments*; and finally establishing a baseline of current *mitigation and response strategies* underway in Morocco.

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Pillar 1: Drought Monitoring & Early Warning

1 Drought monitoring

Drought events have long affected Morocco, with tree ring studies dating back to the 12th century in Morocco revealing recurrent drought periods. **Recent frequent droughts in Morocco illustrate the complex nature of drought impacts on hydrological, agricultural, social, economic and ecological systems.** Drought events further exacerbate the already severe water scarcity Morocco faces, increasingly as population growth, urbanisation and the intensification of agricultural cultivation place additional stress on already scarce and contested resources. The last two decades have been among the most severe (Touchan et al., 2011).

Key drivers of drought in Morocco will continue to push the limits of water supply systems and place increased pressure on social and ecological processes dependent upon freshwater. Though droughts as single events in the past have not been as costly as earthquakes and tsunamis in Morocco, they are certainly more frequent and their intensity and areal extent is increasing (Baubion et al., 2017). Comparisons of the Palmer Drought Severity Index (PDSI) values for the past millennium show that the dry conditions in Morocco since the 1980s have been extreme. Such extremities may have been potentially worsened by long-term regional temperature changes that could be associated with ENSO teleconnections and changes in overall solar irradiance (Esper et al., 2007). Climate change projections highlight that the Middle East

[1] See: http://www.droughtmanagement.info/

will face rising temperatures and reduced precipitation, leading to increased evapotranspiration and changed water balance dynamics during typical and drought conditions (IPCC 2013; Dai et al. 2004).

Together with the timely assessment of a raft of social and environmental impacts, **the importance of effective and proactive drought monitoring and mitigation plans is keenly understood by local policy makers**. Developing a baseline assessment of current drought awareness levels, monitoring procedures, validation efforts, and CDI mobilisation represents a vital technical component of future improvements to drought policy and planning activities.

1.1 Identifying Drought Events

Among some of the most pressing challenges in drought management and more effective drought mitigation and response is **the need to develop a procedure for officially identifying and declaring droughts and initiating the associated follow-up actions**. Even with improved drought monitoring capacity, the effective declaration of the onset of drought requires an officially agreed upon set of reliable indicators with demonstrated efficacy.

The information produced for the CDI can help better understand the cyclical nature of drought and better characterise return intervals and the types of drought Morocco faces and their likelihood of occurrence. Between 1990 and 2016 (27 years), ten years of drought have been observed, of which 3 years are categorised as severe drought. The periods of drought for the years 1995, 2005 and 2016 were prolonged. During this period, there were 4 cycles of one dry year, 3 cycles of two dry year, and 1 cycle of three dry years, with the droughts of 1992, 1998, 2004 and 2015 classified as severe across several regions across the country.

The National Drought Mitigation Centre (NDMC) at the University of Nebraska-Lincoln has long-standing collaboration with Moroccan drought management officials. Since 1999, representatives from the NDMC have been involved in hosting a series of workshops, technical training sessions, and interactions with officials and scientists. The NDMC assisted with the development of the *Observatoire National de la Sécheresse* (ONS), and following its decline in activity, NDMC officials led a stakeholder interview and reporting process that resulted in a set of recommendations about future drought monitoring and management developments (Hayes and Svoboda 2008). Since then, collaboration has focused predominantly on technical components of drought monitoring, most recently the development of the *Moroccan Composite Drought Indicator* and related geospatial analytical products.

1.2 Drought Data Availability and CDI Production

The current work on CDI production builds on previous efforts with an understanding that circumstances may have changed politically, and that new technologies may provide windows of opportunity where they complement capacity that did not previously exist in both the identification of and response to droughts.

At present, the Moroccan government and some academic organisations monitor a wide range of drought indicators, regularly produce drought indices, conduct seasonal climate forecasting and use monitoring data to estimate crop growth, forecast yields and inform pastoral permitting decision-making across key sectors. As a result, Morocco is a regional leader in drought monitoring initiatives and activities, with the government very keen to further improve the monitoring capabilities to better inform decision makers in proactive drought management activities.

1.2.1 Drought indicators

A raft of drought indicators exists, produced by several national stakeholders and covering a variety of climatological, hydrological, agricultural, ecological and socio-economic aspects and manifestations of drought events. Although not exhaustive and by no means publicly available or regularly shared across government agencies, some of these indicators are outlined below:

Climatological indicators are primarily produced by Morocco's meteorological office, *Direction de la Météorologie Nationale* (DMN); and the *Centre Royal for Télédetection Spatiale du Maroc* (CRTS). These include:

- Precipitation
- Evapotranspiration
- Temperature
- Solar irradiance
- Wind speed and direction
- Seasonal forecasting

Hydrological indicators are produced by *Direction de la Recherche et de la Planification de l'Eau*, Morocco’s water research and planning directorate (DRPE); the DMN; and regional river-basin authorities - *Agences de Bassins Hydrauliques* (ABH). These include:

- Groundwater piezometry
- River, wadi and spring flows
- Reservoir volumes
- Soil moisture
- Snowpack

Agricultural indicators are collated by the Ministry of Agriculture and Fisheries *Ministère de l’Agriculture et de la Peche Maritime* (MAPM); and *Office National Du Conseil Agricole,* the national agricultural advisory board (ONCA) and include:

- Cultivated area
- Irrigation and crop zone demarcation
- Livestock mortality rate and birth weights

Ecological indicators collected by MAPM; CRTS; and Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification – the high commission for water, forests and the fight against desertification (HCEFLCD) include**:**

- Rangeland conditions
- Pest conditions
- Animal and plant diseases
- Forest conditions
- Invasive/arid species

Socio-economic indicators produced by MAPM, DRPE, ABH; and the *Office National de l'Electricité et de l'Eau Potable* (ONEE) include**:**

- Municipal water supply availability
- Sectoral allocation conflicts
- Agricultural input and product prices
- Hydropower production

1.2.2 CDI Production

The Composite Drought Index (CDI) is produced using satellite-based vegetation anomalies, two-month Standardised Precipitation Index values (SPI), land surface temperature anomalies (LST), and evapotranspiration anomalies. A prototype was developed which was trialed with institutional partners in Morocco, validated, and subsequently modified to improve accuracy and to be more responsive to local conditions.

In improving the production of national CDI maps, a CDI processing system was established at the country level. This entailed adapting the CDI methodology into a country-specific package using open source applications (including R, QGIS, and data in NetCDF format). Base indicator input parameter data for CDI development (ESI, NDVI-anomaly, SPI-2mo and LIS-Soil Moisture) were subsequently processed. And in 2016, a dedicated processing server was set up to provide archive storage for the 375-m VIIRS ET product across the MENA region. The server is housed at UNL's Holland Computing Center, which provides dedicated support for the system. The new server allows for low latency near-real-time processing of the 375-m ET product.

The four datasets used in producing the CDI are obtained from remote sensing and climatic data at a 5-km resolution and include:

- Monthly soil moisture layers produced by **Land Information System** (LIS),
- The **SPI data** produced from the monthly precipitation layers produced by the University of California, Santa-Barbara. The SPI components used for the CDI were derived from the precipitation data from "**Climate Hazards Group InfraRed Precipitation with Station**" (CHIRPS);[2]
- Monthly **Normalised Difference Vegetation Index** (NDVI);
- Monthly **land surface temperature** from Moderate Resolution Imaging Spectroradiometer (MODIS).

In order to improve CDI production whilst building local capacity, ongoing support and training are offered to local stakeholders and technical experts on using scripts, data management, modelling and analysis.

1.3 CDI Mobilisation

The CRTS is the agency with the most experience in Remote Sensing and ET detection. As such, the CRTS was primarily targeted for producing monthly CDI maps since 2014 and as the primary institutional focal

[2] See: http://chg.geog.ucsb.edu/data/chirps/

point for the MENAdrought project until recently. CRTS produced the CDI and disseminated the underlying data and produced maps through a web hosting platform. Detailed information was made available to senior people at MAPM, HCEFLCD, DRPE/DGE and the Ministry of the Interior. Beyond those ministerial partners, sharing the CDI data would require an MoU or other official mechanism. Whilst hosted by CRTS, key directorates responsible for drought monitoring and management within both MAPM and DRPE/DGE were not receiving the CDI maps regularly if at all and had no input on the configuration of the monito.

Some representatives from MAPM and DRPE/DGE who have direct drought management roles did not even know the CDI maps exist. While individuals who have received the CDI maps and data in those ministries have found the information interesting and potentially useful in ongoing monitoring or research efforts, because it is not always available to them on a regular basis, it cannot be incorporated into existing monitoring, modelling or other efforts. Likewise, it largely eliminates potential feedback CRTS can obtain on the produced maps and input information, which participants from CRTS and other agencies said was a major limitation. In Morocco, drought-related information remains politically sensitive because drought is a politically challenging and divisive topic. Largely in response to these institutional limitations, **the project now primarily liaises with the Ministry of Agriculture's Department of Strategy and Statistics (DSS), which has more actively sought to share drought maps and data sets with institutional partners to support their different workflows and mandates**. This has expanded the range of agencies with access to the maps and their underlying data, and frequency of their accessing the associated products.

Current institutional focal points are mandated to improve access to such information to better inform policy makers, and as such are assisting in widening the scope of access, feedback and improvement of drought monitoring and management products. Currently through the government web portal www.tirhal.com, DSS provides the maps and data on an information sharing platform that connects a wider range of stakeholders to mobilise the drought maps and the associated input data on an open basis.

Sub-national water managers hope to better access seasonal forecasts with rainfall-runoff models and groundwater recharge models to predict water availability with better accuracy. Agricultural agency representatives hope to link seasonal forecasting with crop growth models in addition to cereals; this is especially relevant for rangelands productivity considering the livestock sector is considered the most vulnerable to drought after rainfed cereals. The CDI maps are predominantly and most notably mobilised to inform decisions made around the issuing of permits to pastoralists that are required since 2016 to request permits before moving herds to different parts of the country in search of fodder and water for livestock. Although not currently using the products, sub-national water managers, particularly in the ABH's responsible for the *Souss-Massa* and *Oum el Rabia* basins, have also expressed significant interest in mobilising the CDI maps and data to inform water allocation and planning following periods of drought.

1.4 CDI Validation

The CDI model is based on four datasets that are obtained from remote sensing and climatic data at 5-km resolution and includes the monthly soil moisture layers produced by Land Information System (LIS), the SPI data produced from the monthly precipitation layers produced by the University of California, Santa-Barbara and the monthly NDVI layers and monthly land surface temperature from MODIS.

The current CDI mobilised in Morocco meets the required technical pre-requisites, although there remains room for improvement, further validation work carried out either geographically or sectorally, and the potential to tailor different CDI outputs to different sectors beyond rainfed cereals. **There is demand for an enhanced CDI that is better tailored to detect changes, particularly stressed grazing conditions, in the country's expansive rangelands**. This would significantly support decision-makers in the effective management of drought events and the sustainable management of the often-fragile rangeland ecosystems, and over-exploitation by nomadic pastoralists.

The University Hassan II Institute of Agronomie and Veterinairie (IAV) has worked with the Phase I to validate the CDI with observation data from DMN and crop yield analysis as well as through surveys of technical experts from different regions in Morocco. IAV expressed a strong desire to establish a "network of evaluators" to provide ongoing feedback on its drought map. This is a key avenue to validate and improve the map as well as increase uptake of its usage, and ongoing commentary from sectoral and regional representatives will help DSS re-process information according to stakeholder needs over the long-term. With the network spread out over a diverse geographic area, participants will be able to provide localised input that may not be registered if the drought monitoring activities were housed within a single office. Such an approach also conforms with central government plans to promote the increased decentralisation of governance.

1.5 Validation of Inputs

1.5.1 CHIRPS Precipitation Data vs. Ground Precipitation Observations

With the existing observation network in Morocco not adequately dense enough to cover all agro-ecological areas, and in the absence of the requisite 30 years observed data to form an historical baseline, the Moroccan government relies on remote sensing data to produce SPI values. **This represents a key limitation in the validation of the SPI component of the Morocco CDI.**

The DMN has a network of 42 synoptic and 206 automatic stations that produce ongoing, real-time precipitation and other climatic information. These data are analysed at various time scales to produce products such as deciles, PDSI as well as 3- and 6- month SPI and SPEI scores. In addition, **DMN is responsible for seasonal forecasting using the ARPEGE-Climate model in cooperation with Meteo-France**. Annual data permit establishment of a trend showing higher rainfall in previous years (cumulative rainfall of 356 mm per year) with an annual decline of 0.5 mm per year. When evaluating long-term cycles of cumulative rainfall between 1901 and 2015, four long-term periods could be identified:

- 1901-1946: Declining tendency in rainfall
- 1947-1964: Rise in the average rainfall
- 1965-1985: Decline in the average rainfall
- 1985-2015: Stabilization of the average level of rainfall.

The main indicator used to identify drought years during validation was the deviation of the rainfall from the average of 390mm during the 32 years between 1984/85 and 2016/17.

1.5.2 Model Calibration

Several system refinements have been implemented and evaluated since the initial prototype CDI was developed, including terrain shading correction factor for incoming solar radiation; correction to ground heat flux over pixels with exposed rock; and correction of an issue with CFS-R meteorological data over mixed water/land pixels (coastal pixels).

In early 2017, several advances were made in new scripting and coding, which improved the statistics and the timely execution of the regional drought monitoring system. Improvements were also made in the ranking of the different components of the CDI, the pre-processing of the different components and the post-processing and the smoothing of the CDI maps.

Between January and April 2018 there have been several CDI technical developments:

- A cloud-free Land Surface Temperature (LST) data for the validation of the CDI maps were developed;
- ICBA, FAO, and Nebraska/Maryland University continued collaboration in validating existing evapotranspiration models for the drought monitor;
- Nebraska began a retrospective (375-m) ET processing which was crucial for the historical data drought monitoring;
- Nebraska team also assisted the Holland Computing Center in the implementation of the VIIRS ET data in the new website (https://glodet.nebraska.edu/index.html#/);
- The PyDisALEXI program was updated to utilize satellite Insolation products (i.e. GSIP, Metosat, CERES) to match the insolation inputs of ALEXI ET product.
-

An automated version of the Energy Balance Model SEBAL using MODIS thermal data (since 2000) was developed to strengthen the CDI with a new component informing on the evapotranspiration anomaly at the country scale

1.6 Configuration of Modified CDI

To facilitate the configuration of the CDI for different dynamics of agricultural production, a system of classification of agricultural territories in agro-climatic zones was used. This categorisation takes into account three criteria: rainfall, topography, and hydro-agricultural development. Six agro-climatic zones have been identified in Morocco on this basis. **Further work is needed to better characterise the variegated and often fragile dynamics of rangelands used for pastoral grazing.**

Three areas of rain-fed agriculture follow from the north to the south, with decreasing levels of annual precipitation (see Table 1). Rainfed agricultural areas (referred to locally as '*bour*') range from 'favourable' with an average of 400 to 800 mm annual precipitation, to the highly arid Saharan and pre-Saharan agro-climatic zone (receiving less than 100mm precipitation a year) which are predominantly irrigated agriculture supported by local oases. The more arid areas are located south and east of the High Atlas and in the Anti-Atlas range. Mountain agro-climatic areas cover a large part of the territory.

Table 1 Moroccan agro-climatic zones

Agro-systems	**Agro-climatic area**
Favourable *bours*	Rain 400 to 800 mm
Unfavourable *bours*	Arid 100 to 200 mm
Intermediate *bours*	Semi-arid 200-400 mm
Saharan and pre-Saharan	<100 mm
Mountain	humid and arid mountain
Large hydraulic area	Irrigated perimeter

Despite more frequent drought periods and their increased duration, **increased variability of rainfall across different parts of the country would suggest increased sporadic rainfall, rather than a decline in total precipitation at the national level**. Greater data collection and ground-truthing will help further characterise precipitation fluctuations and drought dynamics across the country. It remains in the favourable and intermediate *bours,* and the mountainous zones that the greatest variations in rainfall can be observed.

Overall, **the process of validation has been crucial in further configuring the system**. The participation of several local partners, including those working in more remote parts of the country, has helped improve the CDI by receiving crucial feedback from regional locations. This has led to code tweaks and data input improvements to better reflect the reality as experienced on the ground. This input has been valuable not only in improving the generated drought map, but in engaging local stakeholder participation and consensus around it.

1.6.1 Indicators weighting

The monthly CDI maps initially produced by CRTS are now being generated the OSS. OSS now produces CDI maps that are generated with the following inputs and weighting:

- Standard Precipitation Index (CHIRPS): 40%;
- Normalised Difference Vegetation Index (NDVI) based on MODIS and FEWS-Net: 20%;
- Evapo-transpiration from MODIS and FEWS-Net: 20%; and
- Day-night land surface temperature differential (used as a proxy for soil moisture) from MODIS 20%.

In order to develop a better weighting, the relationships between the different indicators was examined, identifying combinations that best determine drought severity, frequency and temporal recurrence, and spatial distribution across different landcover categories. The criteria used focused on differentiating agricultural land from non-agricultural areas and distinguishing between the different climate regions. For the hydrological drought investigation, the weighting of indicators related to agriculture, and long-term SPI were minimised where possible.

1.7 Limitations

Important findings and conclusions can be drawn to contribute to the efforts of drought management in Morocco. The lack of detailed data on crop production and yield, and the poor spatial distribution of climatic stations across the country represent important limitations to the accuracy and so efficacy of the CDI mobilised for the drought management system. This includes the need for a specific CDI calibrated for pastoral rangelands in addition to an agricultural CDI.

In summary, several limitations persist to improving the efficacy of CDI mobilisation and drought monitoring in Morocco. There is a need for:

- Better representation of **Soil Moisture data**. Soil moisture estimates across the different agro-ecological regions vary greatly across the country.
- **Mapping heatwaves** is important as they are not uncommon in this region. Heatwaves impact evaporation of surface water sources and agricultural production.
- **Capturing hydrological drought** is a priority for Morocco. While the CDI configuration based on the selected SPI seems to capture the hydrological drought, more work is needed in order to check drought severity in the water sector.
- **Enhanced spatial resolution** of kilometric resolution (1-2 km2) is needed to capture small scale variability. In fact, the complex topography of the country creates high variability in precipitation, soil moisture, and land use practices over short distances.

Options for improving the CDI include:

- Better **temporal resolution** (10 days) to capture the high hydrometeorological variability influenced by the different hydroclimatic zones of the country (for instance, around mountainous and coastal regions).
- **Enhanced CDI memory** is needed to capture drought for months with no precipitation.
- More systematic ground-truthing from a range of stakeholders can help further refine the modified CDI's configuration.

There has also been a request from the Moroccan Government to develop **a cumulative drought monitor** to be able to run alongside the standard one. This would allow data to be generated on rainfall and other conditions from the start of the growing season (September/October) through the year until harvest in June/July. This work is currently underway.

Finally, **there has been significant interest and urgency expressed in the development of a 'pastoral CDI' calibrated to support the effective and sustainable exploitation of rangelands by pastoralists**.

1.8 Conclusion

The validation process included:

- Investigating the correlation between indicators and both barley and wheat yields and productions;
- Parameterisation of the CDI parameters to represent the productions;
- Investigation of the spatial pattern of the parameters.

The vegetation and temperature components of CDI have an added value over the use of SPI alone. This was reflected by the correlations between CDI and crop production and yield which were better than the correlations obtained for SPI alone. Therefore, it is recommended to use CDI over the use of a single index or indicator for drought monitoring and assessment. **The pressing local demand for a pastoral CDI, calibrated for rangelands, provides a key avenue for increasing stakeholder uptake of the CDI maps**.

In terms of drought management plan, the period of December-February is the critical period for agricultural drought as reflected by the results of correlation. Therefore, **seasonal weather forecasting for this period (discussed in the following section) is important for drought management in Morocco.**

The CDI can be also used for this purpose after refining and calibrating the data of CHIRPS and LIS using local data. Cooperation regarding this issue is highly recommended as it will contribute to Morocco's effort in building drought resilience.

The variations in degree of correlation between CDI and crop yield among the different regions indicated the character of each area and reflected the anticipated degree of drought vulnerability. **It is also recommended to use yield data rather than production to overcome some uncertainties in these data**.

2 Seasonal Forecasting and Early Warning Systems

There has been a considerable demand for seasonal forecasting to provide decision-makers with likely weather conditions 30-100 days ahead. This will allow precautionary measures and actions to be taken before the onset of drought, thus minimising its detrimental impacts. It will also further support the effective management of transhumance management and the increasingly frequent conflicts with local communities unpermitted nomadic pastoralism today generates. There is an acknowledged need to further develop the system for declaring a drought, and early warning systems play a crucial role in this.

In the absence of dense observation networks and their reliance on remote sensing, both CRTS and DMN also seek to improve their capacity in statistical interpolation and on downscaling forecasting results. The models mobilised by HCEFLD's Climate Risk management unit do not extensively use past drought information or the CDI maps previously generated by CRTS or more recently generated by OSS. Greater awareness of CDI inputs and more regular exposure to the CDI maps is likely to improve the uptake of CDI map usage more widely by different institutional stakeholders. **The DMN is responsible for seasonal forecasting using the ARPEGE-Climat model in cooperation with Meteo-France**. SPI can be forecast over a 4-month period, and future work includes development of capacity to forecast SPEI as well.

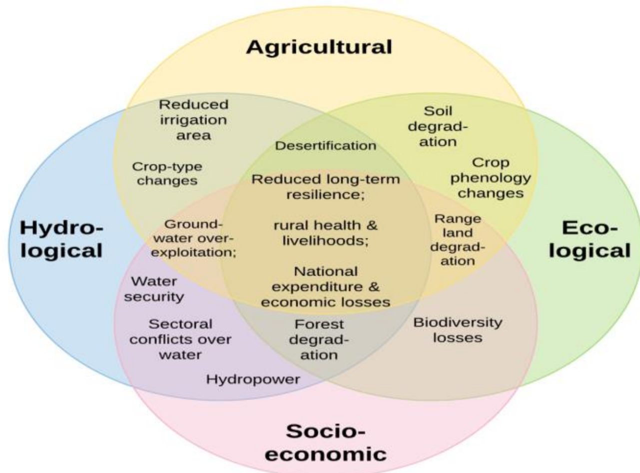
Pillar 2: Vulnerability and Risk Assessment

3 Social Data and Assessment of Drought Impacts

In basic terms, droughts pose risks to assets, the impacts and implications of which for social well-being are largely determined by socio-economic resilience and adaptability. **There remains no clear and comprehensive understanding of the impacts of drought events on different regions, sectors, and social groups across Morocco**. Impacts of drought are cross-cutting and affect many sectors. These impacts also interact with other seemingly separate factors such as global commodity prices or demographic change and as such pose complex challenges for policy-makers. Compiling up-to-date accurate information and learning from “bad years” will assist decision-makers in tailoring action plans to protect assets in the future. As such, grasping drought impacts requires a comprehensive awareness of both the economic dynamics surrounding droughts, and the broader social consequences and dependencies stemming from shifts in water availability.

Drought resilience is a major component of the Green Morocco Plan efforts as usage priorities are set across municipal supply and drinking water, agricultural production, industry, and energy needs. The varying political exigencies of satisfying these often-competing water demands mean that adequately tracking the broader social impacts of drought conditions upon different sectors and their primary stakeholders is crucial in ensuring the balanced, sustainable and proactive management of future drought events. Figure 1 below provides a simplified overview of the overlaps between impacts of different drought types.

Figure 1 Drought type impacts



Among some of the drought management limitations reported by stakeholders preventing more effective drought mitigation and response is **a lack of planning based on studied links between drought management and other social and environmental issues**. Also having such **data disaggregated at the regional and sectoral levels can further inform interventions**. Improving this would involve illustrating the connection between resources that are affected by drought and concurrent issues such as frost, water scarcity, desertification, poverty, zoning regulations, and climate change. **Many of these issues are further exacerbated by similar social vectors such as population growth and migration, land use conversion from fields to housing, poverty, overgrazing, and groundwater over abstraction**. Reforming other areas, (such as targeting agricultural subsidies to encourage necessary shifts in farmer practices) could have follow-on effects for drought risk management in addition to fiscal stability and economic performance. Building upon this, there is **a pressing need to move from a crisis model toward an holistic, integrated approach that is capable of anticipating and mitigating future drought threats proactively**.

As a starting point in assessing the social impacts of drought beyond key indicators of national economic performance, social sub-groups can be identified as having different levels of social resilience. Although there is a paucity of data tracing impacts of drought events on different social groups, and the **variegated vulnerabilities around the associated impacts of drought events on, for instance, food and water security, rural livelihoods, migration, social tension, and environmental degradation**.

Only by further disaggregating drought impacts on producer and household types, across gender, age and residential status can the impacts of drought events begin to be more comprehensively assessed. This represents a significant gap in current assessments of drought impacts, and a formidable logistical challenge for researchers and policy-makers alike. As populations, markets and climatic conditions continue to evolve, both an instructive, granular assessment and a robust framework for ongoing data collection are needed to ensure understandings (and so management plans remain responsive to emerging social and natural dynamics.

3.1 Economic impacts

To date **there are no official reports on the estimated cost of drought impacts on the Moroccan economy**. Economic impacts of droughts that are collated are most regularly discussed at the national level, with macro-economic indicators broadly alluding to key sectors impacted upon. As such, hydrological, agricultural, socio-economic and ecological monitoring data currently produced and collated at the national level provide only a cursory assessment of drought impacts can be developed.

Morocco's economy has historically been dependent upon the agricultural sector, but it has begun diversifying its economy with positive results. From 2004-2011, the average economic growth rate was 4.9%, representing a near doubling of the average rate of 2.5% during the 1990s. The sector and most of its constituents display a much lesser adaptive capacity than others, not least owing to generally poor economic resources and human development, health and education characteristics.

3.1.1 Agricultural Sector

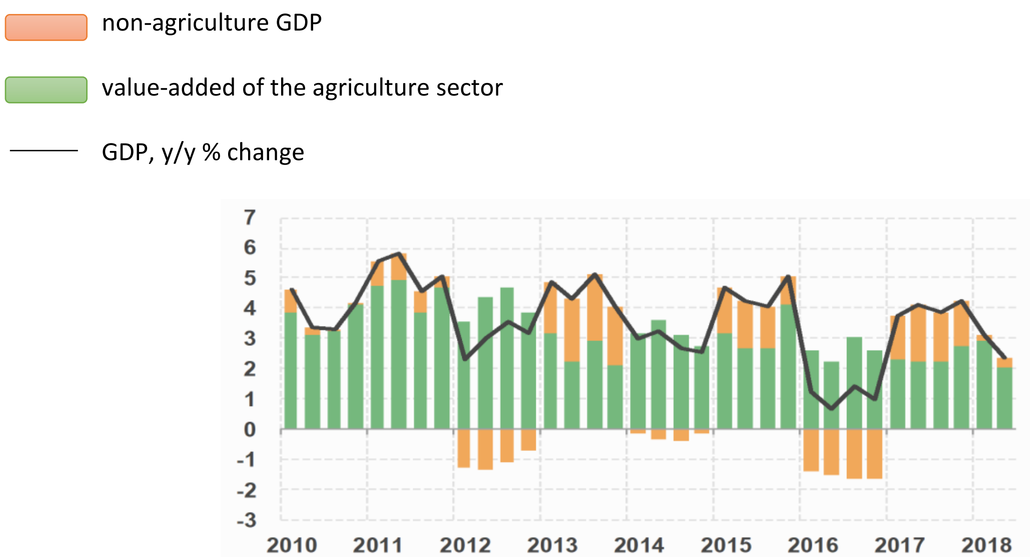
The continued importance of the agricultural sector and the key role the sector plays in livelihood creation and contribution to GDP in comparison to other North African countries contributes to a greater risk of social disruption from droughts. The sector contributes around 15 percent of GDP, and together with fishing and forestry employs some 45 percent of the total workforce.

In 2008, the Ministry of Agriculture, Rural Development and Maritime Fishing launched the Green Morocco Plan framing an ambitious national agriculture development strategy through to 2020.[3] It's two

[3] *Plan Maroc Vert* (PMV). Accessible at: http://www.agriculture.gov.ma/pages/la-strategie

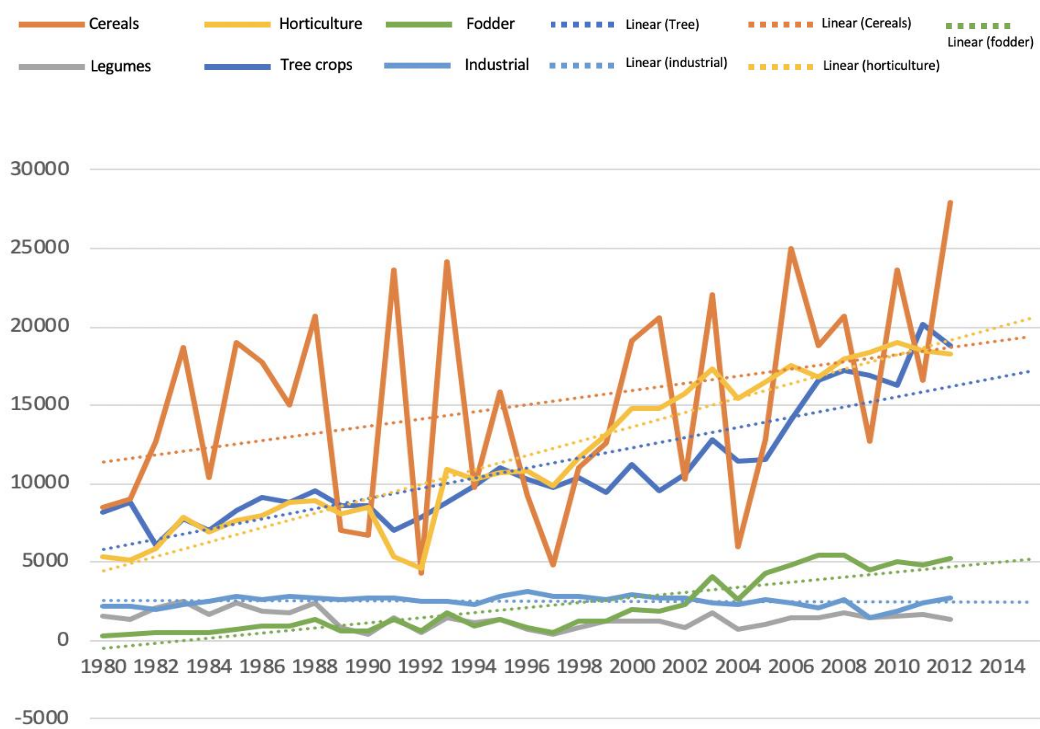
core pillars – agricultural modernisation and supporting small-holder farming – have taken great strides towards stabilising rural livelihoods, access to international markets, and the sector's performance in general. Yet productivity gains remain slow, as do the secondary impacts on other sectors, such as industry. **Water stress remains a key limiting factor and source of volatility** (Figure 2). With the large percentage of small-holder farmers in the sector, policy makers are challenged with balancing the need to accessing the benefits of increased automation, economies of scale and capitalisation for modernisation, with the need to support rural livelihoods. Agricultural activities remain the main source of income in rural areas.

Figure 2 Sector Contribution to GDP Growth (Source: BNP Paribas, 2018)



The recent droughts in Morocco have led to volatile economic growth rates in the country, with year on year impacts to sectoral investment and resulting increased costs on restarting seasonal agricultural activity as yet unmapped.

Figure 3 Value of Crop Production by Crop Type (yr 2000 constant prices)



Despite fluctuations, especially in cereal production, the average increase in crop production across all types is 1.1 billion dirhams each year. Variations in production are lower in arboriculture and vegetable cultivation which remain less volatile, as does the production of fodder crops such as alfalfa (Figure 3).

Despite these disruptions to GDP, **the sector's importance continues in its being a domestic source of important food items particularly fruits and vegetables, its role in foreign currency earnings through exports, its direct and downstream employment potential, and its environmental advantages including the arrest of desertification.**

The direct and indirect impacts of drought on the agriculture sector could be summarised as entailing the following:

- **Decreased productivity** of rain-fed crops (particularly cereals) and of irrigated crops;
- **Decline of production and productivity** of winter vegetables, summer vegetables, citrus, olives and stone fruits

- Lands left **fallow in drought years**
- **Damages in forest areas, and decreased rangeland productivity** and carrying capacity
- **Damages to on-farm infrastructure** and capital losses;
- **Declining number of livestock**, increasing mortality rate and more depend on governmental feed subsidy;
- **Loss of income and employment** of hired seasonal labour (especially affecting women and girls relying on crops harvesting and olives picking);
- **Overuse and misuse of natural resources;**
- **Increase of poverty and malnutrition**, especially among children and vulnerable groups.

Irrigated Agriculture

Irrigated agriculture in Morocco, although occupying only 15% of the total cultivated area. On average, **it contributes about 45% of total agricultural added value and accounts for 75% of agricultural exports**. This contribution is greater during drought years when production in the rainfed (*bour*) zones is severely affected. In recent years, the irrigated sector contributed an average of 99% of sugar production, 82% for vegetable crops, 100% for citrus fruits, 75% for fodder and 75% for milk. **With the high ratio of rainfed to irrigated cultivation, Morocco is highly sensitive to shortages in rainfall**. Given the importance of agriculture and agri-processing in Morocco's economy (and particularly in rural labour markets, where it constitutes about 75 percent of employment), drought has serious economic and social consequences. Smallholder farmers in areas of low rainfall or drought-affected areas rely on less water intense arboriculture crops such as argan and almond trees. With increased large-scale nomadic pastoralism in response to drought periods, conflicts are increasingly emerging between settled and pastoralists (discussed below). With irrigated crops most significantly cultivated by larger producers for export markets, **drought considerably increases energy consumption for pumping water and greenhouse cooling systems**.

Cereals

The agriculture sector in Morocco is highly exposed to drought risks, with estimated annual average losses in the cereals sector alone reaching MAD2.7 billion (~$USD 287 million; MAPM, 2010 as seen in World Bank, 2014). **Cereals account for over 60 percent of agricultural production**, with the planted area for wheat having expanded with government support as a part of PMV. The 2000 drought in Morocco resulted in a 31.5 percent reduction in agriculture sector GDP and a corresponding 7.5 percent reduction in Morocco's national GDP compared to 1998 (Ouraich & Tyner, 2014). **The uneven distribution of these impacts significantly affects rural labourers**, both in terms of stable employment opportunities, salaries, and working conditions**.** While government policy, demand effects and technical change can have impacts on productivity growth, **precipitation volume and technical efficiency in drylands appear to be the most significant drivers of performance** (Azzam & Sekat, 2005).

In fact, cereal production statistics provide a clear indicator of drought impacts across the country: in 2014-2015 there were above-average rains and about 11.5 million tonnes of combined cereals output. In the 2015-2016 drought year, production dropped to less than one third of the previous year (USDA-FAS, 2016). **The 60 percent rainfall deficit of that year contributed to a drop in national economic growth by more than 3 percent, attributed to the drop in agricultural production and subsequent relief measures** (EIU, 2016).

<u>Livestock</u>

Livestock and pastoralism play a significant role in rural livelihoods in Morocco. Three-quarters of farmers own livestock of some form or another. **Livestock plays a strategic role in the economic viability of rural households and farms in general**. In addition to contributing to rural household food security, it also represents a store of wealth for mitigating drought impacts. Half of red meat production comes from cattle, with a quarter supplied by sheep and the remaining amount coming from both camel and goat herds. Of the estimated 300,000 dairy farmers supplying most of the country's beef, more than 85 percent hold less than five heads of cattle. **High feed prices resulting from droughts has been seen to directly impact livestock numbers, low market prices, and thus the overall economic viability of farm activities.**

In addition to feed prices, **droughts and disease significantly affect livestock production**, mortality and ultimately the economic viability of the sub-sector. **Poor fodder production and water availability during droughts are crucial issues for herders** and result in increased intercommunity tension and conflict (discussed further below). With improved access to barley from international supplies of barley, cattle production and recovery periods from price shocks has improved in recent decades, largely as a result of improved trade policies.

Forestry

Forests cover almost 13 percent of Morocco's landmass – more than 9 million hectares. Forests are publicly owned, consisting mostly of broadleaf species and steppe grasslands (see Table 2). More than 30 percent of the total forest area is developed, with the more mountainous northern regions of the country and coastal plains hosting the greatest variety of species. Forest areas are predominantly subject to semi-arid and humid climates. The forestation rate varies between 4 percent in the southern provinces and 40 percent in the Rif and Middle Atlas regions. This corresponds to an average of 8 percent, a value below the optimal rate (15-20 percent) necessary for optimal environmental ecological balance. Nonetheless, Morocco's forestry assets play a vital role in maintaining both ecological and social systems, industrial and artisanal economic and social activity of varying scales.

Table 2 Forest types and main species in Morocco (Source: http://www.eauxetforets.gov.ma)

Forest Type	Hectares	% of Total	Main Species
Leafy species	3,795,840	42	Green Oak; Cork; Argan; Acacia
Resinous species	994,149	11	Cedar, Thuya, Juniper, Pine, Atlas Cyprus, Firs
Artificial forests	451,886	5	(No data)
Steppe grassland (*nappe alfatiere*)	3,343,954	37	Estimate
Shrubland (*mattoral*)	451,886	5	Estimate
Total Forest Area	**9,037,714**	**100**	

Argan forests

The Moroccan argan tree (*Argania Spinosa*) covers around 1 million hectares of the semi-arid and arid lowlands, particularly in the *Souss* Valley and mountainous Anti-Atlas range. Their size has reduced significantly over the past century, with pressure caused by charcoal production, conversion to olive groves, grazing pastures and water scarcity and desertification resulting in the contraction of rangelands (Alba-Sanchez *et al*, 2015). Remaining forest are an estimated 45 percent less dense than in 1970 in one particularly important argan forest (Waroux and Lambin, 2012). The significance of reduced argan forest resilience stems from both its ecological role in staving off desertification and providing local fuel sources, and its role in rural value chains, providing food oil, traditional medicines, fodder, and as the top-tier of integrated farming systems (Charrouf & Guillaume, 2009). In recent decades, both local and global demand for argan oil for food and cosmetics has significantly increased. With prices having increased from MAD40 twenty years ago to upwards of MAD300 in recent years, argan oil has grown to play a significant role in supporting rural livelihoods – often among the poorest and more vulnerable rural communities. **Argan processing and oil production has also predominantly been structured around female-led cooperatives, representing a more participatory and inclusive model of production than other elements of the agricultural sector, discussed in the following section** (Charrouf & Guillaume, 2009; Lybbert et al., 2011).

Despite the rapidly increasing socio-economic value of argan oil, rates of deforestation and density reduction continue to increase, owing largely to poor forest management and the challenges of reforestation posed by water scarcity, underregulated grazing, and soil degradation from intensive cultivation. During drought periods, more aggressive fruit harvesting threatens the health and drought-resilience of argan trees and the likelihood of their early lapse into dormancy. As other sources of income become less viable **during drought periods, the likelihood of argan forests becoming damaged and their being cut for timber and charcoal is increased**.

Climatic shifts and the associated sporadic weather patterns driving drought periods in Morocco are likely to further impact argan forest range, especially in the southern boundaries of argan forests. This threat is most evident in argan's need for relatively cold winters and a baseline of winter season precipitation (Alba-Sanchez et al., 2015). With argan forests having been managed locally for centuries, another source of vulnerability is presented in the resulting similar genetic profiles evident between different argan ecotypes, yet diversity remains within individual rather than across ecotypes. **Research into more drought-tolerant characteristics, together with greater sustainable eco-stewardship of argan**

forests is central to the sustainable management of drought impacts on the argan population and the eco-systems, rural communities and value chains dependent upon them.

3.1.2 Municipal Sector

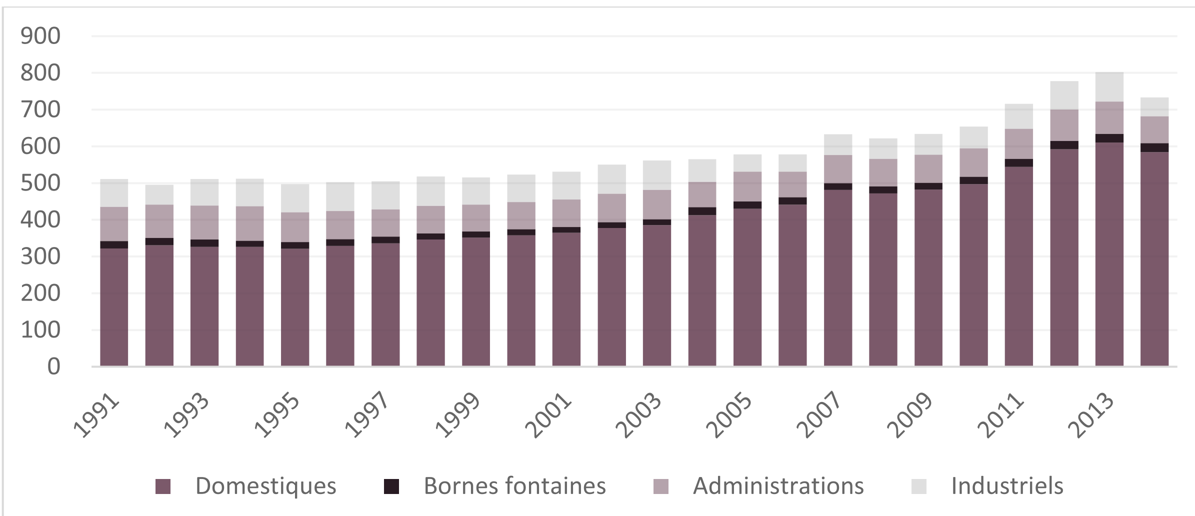
Drought has major impacts on surface and groundwater resources and leads to significant reductions in irrigation water availability. It also has important impacts on water quality: heightened risk of eutrophication and associated toxic algae blooms, reduced flushing capacity and consequent increase in pollutant loads, and increasing surface water salinity and turbidity. In turn, these all increase the costs of potable water treatment and increase the risks of human and animal health problems.

Despite their significance, the impacts of drought beyond the agricultural sector are notably less well-evaluated. One study (EU, 2011) estimated the cost of water resource degradation in the *Oum El Rabia* basin alone during the 2007 drought to be in the region of MAD6.2 billion (~US$ 660 million), representing over 9 percent of the basin's GDP and approaching 1 percent of national GDP. The study noted **the increased costs caused by drought-related water resource degradation, impacting human health, hydropower production, pumping rates and costs, water supply treatment, and sewerage**. Of the total costs, over a third were due to health impacts, nearly a third due to water quality degradation, and around 20 percent directly due to water quantity reduction (Ibid). Although not including losses due to reduction in irrigation or associated agricultural impacts, the estimates highlight **the breadth and intensity of drought impacts in Morocco and the inherent challenges in comprehensively assessing such impacts**.

The main operator of drinking water production and supply in urban and rural areas is ONEE. Its action plan for the period 2016-2020 has a projected budget of more than 25.7 billion DH (without taxes). Planned projects for drinking water supply aim to improve its performance by raising the production capacity by 19 m^3/second and by laying nearly 2,800 km of production and distribution pipelines, representing an investment of 15.7 billion dirhams. This is largely to accommodate demographic growth and urban development, industrial development, and tourism. ONEE also aims to improve access to drinking water in rural areas to reach 98 percent, adding an additional 400,000 users to the network. The volume of investment devoted to rural areas during this period is 4.6 billion dirhams.

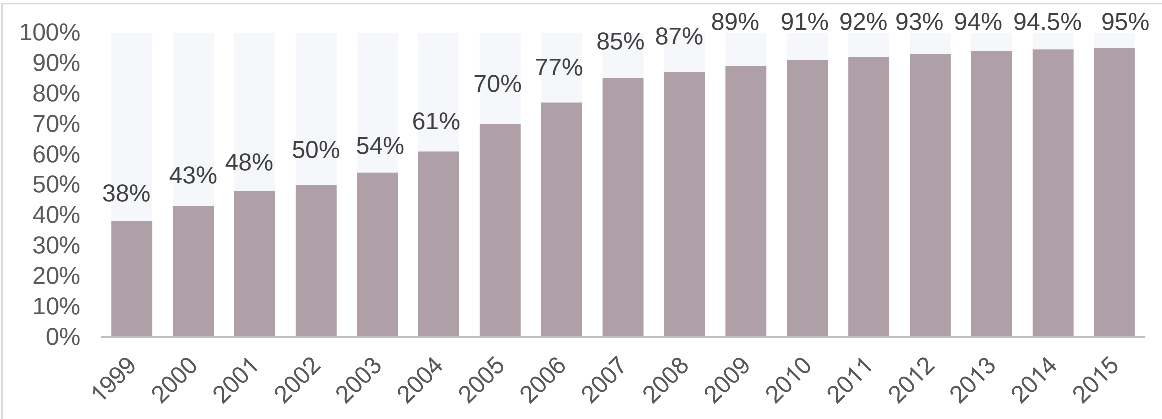
The volume of drinking water supplied by ONEP increased from 777 million m3 in 1994 to 1,068 million m^3 in 2014. Over the same period, sales to various users increased from 512 to 733 million m^3. Households and very small businesses connected to households account for nearly 80 percent of sales. Nearly 3 percent of the volume sold to households goes through standpipes used mainly by households without direct connections in their homes. Figure 4 below outlines the distribution of potable water across different users, clearly highlighting an increase in municipal water consumption. A significant increase in municipal water users further pressures existing water supplies, and despite a prioritisation of municipal water supply, **the longer-term impacts of drought on municipal infrastructure, investment and water availability for other sectors has not yet been comprehensively evaluated**.

Figure 4 Distribution of drinking water supply between different users – domestic, industrial, government and standpipes



The share of households in overall drinking water consumption increased from 67 percent in 1994 to 83 percent in 2014. Over the same period, the share of industrial and commercial activities fell from 15 percent to 7 percent and that of government from 18 percent to 10 percent According to ONEE, urban households have a 100 percent access rate to drinking water through either a domestic connection or a supply from standpipes. It is rural households for which access to drinking water is problematic. In addition, households living in outlying urban areas may experience unfavourable access conditions due to water quality degradation. In rural areas, more than 90 percent of households have had access to drinking water since 2010, increasing to more than 95 percent in 2015 (see Figure 5). **Despite the improvement in connection rate, droughts still present challenges by impacting both supply stability and water quality during affected periods**.

Figure 5 Evolution of rural access rate to water services: 1999 to 2015 (Source: ONEE)



Despite these improvements, **in rural areas chronically affected by drought, water scarcity and poor connections of sewage and potable water supply persist**. The consolidation of housing in rural areas is a response attempting to compensate for these challenges in the following regions: *Draa-Tafilalt, Souss-Massa, Marrakech-Safi, Guelmim-Oued-Noun*. In the regions of Tangier-Tetouan Al Hoceima, Fez-Meknes, Casablanca Settat, Rabat-Salé Kenitra, the connection rates are lower because of the supply limitations and dispersed housing. In other regions, such as Eddakhla-Oued-Eddahab and the eastern and southern parts in particular, rural households are dispersed because of the prevalence of nomadic pastoralism.

3.1.3 Industrial Sector

There are currently no comprehensive studies or impact assessments that detail drought events' interactions or impacts on industrial water users. Industrial water demand makes a small portion of the total water demand in Morocco. However, **due to expected economic growth in the future, industrial water demand is projected to increase**. Increased water scarcity caused by drought events reduces water available for environmental flows (see below), and thus increases costs associated with industrial uses, where return flows require greater decontamination. As such, **it is highly anticipated that droughts and subsequent water scarcity are likely to lead to the accumulation of pollutants in the soil profile and aquifers.**

Renewable energy generation in Morocco is dependent on water resources: hydropower remains significant within Morocco's electricity generation mix, while solar powered thermal generation capacity is increasing rapidly. Total installed hydropower capacity is about 1,750MW (including pumped storage of ~450MW), which corresponds to roughly 25% of total installed capacity nationwide. The 2009 National Energy Strategy set ambitious targets to expand both hydropower and solar power to reach 2,00MW installed capacity by 2020 (Amegroud, 2015).

However, **produced hydropower varies significantly year to year and largely dependent on drought and silt buildup**. In 2000, one of the driest years on record in Morocco, total hydropower production was only 718GW/h – down from over 3,200GW/h in 2010. The loss of generated electricity in the *Oum El Rabia* basin alone in 2007 (a dry year) compared to 2010 (a wet year) totalled about MAD255 million (~$USD 27 million), which was primarily the replacement cost of fossil fuel production and lost profits (EU, 2011).

Morocco's increasing utilisation of solar power also relies to some extent on water consumption, given the role of concentrated solar power systems in Morocco's energy strategy. Current major plants and planned expansions are reliant on ground water for thermal generation and located in desert areas (Amegroud, 2015). As discussed above, groundwater systems and drought are intimately linked.

Overall, understanding the interactions and interconnections between electricity generation, surface water and groundwater storage and pumping requirements, and how to manage and implement relevant drought mitigation interventions is another opportunity for a DMS coalition to prove useful.

3.1.4 Environmental Sector

Environmental impacts of droughts are most tangibly determined in monitoring water demands for maintaining environmental flows to key nature reserves across Morocco. **Droughts interact with social systems and practices further impacting upon environmental resources and flows**. In Morocco, there exist no comprehensive assessments of the environmental impacts of droughts, although stakeholders began to identify a growing number of environmental impacts attributed to droughts. These include damage to plant species and the resultant loss of biodiversity; soil profiles also become more susceptible to both wind and water erosion; overexploitation of aquifers can also impact water quality, causing for instance high salt concentration, increased water temperature, and negative impacts on aquatic flora and fauna.

Recurring drought and decades of over-cultivation have resulted in increased deforestation, desertification and soil erosion, directly impacting agricultural livelihoods, rural food security and regional vulnerability. Relatedly, **increasingly vulnerable rural communities find fewer alternatives to overexploiting natural resources, whether land, water or forests for fuel**. In such regions, the interconnectedness of drought-related environmental degradation and the impacts of drought on the agricultural sector are most evident. **There are currently few studies that explore the complex impacts of droughts on water quality, forestry, agrobiodiversity and the social systems increasingly dependent upon them.**

__Water Quality__

The effects of **droughts compromise the quality of both surface and groundwater supplies**, particularly where droughts reduce the dilution of various solid and liquid pollutants. Reductions in environmental flows also amplify the impacts of agricultural runoff, and urban and industrial discharge.

A water quality analysis conducted in 2014-2015, however, indicated that only 29 percent of the sampled stations reported poor to very poor water quality. Some 45 percent of groundwater stations indicated degraded quality due to nitrate and salinity seepage. The lack of sewage infrastructure often leads to the discharge of untreated wastewater into watercourses or the sea. The failures of the solid sanitation system lead to the concentration of leachates in landfills that do not comply with legal standards, causing infiltration into groundwater and watercourses. The pollutant load generated by urban and rural liquid discharges is estimated at nearly 400,000 tonnes of oxidizable materials.

As for **the volume of wastewater discharged by industry**, it reaches nearly 964 million cubic metres per year, of which 80 million cubic meters is discharged into public systems (EPRE 2014). Industrial activities are undertaken at more than 8,000 sites and consist of 227 activities, of which 81 are considered potentially polluting. As part of the Industrial Pollution Control Fund (FODEP), 74 liquid waste treatment projects were completed and treat 40,000 m3/d of wastewater, or about 14.5 million cubic meters per year. Industrial discharges cause an increase in the temperature of water resources, a change in pH, increases in turbidity and oxygen consumption, and have inhibitory and toxic effects due to organic and metal micro pollutants. The mining industry is also a significant source of water pollution through mine water and mine washing, wastewater and solid waste generated by the extraction and processing of minerals. **Drought periods and the reduction of environmental flows will continue to further intensify the environmental impacts of such sources of pollution until adequate measures can be put in place** to reduce such sources of pollution or maintain the volumes of environmental flows.

Diffuse pollution is generated using chemical agricultural inputs (fertilisers and pesticides) **and affects surface water and groundwater by the leaching of contaminants.** Groundwater quality degradation is observed due to nitrate pollution. High levels of nitrates were recorded in the Beni Amir, Béni Moussa, Maâmora (73 mg/l) and Fès Meknès aquifers, which reached 154 mg/l. **Nitrate pollution is a major pressure on groundwater resources and poses a threat to human health, particularly in rural areas where it is used for drinking water, particularly following drought periods**.

Drought also causes deterioration of coastal aquifers both on the Atlantic and Mediterranean coasts due to saline intrusion, occurring when pumping exceeds the renewal capacity of the aquifer and the resultant lowered groundwater tables. As surface water supplies and rainwater are less available, over-abstraction from groundwater sources. **Several cases of seawater intrusion into coastal aquifers are observed along the Atlantic and Mediterranean coasts**.

<u>Forestry</u>

There is a clear relationship between the intensity and frequency of drought and the intensity and frequency of forest fires. The annual frequency and extent of forest fires in Morocco is high relative to the low rate of forestation. The general challenges in forestation and water scarcity highlighted above also present significant challenges for subsequent reforestation and forest regeneration. Figure 6 and Figure 7 below highlight the evolution of forest fire between 1960 and 2014. **Between 2005 and 2014, an average of 3,635 hectares of forest were burned each year**.

Figure 6 Number of Fires (Source: HCEFLCD communication, 2015)

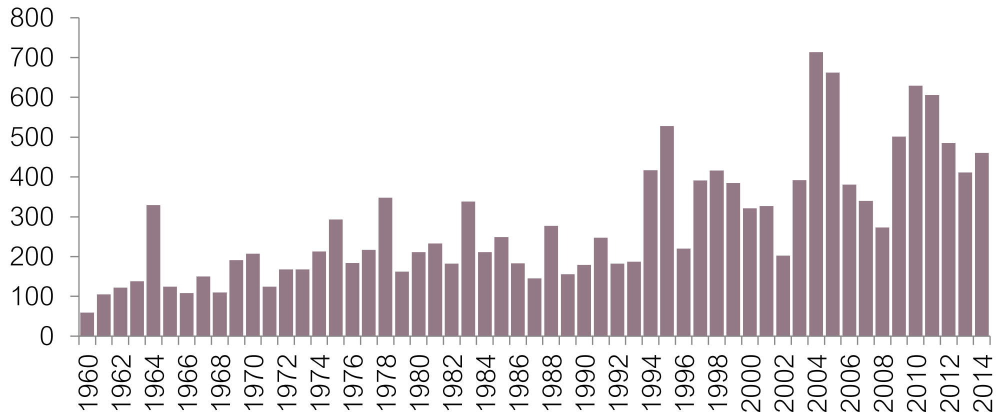
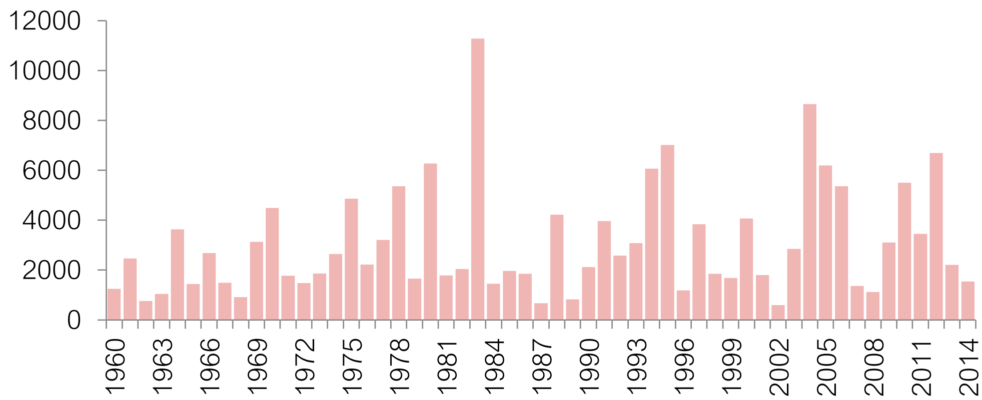


Figure 7 Burnt Area – hectares (Source: HCEFLCD communication, 2015)



Forest fires have several impacts and associated costs:

- Loss of ecosystem services (the value of provisioning and cultural services provided by forests);
- Regeneration planting costs;
- Reforestation costs;
- Costs related to other silvicultural work and fencing installation.

As drought events increase, increasing with them the likelihood and extend of forest fires, detailed assessments of such impacts are needed to further make the case for more comprehensive drought management plans that incorporate proactive mitigation strategies to reduce such risks.

<u>Rangelands</u>

The country's rangelands are complex, evolving and increasingly fragile bioclimatic zones that play a vital role in reducing the negative effects of desertification. **Rangelands also provide a vital source of biomass for both traditional smallholder pastoral activities and largescale livestock production**. In the *Souss* region, the rangelands are a 'greenbelt' acting as a frontier staving off creeping desertification. Increased drought periods impact local fodder prices and nomadic grazing practices and durations of transhumance. When not effectively managed, such shifts (discussed further in the subsequent section) place additional pressure on the unique conditions of the country's rangelands, with over-exploitation of rangeland biomass threatening the biodiversity of local ecosystems. **The diverse agro-meteorological and bioclimatic zones across the country require localised assessments of drought risk**. More localised studies would better assist efforts to accurately target interventions and offer communities the support they require. Assessments can lead to more efficient ways of approaching cropping, food storage systems, water resource management, and infrastructure development. **Understanding local social and environmental vulnerabilities can also inform more proactive drought and water management,** and cultivation models that more adeptly respond to future drought conditions.

The MoA is actively using the CDI maps generated as a part of the MENAdrought project to inform decision-makers in granting permits for transhumance, in a bid to manage rangeland exploitation. Although their use represents a significant improvement to rangeland management and mitigating the effects of droughts, **further calibration of local CDI models to better suit bioclimatic conditions in the country's pastoral rangelands could greatly improve the efficacy and accuracy of drought maps and rangeland management**.

3.2 Social Vulnerability

Drought events significantly affect the viability of rural livelihoods and generate a host of direct and indirect impacts, such as 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, employing short-term mitigation strategies, often to the detriment of mid-term stability.

3.2.1 Food insecurity

As outlined above, the **sudden onset of drought impacts food security in several ways**, by disrupting agricultural systems, reducing soil fertility, jeopardising rural livelihoods, increasing national food import bills, and increasing prices of basic food stuffs. **Droughts impact the economic viability of the sector, the yield and productivity of producers, the livelihoods of rural producers, and the availability and affordability of food at the national level**.

As discussed above, drought events reduce the productivity of the agricultural sector and thus contribution of the sector to balancing the food import bill (currently around 20 percent of its total export revenues). Consistent with the conditionality and recommendations of international financial institutions, **modernisation of the agricultural sector has led to shifts towards the specialised production of cash crops, such as fruits and vegetables for export, rather than cereals production**. This has led to an increased water productivity per hectare due to the added value of the crops but also greater reliance on international markets to satisfy local food demand, particularly for cereals. The relative inelasticity of more water intensive crops such as cereals, combined with a high imported cereal dependency ratio of 54 percent, implies that drought events will continue to threaten not only food access at the household level, but also availability at the national level (Ghanem, 2015). **Increased reliance on world food markets as a result of drought-related impacts on domestic cereal production also further exposes Morocco to high and volatile world prices of basic commodities**.

Morocco has made significant efforts to improve food security, from ***access***, ***availability***, and ***utilisation*** standpoints. The **most recent estimates show that the prevalence of food insecurity in the country remains considerable despite these efforts**. A recently conducted food insecurity survey showed that **12.8% of the total population was affected by severe food insecurity**. The latest data on ***utilisation*** and malnutrition shows that **15% of children under five years of age suffered from nutrient deficiency-related stunting, and 2.3 percent from wasting** (FAO *et al, 2018)*. Although other issues, such as poor parental knowledge around healthy feeding may play a role in such figures, increases in food costs anticipated by **droughts are likely to only increase the number of households to utilisation-related food insecurity.**

With regards to food ***availability***, reliance on the international markets for food exposed swathes of the country to food price increases. **Drought periods increase vulnerability to global food price fluctuations as regional trade and food availability declines**, generating increased regional demand on food imports which further drives price volatility. This results in a significant increase in the share of money spent on food and hence presenting a burden for the average household. **From an *access* perspective, food insecure households have lower per capita expenditures, more debt, and must allocate the majority of their expenses on food**, as opposed to medical services or education. The average Moroccan household allocates around 40 percent of income to food consumption. For poorer households the share of income spent on food increases to 75 percent (Ghanem, 2015). When considering food insecurity from the perspective of access, were world food prices to increase similar to the world food price shocks of 2007, average household disposable income would face a considerable decline in real terms. **Such factors further exacerbate the pressure of droughts on livelihoods, particularly among the predominantly rural poor**.

Although no studies as yet quantify the impact of drought periods on imports, **increased drought events and thus water scarcity are likely only to further increase food import dependence** and deplete foreign currency reserves.

3.2.2 Women

Women comprise a significant and growing component of the agricultural labour force in Morocco. Female labour force participation is increasingly concentrated in the lower productivity agricultural, forestry and fishing sectors. The sectoral share of participation increased from 3 and 4 percent of all employed women and men respectively in 1990, to 60 and 31 percent of all women and men respectively by 2018 (ILOSTAT, 2019). This significant increase in the share of total employment reflects a transition from subsistence to waged agricultural work, most notably due to the increased intensification of agricultural production. Within these shifting dynamics are obscured significant gender-based inequalities and vulnerabilities, particularly around wages, working and contractual conditions, landlessness and decision-making. **Only 30 percent of beneficiaries of compulsory health insurance coverage are women, with 98 percent of women in rural areas lacking medical coverage, further exposing women to drought-related health risks – particularly in rural areas** (Oxfam, 2018).

Clear divisions of labour exist for women and men that often translate into variegated bargaining power and as such adaptive capacity to increased economic pressure on the sector caused by droughts and growing water scarcity. While men are most likely to be employed in physically more strenuous farming task, handling tools and machinery, and supervisory tasks, women are traditionally employed in grafting, weeding, sorting, packing and processing. Consequently, women are less exposed to opportunities to develop skills around seeding, irrigation choices, planting timing and other vital elements to enhancing agricultural practices in response to drought challenges.

Across different agricultural tasks, farm sizes and crops, **women are often paid significantly less than men**. One study found that men on average receive almost 20 percent more than women for conducting similar tasks, while in crops such as wheat, men could receive between three and ten times the daily wage rate of women (Najjar *et al*, 2018). While the emerging gender wage gap may be associated with women's greater willingness to accept lower pay for tasks or attributable to lower workplace bargaining power, **such variations have very significant implications for the differential impacts of drought events on women in rural areas working in the agricultural sector.**

The agricultural wage labour sector represents one of the largest and most precarious livelihood strategies for both men and women alike. Poor pay, the seasonality of contracts, and invariably the total lack of access to social protection and welfare services combine with the increased intensification of agriculture and incorporation into opaque global commodity chains to undermine rural livelihoods as options for mitigating drought impacts. Yet, **a substantially larger share of all working women rely on the sector for their livelihoods and thus proportionally more vulnerable to drought-related impacts on the sector**.

The longstanding marginalisation of women from discussing gender-specific challenges such as pregnancy in decision-making circles highlights a lack of opportunities to improve conditions within the sector, or to seek employment opportunities outside the sector. In more remote, less developed agricultural areas, where communities are typically more conservative, perceptions around women as waged labourers is also likely to lead to greater restrictions and thus lower social bargaining power. **Social responsibilities and stereotypes often prevent women from migration and seeking employment in more economically viable agricultural areas of the country**.

More recently, increased organisation and collective action has resulted in significant – if small scale – advances in improving the welfare and dignity of both male and female farm labourers, and provide constructive examples for sectoral development. Yet **women's cooperatives still face significant disparities in capacity and benefits when compared with men's cooperatives.** Of the now more than 2,000 registered women's cooperatives (representing almost 15 percent of all cooperatives nationally), the average capitalisation was 482 Moroccan dirham per member, compared to 15,400 per member in male cooperatives. Women's cooperatives are primarily active in lower-skilled sectors such as agriculture (36.3 percent) and handicrafts (36.1 percent) (MoEF et al, 2017). Due to their not contributing to the *Caisse Nationale de Sécurité Sociale* (CNSS), they also will not have access to social protection benefits at retirement. Nonetheless, **recently achieved collective agreements have resulted in seasonal bonuses being offered to both women and men, uniforms and adequate footwear, access to training and tasks such as pruning, and raising important issues such as sexual harassment and gender-based violence**.[4]

Women in Morocco often face significant social, economic, and political barriers that diminish their coping capacities during droughts. An important mechanism for mitigating divergent vulnerabilities of different elements of society to drought events is to ensure adequate involvement during the reporting, policy design and execution stages of drought management. In 2016, Morocco ranked 113th out of 152 countries in terms of inclusion, justice and security indicators.[5]

Across Morocco, just 7 percent of women have access to immovable property, and just 1 percent in rural areas. **Just 2.5 percent of all cultivated lands are held by women, with smaller average farm sizes (<3 hectares) than those held by men** (CESE, 2014). Despite both national and religious legislation supporting women's inheritance rights, women are often pressured to renounce land inheritance to male siblings, further differentiating land ownership along gender lines.[6]

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[4] See: https://www.equaltimes.org/women-farm-workers-achieve-justice?lang=en#.XYVDJSgzY2w

[5] See: Women, Peace and Security Index and indicators, 2016. Accessible at: https://www.prio.org/Projects/Project/?x=1767

[6] See: FAO *Gender and Land Rights Database*. The database provides in-depth overviews of the different national, religious and customary laws governing land ownership.

Women in rural areas also often have greater difficulties in accessing financial resources and loans, with only 26 percent of women holding an account independently at a formal financial institution – half that of men. Around 93 percent of men have access to finance and credit facilities, compared to only 40 percent among women (World Bank, 2015). This may be due to traditions of wealth being stored in moveable assets such as gold and jewellery (OECD, 2017).

Beyond the specific impacts on employment, the gender discrepancies and inequalities outlined above in access to resources, decent working conditions and stable livelihoods are especially pronounced when women are sole breadwinners. **Due to these social constraints, female headed households with dependent children are more likely to struggle with food insecurity and other issues**. Some 18 percent of households in Morocco are headed by women, having increased from 15 percent in 2012 (ONDH, 2018). More than half of female headed households are the result of spousal death, and around 14 percent due to divorce (MoEF *et al, 2017)*. Compared to their male counterparts, **female-headed households are more likely to experience poor food consumption in addition to lower dietary diversity, and thus experience the impacts of drought more palpably**.

The lack of gender-disaggregated data for Morocco poses significant challenges when attempting to assess the variegated impacts of drought on women across the country as a whole and in the agricultural sector in particular. Yet such dynamics would suggest a reduced adaptive capacity due to lack of transferable employment experience or skills, and increased vulnerability among unemployed women in drought-prone regions of the country. Again, although only cursory data exists, it is highly feasible to anticipate **drought events in particular and the associated consumption losses as disproportionately affecting the well-being and vulnerability of women and female-headed households**.

3.2.3 Livelihoods, Debt and Financial Inclusion (access to assets, credit facilities etc.)

Livelihood resilience remains a joint outcome of pre-existing social conditions, crisis-related disruptions, and climatic shifts. Pre-existing conditions impacting livelihood resilience across Morocco include resource scarcity, population growth and migration, and suboptimal climatic conditions. These challenges fuse with crisis-related disruptions to the agricultural, industrial and tourism sectors, increased competition for limited jobs, inflation, and the food and agricultural input price shocks that have typically accompanied drought events.

There are no current data sets 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 labourers generated as a result of drought conditions.

The impacts of droughts hit poor farmers in two forms: directly through the damage to assets; and indirectly by encouraging the tendency to plant low-risk, low-return crops due to the implications of a potentially poor year. As such, even when weather is optimal for cultivation throughout a season, farm income can be reduced by such risk aversion, and falling into indebtedness is invariably the most common mitigation measure deployed.

When agricultural livelihoods are threatened by drought and sudden water scarcity, typical responses employed by farmers – in the absence of alternatives – **may provide short-term mitigating opportunities at the expense of longer-term stability and increased vulnerability**. Reducing on-farm investment, consumption and resources allocated to efficient and waste-reducing production and processing are often primary short-term mitigation practices mobilised in response to the sudden onset of drought conditions. Reductions in resources allocated to production may affect soil quality through reduced use of fertilisers, tillage operations, reductions of the sown surface area, and increased fallow share. Liquidating assets such as livestock can increase house-hold costs derived from household dairy and meat processing. Reductions in investment, debt, and seasonal migration for wage labour can also increase the costs of restarting farming activities for the following growing season.

For rural households, such mitigating strategies may include reductions of investments and family expenses (housing construction, marriage, etc.), impacting the developmental objectives of both farm and family. Reductions in family consumption (food and clothing) are another common response among smaller farmers and the households of agricultural labourers. Such practices often combine with greater reliance on food markets as subsistence farm yields are affected by droughts.

3.2.4 Health

Decreased water availability is a defining feature of most droughts. Invariably, with increase water scarcity, water quality is also affected. The relationship between water quantity and quality is complex.

An important if obvious point, yet not always fully appreciated, is that both are necessary for good health. **Seasonal variations in water-related health outcomes are well-recognised.** Yet while long-term water scarcity can become normalised and accommodated over time, **the sudden onset of drought periods in such contexts can more easily upset the fragile health and wellbeing equilibrium among water-scarce communities.**

Drought-related degradation of water quality can have adverse effects on human health and contribute to the spread of a wide range of diseases from ingestion (diarrhoea, arsenicosis, fluorosis), insufficient water for personal hygiene (diarrhoea, trachoma, scabies, Japanese encephalitis), and contact (schistosomiasis and legionellosis). **Diarrhoea is one of the leading causes of death among children under 5 years in developing countries** (see Prüss-Ustün et al., 2002). However, it is important to note that in Morocco, the mortality rate for this age group has decreased considerably in recent decades. Annually, there are 1,080 infant and child deaths due to diarrhoea in Morocco (OMS Database). Recently, the OMS has estimated that **water-related diseases are responsible for 50 percent of deaths from diarrhoea in Morocco**. That is nearly 540 infant-juvenile deaths caused by lack of adequate drinking water supply, sanitation and hygiene. A World Bank CDE study (2017) estimates the impacts of water-related disease effects on health across the population represent 0.33 percent of GDP and are mainly induced by diarrhoea. Another study identifies the lack of access to safe drinking water and water for sanitation is estimated to cause 19.36 new-born diarrhoea deaths per 1,000 inhabitants and economic damages of over MAD 2.2billion (~$USD 236 million) in the Oum Rabia Basin (EU, 2011).

Studies conducted elsewhere in the region have drawn links between drought events and health issues, particularly diarrhoea. A multi-variant statistical regression analysis was conducted **examining the relationship between diarrhoeal incidence and different drought indicators**. Findings suggested that increased water consumption led to a reduction in diarrhoeal infection. Increases in the precipitation index correlated with decreases in diarrhoeal incidence, whereas increasing temperature were seen to correlate with increased cases of diarrhoeal diseases.

Droughts are likely to disproportionately affect women and children – particularly among the poorest communities. The decreased profitability of farming during drought conditions (e.g. from increased pumping costs, decreases in yield etc.) can lead to increased casualisation of the labour force, lower wages, and increases in child labour – both with families increasingly relying on the supplementary income, and willingness to work for lower salaries. The early years exposure to dangerous agricultural inputs, truancy from school, and hard labour in conditions of chronic food insecurity affect the long-term physical and mental development of children. **No specific data examining the impacts of drought events on such existing patterns of vulnerability is currently available at the national or even basin level.**

Drought-related reductions in environmental flows and quality of agricultural inputs is also likely to impact the health of agricultural workers. Pesticides pose a health risk either through direct contact or by consuming contaminated water or food products. Chemical analyses to detect the presence of heavy metals and pesticides in water intended for consumption are carried out by the National Laboratory of Hygiene. The control and organisation of trade in pesticides for agricultural use is governed by Law No. 09-94 of 1997.

In summary, despite there being inadequate documentation providing a more comprehensive examination of such health impacts, **drought events can be seen to result in a change in distribution of some disease vectors, increased number of people exposed to malnutrition, diarrhoea, cardio-respiratory issues due to increased temperature, other infectious diseases, an increased burden on health services (expenditure, and ultimately increased morbidity and mortality rates**. Climate-sensitive health issues that may increase during drought events include:

- **Increased chronic respiratory diseases** including bronchial asthma and COPD;
- **Increased water and food-borne diseases**;
- Increased **vector-borne diseases** (VBDs) risk with increasing temperature. Areas with scarce water like the Eastern Desert will become an area of higher risk due to water harvesting projects. Water projects will certainly have impacts on the intermediate hosts or vectors responsible for the transmission of malaria, schistosomiasis and leishmaniasis;
- **Reduced access to nutritious food** is expected; dietary quality and eventually quantity declined, and micronutrient malnutrition (or hidden hunger) increased as indirect impacts of drought;
- **Increase in a spectrum of disorders related to the expected increase of heat waves** due to climate change such as sunburn and fatigue, heat rash, heat cramps, heat syncope, heat exhaustion, and heat stroke. The most serious of these are heat exhaustion and heat stroke, which can lead to death. In addition, exposure to hot weather may exacerbate existing chronic medical conditions; and

- **Outdoor workers' overexposure to solar ultraviolet radiation** (UVR) to cause a range of health impacts. The greatest burdens result from UVR-induced cortical cataracts, cutaneous malignant melanoma, and sunburn. Heat stress due to high temperature and humidity can lead to an increase in deaths or chronic ill health after heat strokes. Both outdoor and indoor workers are expected to be at risk of heatstroke. Indoor (chemical industries) workers and farmers may be exposed to higher levels of air pollutants due to increased temperatures

3.2.5 Regional variation in drought impact

Drought vulnerability varies greatly across different regions of the country. During a recent vulnerability assessment, *exposure* to drought risk was assessed using observed rainfall data; *sensitivity* using population, agriculture, and livestock indicators; and *adaptive capacity* using poverty statistics, per capita municipal water supply, and maps of groundwater wells to derive irrigation water availability. The vulnerability of rangelands, particularly in conjunction with overgrazing affects large swathes of the southern regions, particularly in the *Souss-Massa* basin (discussed above). Owing to the often delicately balanced ecosystems they comprise, **oases can also be particularly affected by drought events**.

Oases are vital agro-ecosystems dependent on careful management of plant, water and soil resources. Over 5 million Moroccans live in oasis zones, which cover about 40% of the nation's territory (Bachri, 2016). Oasis zones straddle the Atlas Mountains and the Sahara desert. In these transition zones, dryland farming is possible in some years (Ilahiane, 1996). Rainy conditions during the growing season (beginning in the fall) have been linked with increases in the percentage of arable land, and a number of springs, artesian wells, private wells, cooperative pump stations, and diversion canals supplement the water supply of naturally-fed systems (Ibid). These areas are often suitable for canal water delivery due to their elevation gradient. The crops and growing activities in these areas depend upon the vital support of these various irrigation practices (Ilahiane, 2004). However, development pressures have strained the political structures and community practices that are designed to support water allocations.

Oasis areas have degraded significantly over the past half-century due to a combination of many factors: exponential population growth and concomitant rise in agricultural intensification and its market focus, livestock grazing pressures, settling of nomad populations, groundwater overdraft, recurrent drought cycles, catchment hydrology changes associated with dam-building, sand encroachment, temperature increases, pests such as locusts, and the "bayoud" palm disease that has killed an estimated two thirds of all palms in Morocco over the past 50 years (FAO/GEF, 2016; Bodian et al., 2012; Chelleri et al, 2014). In particular, the decimation of date plantations and the shift to water-intensive market crops, rather than integrated farming systems, and the connected expansion of private groundwater-dependent irrigation systems have contributed to widespread water resource and soil degradation in oasis systems (Chelleri et al, 2014).

Recognising such pressures, **Morocco's Green Plan development strategies focus heavily on oasis zones for sustainable development objectives, combatting desertification, and supporting local populations** given the high rate of outmigration from oasis areas (ibid.). Indeed, remittances are the primary income source in many large oasis areas (FAO/GEF, 2016).

The crops and growing activities in these areas depend upon the vital support of various irrigation practices (Ilahiane 2004). Given the precarious balance of oasis agro-ecosystems, and their reliance on micro-climates produced by tiered cultivation, they are highly vulnerable to drought conditions and subsequent reductions in surface and groundwater availability. **Drought affects Moroccan oases in myriad ways** (Karmaoui, 2015; Heidecke, 2009):

- **Decreased water availability**: inter-annual variation in precipitation can result in water availability shifts of over an order of magnitude in particular oasis zones.
- **Wind and soil salinisation**: high temperatures and desert winds associated with droughts greatly increase evaporation rates and soil salinity; without increased irrigation plants will die, and increased irrigation causes further salinization, driving down agricultural productivity.
- **Groundwater overdraft**: during droughts farmers have increased reliance on groundwater, which in most oasis zones is higher salinity than surface water.

These impacts create a negative cycle of feedback loops that in combination with intense demographic pressure on natural resource systems, can lead to significant land abandonment and outmigration as well as rapid groundwater depletion (Chelleri et al, 2014). When carefully managed cultivated areas suffer and agricultural areas of oases are abandoned, the desert encroaches (Ilahiane, 2004). Such impacts have significant secondary impacts on both the vulnerability of new 'frontline' territories following desertification, the significant costs of reclaiming desert land and restarting agricultural activities in the future, further pressure on rural-urban migration, and the loss of valuable ecosystem assets across the country.

There remains a need to further study and calibrate both drought indicators and comprehensive impact assessments to more effectively capture the impacts of drought on the extensive desert regions and communities supported by oases.

3.2.6 Migration

Government and NGO publications cite drought as a major contributor to rural out-migration (Tangermann *et al*, 2016). **Unfortunately, climate migration research is severely limited in Morocco and virtually no data exist on the proportionality of long-term internal migration or emigration caused by drought and linked environmental causes (Ibid)**. Studies on rural outmigration focus on the economic push and pull effects with little explicit focus on drought's role in the dynamic. **Further evaluation of the relationship between drought, water scarcity and migration are needed**, that also incorporate the role of other social impacts and adaptive capacities.

Analyses of demographic surveys show broad consistency in the reasons for rural out-migration from the 1980s to mid-2000s, when the most recent widespread survey was undertaken. Data from the 1980s indicate that rural outmigration averaged 3.6 percent each year and was driven primarily by economic hardship in villages and the desire for access to better economic opportunities and health and education services (African Population Newsletter, 1995). **Economic problems in rural areas in the earlier period linked explicitly to reduced water supplies, degraded land, and arable land fragmentation, although the proportion of each is not determinable from the data**.

At the individual farm level, there is significant variation in response to drought. Moroccan farmers have various ways to cope depending on their income and farm types. Wealthier families are able to rely on stored grains, sell their sheep and goats, and receive subsidies from the state while poorer farmers borrow money beyond the farm operation, are incentivized to sell large animals such as cattle, and may choose to lease their lands (Achy, 2012). These strategies are costly in the long run because they make it more difficult to recover over time, and they likely contribute to increased outmigration.

Recent research (Baubion et al, 2017) on rural outmigration within Morocco finds that economic opportunities are still the primary reason for rural to urban migration, with access to health and education following. Rural to urban migration is associated with people leaving agricultural activities, and thus migrants are less likely to have productive agricultural assets than non-migrants. Similarly, rural migrants are relatively poorer and less educated than those who do not migrate.

Whether such factors translate into higher internal migration caused by drought events requires further research and examination, but the factors help contextualise potential drivers of dislocation (Tangermann et al, 2016). Indeed, considering the findings of Baubion et al. (2017) on the characteristics of migrants and the impact of drought on agricultural GDP, one can infer drought has highly negative effects on productive assets and will translate into increased rural outmigration. As residents move from rural areas into urban zones, they are often forced to adopt a lower standard of living due to higher amenity costs and the loss of social support formerly provided by extended family members, such as childcare. The net effect of this is a growth in informal urban settlements. **The OECD estimates that the number of people living in informal settlements decreased in the first half of the early 1990s, but as drought set in during 1994, 1995, and 1999 and 2000, the "exodus" from rural areas engulfed existing slums and resulted in the emergence of new ones** (Baubion et al., 2017).

3.2.7 Tension between communities

The impacts of drought can lead to increased tensions between communities. Social cohesion indeed reflects community relations and individual perceptions. In practical terms, it manifests as a function of access to resources and public services. Some studies have drawn correlations between the intensification and duration of droughts, and the likelihood of local conflicts (Maystadt & Ecker, 2014). This is particularly evident in predominantly low income and poor, agriculture-dependent communities (FAO et al, 2018). The prolonged drought periods that affected Morocco in the early 1980's, for instance, culminated in macroeconomic collapse and food riots (El-Said & Harrigan, 2014).

In addition to drought impacts on local food security, **droughts affect fodder available to transhumant pastoralists, triggering migration and even conflicts with sedentary communities**. Particularly in arid regions, pastoral mobility is central to the effective management of sparse vegetation, the fragile ecosystems that support it and the avoidance of overgrazing and soil degradation.

A recent example is evident in conflicts that have arisen between increasingly challenged nomadic pastoralists from the south of the country, and settled Amazigh communities in the *Souss* region. Traditional migratory patterns in place for decades have seen the seasonal movements of pastoralists to relatively confined grazing regions. **Drought-related water scarcity and rising temperatures have driven pastoralists to extend both the duration and range of grazing areas, often in direct conflict with local residents** often dependent upon the lands for cultivation. While the grazing of goats is seen as less invasive, camel herds have a greater impact, with their grazing damaging local almond, olive and argan forests. Lingering grievances from colonial-era land sequestration from the local Amazigh tribes have further intensified the spectre of such conflicts and also let to protests challenging the government's management of issues of indigenous land rights. **Despite the decrease in nomadic shepherds, the Ministry of Agriculture has identified an increase in herd size – to 3.15 million heads of livestock – as contributing to the character of emerging conflicts**.[7]

In response, a government decree was drafted in April, 2018, relating to the effective creation, development and management of pastoral grazing areas sustainably. **With the increased pressure to such fragile ecosystems anticipated by increased drought events, local authorities have begun requiring permits for nomadic migration movements, currently using monthly generated CDI maps to support the coordination of such efforts**.

As drought events become more pronounced and competition for remaining resources increasingly prospect of intercommunal conflict, effective land and water management will require the increased consideration of both the preservation of nomadic grazing rights and ways of life in tandem with the protection of settled rural community livelihoods. Government intervention during drought includes upgrading or improving irrigation infrastructure, and also a range of livelihood creation programmes for drought-affected individuals. **Future analysis of drought management plans should consider the importance they place on maintaining social stability during major drought events**. Further quantification and qualification of the relationship between social stability and drought is crucial to understanding how drought is a causal factor in processes such as desertification and water scarcity that frame current rural outmigration patterns (Tangermann *et al*, 2016).

[7] See: https://gulfnews.com/world/mena/drought-sharpens-morocco-nomads-farmers-dispute-1.1558248480129

Recent legal reforms have attempted to address water allocation challenges among user groups; the past legal regime was outpaced by the spread of pumping infrastructure (Kooij, Swarteveen, & Kuper, 2015). As a result, **drought has aggravated social conflicts as water users and water user groups were required to interact directly with one another in the absence of legal codes to mediate their interactions**. Recent water legislative amendments have attempted to deal head-on with these allocation challenges amongst users. Modern irrigation practices like drip technology are usually associated with large agricultural production systems and private well water, but in some areas, such as the *Seguia Khrichfa* irrigation system in the northwest, they are used to distribute water from springs and canals (Ibid). In this case, t**he secondary and tertiary impacts of drought may not yet be fully known, particularly as they feed into local power dynamics and conflicts**. In the irrigation system used in this area, new technologies are outpacing legal and institutional mechanisms to support allocation (ibid). As such, drought has been seen to aggravate social conflict as water users and water user groups are required to interact directly with one another when there are no legal codes to mediate their interactions.

To date, there are no impact assessments monitoring drought impacts on agricultural and pastoral communities. However, increased water scarcity more generally impacts communities where poverty and ecosystem livelihood dependence are most prevalent. **As tension around accessing resources and limited agricultural jobs increase, public perceptions of economic migrants and marginalised communities can be expected to become less tolerant.**

3.3 Conclusion

A deeper understanding of indicators and impacts amongst ministry officials would facilitate coordinated action. More detailed, disaggregation of impacts upon such vulnerable groups can assist in ensuring policy instruments are more finely targeted on mitigating their marginal vulnerability and exposure to drought risks.

While labour force participation rates differentiated by sector, gender and age group exist, the monitoring of fluctuations in such rates as potential corollaries of drought events has yet to be conducted. As a consequence, **a paucity of data collection (disaggregated by stakeholder category) prevents comprehensive national or basin-wide assessments of drought impacts on labour force participation rates being made**. Such assessments would also require examining more nuanced impacts of drought events on the agricultural sector, and the subsequent and variegated impacts on working hours, farm labour casualisation and seasonality, wages differentials, and impacts on work-related costs such as transportation, food and water, childcare, and unpaid work ratios etc.

More nuanced assessments of drought impacts are also needed across different agro-climatic zones across Morocco, where basin-level water accounting can also be used to develop more targeted interventions and resilience-building strategies. **Conducting more granular vulnerability and impact assessments across key stakeholders in several regions across Morocco** will vastly improve local mitigating measures employed locally to adapt to the onset of droughts.

Pillar 3: Mitigation and Response Strategies

4 Water Accounting

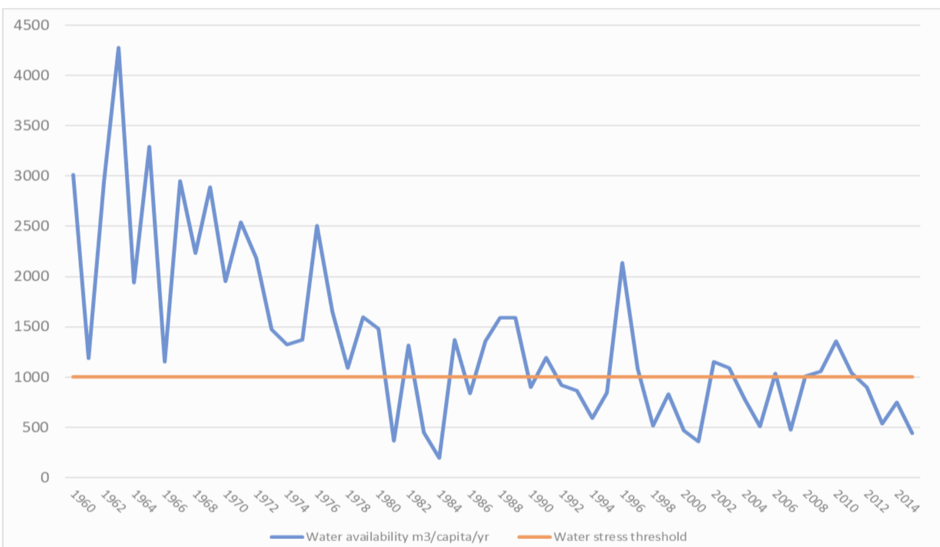
Comprehensive water accounting can play an important role in mitigating the depletion of increasingly scarce water resources during drought periods. Groundwater extractions can be estimated, verified and monitored using the water accounting reports, satellite data and field observations. Water accounting reports also provide insight into current water flows in the river basin and guide the discussion of potential water allocation changes. **Improved water accounting facilitates improvements in crop water productivity to translate into reductions in impacts of drought-related water scarcity, by better managing supply, demand and re-use in advance of and during droughts.**

Table 3 Morocco's water resources in MCM/yr (Source: Morocco's Statistical Yearbooks, HCP)

Hydrological year	2008	2009	2010 - 2011	2011 - 2012	2012 - 2013	2013 - 2014	2014 - 2015	2015 - 2016	Long-term annual reference
Precipitation	165,000	165,000	146,000	91,000	146,400	90,000	145,000	82,200	140,000
Evapotranspiration	No data	122,000	122,000	79,500	119,600	77,700	122,500	73,100	118,000
Total water resources	**41,000**	**43,000**	**24,000**	**11,500**	**26,800**	**12,300**	**22,500**	**10.400**	**22,000**
Underground water supply	4,000	No data	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Surface water supply	No data	38,500	20,000	7,500	22,800	8,300	18,500	18,000	18,000

The water resources available in Morocco face significant natural limitations. Current capacity to capture and mobilise water in the country limit available water supply to 22 billion cubic metres, of which 18 billion cubic meters are surface water and 4.3 billion cubic meters are groundwater (DRPE, 2014). **With steady demographic growth over the past decade to over 35 million inhabitants, and a long-term average availability of 22 bcm of water per year, water availability is just over 600m^3 per capita per year**, categorising Morocco as water stressed. Figure 8 shows net water availability (blue line) and the threshold of water stress per capita (constant red line indicating the threshold of 1,000 m3/capita/year). It highlights that Morocco has been in a situation of chronic water stress since the 1980's, with the water deficit increasing significantly during the past three decades. This estimated figure is derived from precipitation intensity and rates of evapotranspiration – both indicators of drought conditions (Table 3).

Figure 8 Estimated water availability per year per inhabitant (1960 -2016)



From 1980 to 2016, the volume of available water dropped below the stress threshold in twelve years of 27. In only 3 years between 1998 and 2016 did water availability exceed the stress threshold. **Rainfall inputs are characterised by a strong irregularity in both time and region**. Approximately 50 percent of these flows are concentrated in only 15 percent of the total area of the country, and 67 percent of surface water resources are stored in the hydraulic basins of *Loukkos*, *Sebou*, and *Oum El Rabia*. As such, **water availability and water stress are highly contingent upon precipitation, and thus impacted by drought.**

4.1 Surface water

All basins in Morocco are hydrologically characterised as experiencing high inter-annual and inter-regional variability, with years of severe drought and contrasting strong hydraulic flows. The regional disparity in precipitation volumes contributes to a significant variably in surface water flows, with annual flows varying from of just a few million cubic metres in the Saharan basins, to more than a billion cubic metres in the more rainfall abundant regions.

The variation in precipitation is also contrasted with a variation in population density and sectoral demand. The *Sebou* basin, for instance, covers 6 percent of Morocco's landmass and hosts 18 percent of the country's population, yet holds almost a third of the country's surface and ground water resources (UN, 2014). **Particularly following droughts, such disparities have led the country to increasingly rely on costly inter-basin water reallocations**. For instance, some 300,000m^3 are transferred annually from the *Oum El Rabia* basin to support irrigation in Tensift as a result of more frequent drought periods. Transfers are also made from *Sebou* and *Oum El Rabia* to provide municipal water supplies for Bouregreg. Some 120 significant natural lakes exists, mostly between the Middle and High Atlas mountain ranges. Coastal lagoons and marshes are an important recipient of environmental flows, playing a vital role in maintaining a unique biodiversity over more than 270,000 hectares of wetland across 24 sites.[8]

[8] FAO AQUASTAT, 2015. Morocco.

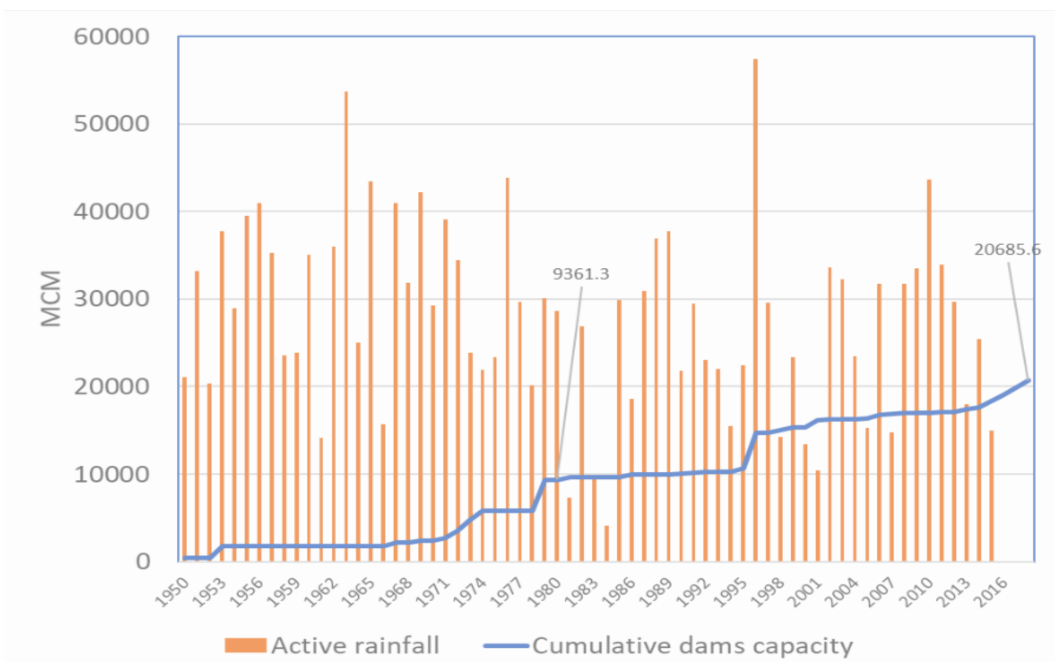
Table 4 Morocco's hydrological basins' characteristics (Source: National Water Strategy)

Name of basin	Area (km2)	Flow (MCM)	Exploitable potential (MCM/year)
Loukkos, Tangier & Mediterranean coastal	12,805	3,600	190
Moulouya, Figuig-Kert-Isley-Kiss	76,664	1,610	512
Sebou	40,000	5,560	1300
Bouregreg and Chaouia	20,470	850	120
Oum er-Rbia & el-Jadida Safi	48,070	3,315	405
Tensift & Ksob-Igouzoulen	24,800	800	520
Souss-Massa-Draa	126,480	1,444	691
Guir-Ziz-Rhéris	58,841	626	313
Sakia el-Hamra & Oued Eddahab	302,725	390	16
Total	**710,855**	**18,195**	**4,067**

Table 4 lists the nine different river basins in the country, together with area, flow data and exploitable potential.

In terms of the water capture infrastructure, **Morocco has over 140 large dams. As of 2018, the total retention capacity reached over 20 billion m³** (Figure 9). There are several thousand wells for abstracting groundwater. This infrastructure has made it possible to support irrigation across an area of nearly 1.5 million hectares, the supply of drinking water to almost most of the population, both urban and rural, the satisfaction of industrial and tourist water needs, and the generation of around 10 percent of electricity consumed.

Figure 9 Annual active rainfall and cumulative capacity of dams



Despite the country's heavy reliance on rainfed agriculture, water for irrigation is by far the largest consumer of water across Morocco. **Water managers are often challenged by inadequate data – on both optimal irrigation requirements by crop type, and on water availability**. This results in challenges in allocating resources across sectors. In the *Oum El Rabia* basin for instance, the local ABH managing the *Bin El Oudiene* reservoir relies on crude water level data to inform allocation for irrigation, industry and municipal supplies. From 2020, the basin will supply municipal water to Marrakesh, in addition to Casablanca, regional industry, and the large agricultural community in the region. **More accurate water accounting could both significantly improve the efficiency and sequencing of allocations and allow for the timely distribution of information and training to local water users around more effective water management during drought periods**. There is also a need to ensure that allocations of resources from reservoirs anticipate reductions in supply for following irrigation periods during drought periods. If reservoir levels are deemed adequate during a drought period, allocative volumes and water saving measures may not take effect, despite the strong likelihood of water levels dropping significantly for the following year. As such, **real-time drought monitoring, seasonal forecasting and effective water accounting can greatly improve drought mitigation measures.** This can support, for instance, timely supplementary irrigation to reduce the short-term effects of drought on rainfed agriculture, even if irrigated agriculture remains more insulated from the sudden onset of drought.

4.2 Ground water

Understanding the relationship between groundwater supplies and droughts in central to the effective management of drought and the sustainable exploitation of local water resources. Drought conditions directly impact groundwater supplies by reducing aquifer recharge rates, and indirectly by increasing reliance on groundwater sources, particularly for irrigation. Subsequently, declining groundwater levels result in higher drilling and pumping costs for groundwater users across all sectors. In addition to the amount of renewable water, **the storage of groundwater represents a resource of strategic importance in managing future droughts**.

Available assessments of the potential renewable groundwater in Morocco indicate a volume on the order of 10 billion m3 per year, nearly 33% of the total water potential of the country. This potential is distributed between public sector wells (ONEE; National Office of Electricity and water) and private sector wells used by farmers and industrial users.

Of the 126 aquifers of known regional or local importance, nearly half are deep aquifers (

Table 5). **Overexploitation of groundwater is observed in almost all the identified groundwater bodies**: *Souss-Massa, Haouz, Bahira*, the Rabat-Safi coastal zone, *Saïss, Triffa, Jbel Hamra* and the groundwater in the basins of the South of the Country. The piezometric drops are almost ubiquitous and reach alarming rates that sometimes exceed 2 metres per year. This widespread and continuous decline has resulted in a sharp decrease in water supplies, the drying up of springs, *khettaras* and a significant degradation of the quality of the water by sea intrusion. Potential available groundwater resources are estimated at 4 to 4.3 BCM.

Table 5 Potential for groundwater resources

Basin	Number of identified aquifers		Exploitable water potential (MCM/yr)
	Superficial	Deep	
Loukkos, Tangérois & Costal Méditerranéens	12	3	226
Moulouya	10	30	779
Sebou	3	3	453
Oum Er Rbia	4	4	326
Bou Regreg	2	1	126
Tensift	11	3	458
Souss- Massa	1	1	240
Atlasic South	21	15	762
Sahara	1	1	16
Diffused flow	-	-	614
TOTAL	65	61	4.000

4.3 Rain water

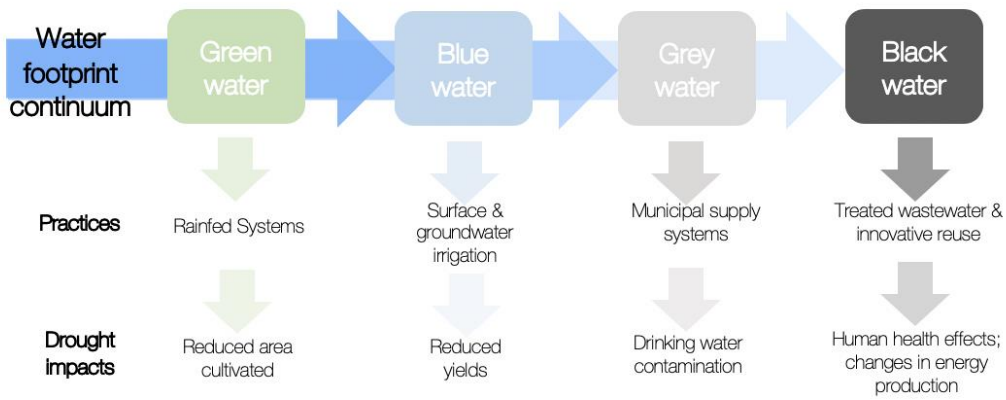
Green water from rainfall is stored in the soil profile and contributes to surface water supplies and the recharge of aquifers, lakes and dams. Measuring quantities of available water and the amounts consumed help understand blue water availability, with the remaining amounts playing an important role in maintaining environmental flows and ecosystems (Hoekstra et al 2011). A significant influx into the surface water system comes in the form of flash floods, usually over a period of a month in the southern basins, and over two to three months for basins in the North and *Moulouya*. As discussed above, of the 140 billion m3 of rain water that Morocco receives, it is estimated that it is able to mobilise a maximum of 22 billion m3, including 18 MCM surface water and 4 MCM of groundwater. However, as Table 3 highlights, several dry years result in contributions far below this average, particularly across the most disadvantaged basins, such as the Saharan basins (30 MCM), the Souss-Massa (700 MCM), and the Ziz, Rhéris and Maïder (390 MCM). Due to Morocco's heavy reliance on precipitation, local capacity to effectively harvest rainwater and increase the productivity of rainfed agriculture exposes the country to impacts of drought. **More effective monitoring and data collection around precipitation and the dynamics of aquifer recharge are necessary to effectively characterise drought impacts on water availability**.

4.4 Water Treatment

The impacts of drought on grey and black water for reuse and treatment are most significantly borne by municipal water supplies and the tourism and health sectors. As Groundwater drawdown and drought lead to water quality degradation, which can increase the prevalence of waterborne diseases as water supply and sanitation systems fall under strain. The public health impacts resulting from drought-related water quality and quantity decline (discussed above) represent an urgent priority for improving water and sanitation infrastructure.

Greywater can be reused for a variety of purposes (Hoekstra et al. 2011). With proper supply systems, it can be delivered for irrigation at varying scales: untreated for household garden plots (Allen, 2017) and reused when it is treated by municipalities. In addition to increasing supply, utilising greywater also reduces the strain that is placed on municipal wastewater treatment plants. Black water (water that has come into contact with sewage) must undergo more costly wastewater treatment before being returned to the hydrological cycle. Figure 10 places these **water types with their supply systems and common uses, and the potential impacts during drought years**.

Figure 10 Water supply systems, use classes, & drought impacts across the continuum from rainwater to wastewater



5 Drought Resilience and Technology

Innovation around **desalination and wastewater reuse** would reduce freshwater demand, **soil conservation practices** that enhance moisture retention and reduce erosion, **training on irrigation at key growth stages of different crops**. Alternative water sources such as **rainwater harvesting** also alleviate the strain on supplies of related equipment.

5.1 Supply: Non-conventional facilities in operation/planned/under construction

Supply-side measures – such as treated wastewater re-use, desalination, and groundwater abstraction – all offer buffers against reduced spring discharges and surface water inflows that result from drought, as well as its attendant effects on water quality. Morocco is currently continuing the expansion of its capacity to mobilise non-conventional water supplies to alleviate deficit and mitigate drought events. However, over-abstraction and increasing use of fossil water does not provide a sustainable solution to such reductions. As with many countries in the region, **current groundwater abstraction practices are eroding long-term water security and resilience to drought**.

The National Water Strategy (SNE) put in place measures for artificial recharge of groundwater by 2030 of about 280 million cubic metres per year, about one-third of which is from treated wastewater. The desalination of seawater is a solution for the supply of drinking water to southern water-scarce provinces. The volume of seawater currently desalinated is 300,000 cubic metres per day, or 109.5 million cubic meters per year. The SNE anticipates the expansion of seawater desalination by 2030 to nearly 400 million cubic meters per year. This is to be pursued by developing short- and long-term units in Laayoune, Agadir, Tiznit, Sidi Ifni, Chtouka, Essaouira, Safi, El Jadida, Casablanca, Al Hoceima and Saidia. The National Water Plan currently being finalised by the Department of Water aims to reduce the projected increase in the water deficit (expected to be around 3 to 5 billion cubic metres by 2030) to ensure per capita water availability does not fall below 700m^3 each year, despite population growth.

5.1.1 Desalination

Seawater desalination features centrally as a strategy to both mitigate climatic and demographic shifts over the long term and insulate against the effects of sudden drought events. As a part of the National Water Plan, the Moroccan government plans to produce nearly 515 million cubic metres each year by 2030 (Houzir et al, 2016). As of 2016, 15 desalination installations were operational across the Kingdom with a total capacity of 132 million cubic metres per year. The majority of the plants operate by reverse osmosis (RO). Importing nearly 95 percent of its energy, RO remains the most effective plant type being less energy intensive relative to other desalination technologies. As renewable energy sources become prevalent and more economically competitive for operating large-scale production plants, future projects are likely to include other desalination technologies and energy mixes. The desalination plant under construction in Agadir is estimated to be delivered at a total cost of US$112 million, using RO technology to produce 36 million cubic metres per year, providing the drinking and irrigation needs of almost a million people (~120 litres/capita/day). Two other desalination plants under construction in Jorf Lasfar – el Jadida and Safi will have a combined capacity of 100 million cubic metres per year for municipal and industrial supply when coming online in 2025. **Such supply-side measures demonstrate significant commitments to mitigating drought, particularly for municipal water supply**.

5.1.2 Treated wastewater

Significant advances have been made in the wastewater sector over recent decades to improve the volumes of wastewater and treatment. The production of wastewater increased more than 15 times between 1960 and 2012, from 48 to 750 million m^3 per year. However, treatment infrastructure has not grown comparably. About 90 percent of urban liquid discharges return to the sea or fluvial natural environment. In rural areas, liquid discharges are rather diffuse. **Morocco has a significant deficit in sewerage infrastructure, which has affected the overall quality of surface and groundwater**.

The treatment rate in Morocco has increased significantly, from 6 percent in 2005 to about 34 percent in 2013. The development of sewage treatment methods has had a direct positive impact on the recorded pollution abatement rate. In fact, in treatment plants managed by the ONEE, the rate increased from 5 percent in 2003 to almost 51 percent in 2012. **The improvement in the rate of pollution abatement in treated wastewater has encouraged its reuse, particularly in irrigation of agricultural areas and golf courses**. The number of functional wastewater treatment plants has increased from just 2 in 2003 to 45 by 2011. The treatment process has also improved during this period, with more than 20 percent of treated wastewater having received tertiary treatment across 30 treatment plants.

By 2020, the National Sanitation Programme (devised in 2005 and revised in 2008) has targets to reduce pollution by 60 percent by ensuring 80 percent of urban populations are connected to sanitation networks. Another 50 treatment plants are being built to serve 52 urban centres and cities, benefiting a population of about 3 million. The volume of wastewater to be treated is expected to reach 111 million m^3 per year, or 15 percent of the volume of wastewater produced in 2012. Also, 15 wastewater treatment plants will be equipped with tertiary treatment devices, allowing purification of almost 10 percent of the total volume of treated water.

Drought-related limitations in surface water availability (discussed above) has resulted in overexploitation of groundwater resources. In total more than 120 wastewater treatment plants have been built, with a total treatment capacity of nearly 1 billion cubic metres per year. The PNE has also set clear targets for wastewater reuse of 325 million cubic metres by 2030 (Houzir et al, 2016). Currently, wastewater reuse remains low, with 60 percent discharged directly into the Atlantic and Mediterranean and 40 percent to the natural environment (NEA, 2018).

Table 6 Wastewater reuse projects by basin for 2030 (Source: Netherlands Enterprise Agency)

River Basin	Irrigation	Industries	Landscaping / golf courses	Groundwater recharge	Total
Loukkos	20	-	7	-	27
Moulouya	12	-	9	-	21
Sebou	34	-	15	10	59
Bouregreg	19	-	1	-	20
Oum ErRabia	15	16	4	-	35
Tensift	1	1	56	-	58
Souss Massa	38	-	40	10	88
Sud Atlas	3	-	1	-	4
Total	**142**	**17**	**133**	**10**	**312**

Table 6 above shows the number of wastewater reuse projects planned for each basin. Currently, **18 wastewater reuse projects operate across the country providing treated water totalling 38 million cubic metres per year**. 70 percent is used for the irrigation of parks, golf courses and green spaces, 13 percent is used for agriculture, 17 percent for industry (particularly phosphate mining) and around one percent for groundwater aquifer recharge (NEA, 2018). Despite these advances, large disparities exist across different regions and across watersheds. **The continued expansion of the wastewater treatment capacity of the country, and the improved mobilisation of treated wastewater for reuse across different sectors represents a solid advancement in Morocco's efforts to mitigate future droughts**.

5.2 Demand: crop varieties, strategies, technologies used by various water stakeholders

Agricultural water demand management can continue to be improved through increased water use efficiency. The current gap between water supply and demand (estimated at 2 billion m^3) is largely offset by the overexploitation of groundwater (estimated at 860 million m^3 beyond the renewable volume of 3,400 million m^3). This situation is likely to worsen in the future as a result of climate change and increasing demographic and economic pressures. Small farmers who cannot afford to deepen their wells and upgrade their pumping equipment will be the first to be affected by the degradation of water resources. Previous pilot projects developed using participatory approaches for groundwater management have highlighted the need for full involvement of local authorities (Ministry of the Interior) and decentralised services of the Ministry of Agriculture to ensure the buy-in of the users. This type of process supports government actions to strengthen participatory groundwater management through well-designed, effective and mutually agreed agreements. When properly managed, **such efforts can significantly improve the management of water resources by local water users, and reduce the impacts of drought on shard infrastructure, or around supplementary irrigation scheduling and crop selection**.

5.2.1 Technology and irrigation practices

Drip irrigation is a common method employed to reduce local water demand and improve basin-wide water availability. It offers a key policy tool employed as part of drought mitigation strategies and plans. **There are, however, drawbacks that can either prevent uptake or limit the efficacy of the measures**. For instance, the high costs and new methods necessary for converting an existing farming operation to drip irrigation can represent unsurmountable barriers to entry, particularly for poorer or smallholder farmers.

Other farm operations may not reduce total water used, but instead use the local water savings to expand cultivated areas. Also, drip irrigation can have other impacts such as reducing groundwater aquifer recharge. As such, **for supporting the shift to drip irrigation and the modernisation of irrigation methods to be an effective mitigating strategy requires it embedded in broader institutional efforts** to support financing, training and improved monitoring and crop type selection. **Morocco has made significant strides in both promoting technology packages and committing support to the institutional and financial prerequisites of such transitions**.

The low efficiency of water use is manifested in poorly performing irrigation systems and drinking water systems that have significant losses of water volumes. Efforts are being made to achieve water savings in irrigation by promoting the adoption of localised irrigation systems as well as improving drinking water distribution networks and billing processes. Law No. 36-15 stipulates that no agricultural project can be approved if could result in the degradation of water resources or cultivated soils.

In 2007, **the MoA estimated that the conversion of flooding-fed irrigation to localised irrigation involved a minimum of 141,570 ha, or 9.7 percent of the total managed area** .A Large Irrigation Improvement Programme (PAGI) was launched with the objectives of improving the hydraulic performance of irrigation systems, crop productivity, and the operational efficiency of the Regional Offices for Agricultural Development (ORMVA). The Green Morocco Plan (PMV) considers that water stress is the main limiting factor for improving agricultural productivity. As part of the PMV, a National Programme for the Economy of Irrigation Waters (PNEEI) was initiated. This programme aims to save water, reduce the vulnerability of irrigated agriculture to climate change, and realise an increase in water productivity. It focuses on the conversion to micro-irrigation of approximately 555,000 ha of land by 2015.

Micro-irrigation has been encouraged through subsidies for irrigation equipment and management systems. flooding-based irrigation techniques tend to be replaced by localised irrigation. The introduction of drip irrigation technology in Morocco was originally a private initiative. Prior to 1996, the first grants only covered certain elements of the facilities or support for the import of equipment. Since then, subsidy rates have steadily increased: from 10-30 percent of the cost of installation in 1996, they rose to 30-40 percent in 2002, were raised to 60 percent in 2006, then to 80-100 percent in 2010. **Today, subsidies to irrigation schemes represent the bulk of the financial support provided to the agricultural sector**. Since

2007, state subsidies for water management and irrigation equipment represent almost 60 percent of the total sum allocated to agricultural grants (Finance Act, 2017). At the same time, **conditions of access to the grant have been greatly simplified to facilitate access and uptake**. The grant is conditional on the design and implementation of the project by approved companies, allowing farmers to benefit from expertise in the design of the drip project and access to approved equipment of good standards. **Supporting water saving technological improvements with improved technological standards, improved access to financing, subsidies and training represents a significant effort to improve the overall drought-preparedness**, particularly in the agricultural sector.

5.2.2 Rainwater harvesting

The largest proportion of water usage in the Middle Draa valley, is agricultural irrigation (Johannsen et al., 2016). Water stress in this region will increase under future climatological conditions and demands as population and irrigated area expand. Simulated water demand models show that under various scenarios, the Mansour Eddahbi reservoir will rarely be filled to capacity despite decreasing storage volume over time due to sedimentation (Ibid). More dramatically, WEAP modelling indicates that within 20 years the aquifers in the basin will be empty regardless of the water management scenario used. Intervening variables such as increased irrigation efficiency and reduced irrigation area could make a difference on the supply-demand imbalance, but this is dependent on farmer uptake of new practices (Johannsen et al., 2016) **such as green water management utilisng water harvesting techniques used in hillside cultivation like stone lines, bench terraces, and contour tillage procedures** (Droogers et al. 2011). **These practices direct rainfall distribution and infiltration on sloped agricultural lands and reduce demand on surface and groundwater sources**.

5.2.3 Crop-type choice and farming practices

Although in-depth comparative studies are not yet available, anecdotal evidence indicates that **agricultural livelihoods in more peripheral rural areas, such as oases, are both more susceptible to drought events, and that women in these areas are more likely to be disproportionately affected**. The UNDP's Tafilalet Oases Sustainable Land Development Programme represents a potent example of an integrated drought mitigation project. With aims of conserving the fragile ecosystems of the oases, combatting desertification, improving rural livelihoods for women and mitigating climate-related water scarcity through the introduction of high economic yield, low water requirement medicinal and aromatic crops, such as saffron.[9] **Using different the irrigation and cultivation technologies outlined above can significantly improve these typical water requirement when coupled with improved producer practice**.

6 Drought Insurance

Crop and livestock drought insurance schemes, and other innovative financial mechanisms provide important tools for managing drought risk. Drought is the main climatic factor causing crop failure in most instances. Frost, hail or flood have negligible effect on the country's crops. Even drought does not seem to be a danger of permanent nature. Nonetheless, **drought insurance, and risk and crisis funds have a significant role to play – when adequately developed – in mitigating drought risks**.

Financial mechanisms such as national drought contingency funds or livestock and crop insurance offer effective ways of engaging the private sector in partnerships to mitigate the risks and impacts associated with droughts. **Since 1993, the Moroccan government has been developing an effective system for guaranteeing cereal production against drought, in order to reduce the vulnerability of agriculture to droughts risks and rehabilitate the domestic cereal market**. By guaranteeing the recovery of Crédit Agricole du Maroc (CAM) loans and better allocate (and ultimately reduce) state support for disaster relief, the cereal production guarantee programme has helped motivate farmers to invest despite anticipated drought risks.

The programme is managed by the Ministry of Agriculture and Maritime Fisheries in collaboration with the Ministry of Economy and Finance and CAM. It is insured, on behalf of the State, by the Moroccan Agricultural Mutual Insurance Company (MAMDA). In collaboration with the Ministry of Economy and Finance, CNRA and MAMDA the MAPM has highlighted a pilot programme to guarantee cereal production against drought risk. Based on a study carried out by the English studies office, "Agricultural Risk Management Limited", specialising in drought risk, a test programme was launched during the 1994-1995 campaign across 22 rural municipalities in favourable rainfed areas, covering an area of 94,000 hectares.

9 See: https://www.undp.org/content/undp/en/home/ourwork/ourstories/maroc---les-plantes-medicinales-pour-valoriser-les-femmes-et-sau.html

3 rural communes located in three different climate zones were selected in order to analyse the behaviour of farms in relation to the insurance modalities proposed to cope with drought-related risks. **Today, insurance covers 1 million hectares of cereals and fruit trees**.

7 Drought Management

Within the IDMP context, **drought policy refers to the overarching set of goals, values, and measures that a country endorses when preparing for and responding to drought conditions**. This includes any drought-related legislation and/or drought plans put in place at an institutional level. A national drought policy should establish a clear set of principles or operating guidelines to govern the management of drought and its impacts.

Drought management, then, refers to the specific actions taken during a drought, or proactively before a drought occurs, to reduce drought impacts or prevent them from occurring. The intent in both the policy and management settings is to facilitate the implementation of actions in advance of drought that increase resilience, and to ensure drought responses during a drought event are coordinated, timely, and targeted towards specific impacts that are taking place to reduce hardships on both humans and the environment. The overriding principle in both concepts is an emphasis on risk management through the development and implementation of preparedness and mitigation measures.

Since the mid-2000's, Morocco has focussed on moving towards a pro-active drought risk management framework. The introduction of North Africa's first drought insurance scheme (discussed above) can be considered as a significant and committed step in that effort. Since the 1980s, **the government of Morocco has implemented programmes designed to reduce drought impacts for small livestock farmers**. These state interventions include provision of feed subsidies, veterinary care, and water tanks (Hayes & Svoboda, 2008). The modern framework for drought management includes both pro-active drought risk management and reactive mitigation components and dates from the 1995 Water Law.

7.1 Drought management systems

The Moroccan government's drought management strategy has both pro-active mitigating components, and reactive crisis management components. Long-term measures for drought risk management are integrated with the Green Morocco Plan, National Water Strategy, and the National

Water Plan, which outline methods for achieving greater long-term sustainability of agricultural practices – from the uptake of conservation and farming practices, to the security of short-term supply systems. **Planned investment under the Green Morocco Plan incorporates numerous water efficiency programmes** including:

- The large-scale conversion of marginal cereals production land to olive cultivation;
- Subsidised introduction of drip irrigation systems; and
- The introduction of soil conservation techniques.

Implementation efforts have included conversion from channel irrigation to drip systems, dam-building operations to facilitate transfers of water from the North to the South, and additional PPI governance units. **The National Water Strategy and Plan primarily emphasise supply-side solutions**, including the construction of multiple large storage dams, new desalination and waste-water treatment and re-use capacity (discussed above), and water transfer infrastructure including a planned 450km North to South pipeline intended to reduce pressure on the Rabat, Marrakesh and Casablanca basin. **Demand-focused measures** include water metering, water charges, developing allocation decision-making frameworks, and urban education campaigns (Khatri & Hairech, 2014; Baibouan, 2017).

The new Water Law 36-15 focusses heavily on **sustainable groundwater resource management and participatory management mechanisms,** including clarifying the concept of the public water domain. Under Law 36-15, each basin has its own drought management plan. The law inscribes the principle of sustainable groundwater abstraction and strengthens the existing legal framework of water management institutions:

- It **improves the legal standing of ABH governance structures** and includes the elaboration of more effective consultation and participatory processes in water resource management, especially through the creation of eight river basin committees;
- It provides improved planning mechanisms by **linking the National Water Plan, regional Master Plans** and promoting integrated development of water resources at the basin level;
- It also provides clarity around **non-conventional water resources and re-use of wastewater in agriculture** (World Bank, 2016).

In sum, **drought management in Morocco has been planned primarily at the national, but in recent years has move toward governing at the basin level**. Each ministerial directorate has its own action plan that includes drought management components to be implemented at the regional and local levels. Also, **ABHs**

have a legal remit to lead water management within their territory during droughts, and the Green Morocco Plan includes integrated sectoral strategies to deal with drought.

7.2 Drought adaptation policy

In 1995, the Kingdom adopted a **National Strategy for the Protection of the Environment and Sustainable Development**. The state has also drawn up a **Sustainable Territorial Planning and Development Strategy for the Middle Atlas** (2001), which has led to the introduction of three pilot basins for urgent intervention in sustainable development in Moulouya Valley; the Middle Eastern Atlas; and Taza.

In 2002, the **2030 National Action Plan for the Environment** (PANE), defined priorities for sustainable resources management, risk prevention, the improvement of the environment and communication, as well as actions and resulting financial measures. This plan also stipulated the creation of a series of national action plans, including:

- A **national committee for the implementation and monitoring environmental programmes**.
- A national action plan to **combat desertification**;
- A national action plan for **biodiversity conservation**,
- A series of **watershed management** plans; and
- A national **reforestation** master plan.

Morocco has developed an **Oasis Management and Development Strategy** (2004), which has made it possible to identify options and recommendations for sustainable territorial development in oasis areas. This strategy led to the establishment of territorial development programmes for oasis areas, among others the *Tafilalet* Oasis Programmes (POT) in 2006 and the *Drâa Moyen* program (2010). **All such plans provide the institutional mandates and organisation to both combat the short-term impacts of droughts and mitigate again the longer-term threats caused by the increased frequency of droughts**.

In 2010, the national debate on the development of the **National Strategy for the Environment and Sustainable Development (CNEDD**) was held, resulting in the approval of a law in 2014. In order to make recommendations for concrete actions, the Department of the Environment (delegate Ministry for the Ministry of Energy, Mines, Water and Environment, responsible for Environment) has developed a new "Incentive to Action" strategy, the main objective of which is to speed up the implementation of actions for environmental management. The main focus of this strategy revolves around monitoring the state of the environment, protecting natural resources and ecosystems, improving the living environment of the population, and the systematic integration of the environmental considerations in all development programmes, contractual accountability of local actors, environmental performance of industries, and strengthening environmental management legal, regulatory and institutional frameworks.

The **Sendai Framework for Disaster Risk Reduction 2015-2030** was adopted by the UN on 2015. This framework led to country-level programmes and a contract between the OECD and the Kingdom of Morocco. In a recent report from the process, drought is placed amongst other natural disasters including flooding, earthquakes and tsunamis. Drought is identified as causing major losses of agricultural GDP and severely affects rural populations who are forced to migrate to larger cities following these losses (Baubion et al., 2017). The **OECD recommended that drought be placed within a general risk policy framework, so that it can be placed on par with other natural disasters that have immediate recognition of being costly and difficult to recover from**.

7.3 Drought interventions

Drought interventions are controlled by pre-developed legal guidelines and strategies that clearly state actions to take under specific conditions and whether they require official drought declarations. However, the **political difficulty of drought declaration, lack of information sharing before the drought hits crisis stage, and poor coordination of efforts at the beginning stages of the drought response impair the implementation of existing drought management efforts**.

Drought management could be characterised as two-tiered, since agencies may begin certain interventions prior to official drought declaration by the Minister of the Interior. The apparent difference in the two approaches is largely **operational and financial support**. Without drought declaration ministries must utilise existing budgets, whereas in the case of national drought declaration there is a separate budget from the central government and further mechanisms of cooperation and coordination that are triggered. **Marginal semi-desert and desert areas do not receive extensive agricultural support during droughts due to their inherent vulnerability**.

Official drought declarations in Morocco, as elsewhere, remain highly politicised, not least owing to the significant financial ramifications they entail. The ultimate decision-making criteria are not fixed but consist of a mix of physical, social and political factors with a strong emphasis on ground-level surveys of impacted areas and assessment of regional history of drought impacts and vulnerability. The committee that declares drought and the impacted zones eligible for particular interventions includes the Ministries of Interior, Finance, Agriculture and Water. Last year, CRTS was asked to provide its drought map, and the committee also requests DMN to provide observational data and forecasts. This year, **the MoA has used the CDI drought maps currently produced monthly to inform decision-making processes around permitting and transhumance. The CDI maps are now published on a government website, significantly improving awareness and access to monthly information**. In the case of an officially-declared drought, government interventions are pre-developed and have changed in recent years to include climate risk insurance and also the coordinating role of the ABHs.

7.3.1 Livestock interventions

Livestock programmes are the primary focus of agricultural agencies during drought emergencies, with the vast majority of interventions requiring official drought declaration. This is primarily because insurance products for livestock cannot incorporate climate risks, livestock farmers are highly vulnerable from a socio-economic standpoint, and smallholders are at great risk during drought events. Livestock safeguard programmes include multiple elements in drought-declared areas. **Subsidised feed is provided through commercial feed-in subsidies in larger markets and direct provision in rural areas**. In 2016, feed was subsidised nearly 50% in certain areas. **Farmers are allowed to purchase set amounts at subsidised prices** depending on registered herd size. Both livestock registration and feed allocation can be a source of tensions, as it is often reliant on self-provided evidence and requires tight supervision to prevent distortions, profiteering and corruption.

Government agencies also provide water directly or drill wells for livestock and work to improve sanitary conditions. **Vaccination programmes** are also accelerated, and agencies increase monitoring of animal diseases to prevent and control outbreaks more likely to occur during droughts.

7.3.2 Crop interventions

In rainfed areas, the primary interventions depend on the seasonality of drought onset. When extreme droughts occur in autumn, **government agencies provide subsidies, extension services and preferential loans for farmers to plant spring crops**, especially sunflower and corn, starting in January. In the case of winter and spring drought, **climate risk insurance pay-outs may be administered to rainfed wheat and barley farmers in drought-zoned areas**.

In public irrigation areas (PPI), irrigation water allocation changes during droughts, whether declared or unofficial. The hierarchy of allocation gives preference to arboriculture so as to ensure tree survival; then for seed production systems and alfalfa; followed by industrial crops such as sugarcane and sugar beets. PPI authorities may also augment groundwater pumping, and departmental authorities may speed up the processing of well license applications outside of PPIs.

7.3.3 Financial interventions

Multi-risk climate insurance was first introduced in 2011 to replace a national guarantee fund that covered approximately 65,000 hectares; insurance now covers approximately 1.1 million hectares of rainfed lands. **Government subsidies cover 55-90 percent of insurance premium costs depending on the size of farmers' holdings, with smaller holdings provided higher subsidies**. In addition to drought insurance, government financial interventions support credit systems and work-creation programmes.

Most of the official agricultural credit is provided through the state-owned CAM bank, with 'non-bankable' clients utilising its subsidiary, *Tamweel*. *Tamweel* has a stability fund 50 percent of which is funded by CAM-funding and 50 percent by the government as a risk alleviation facility for smallholders. ***Tamweel* and micro-credit banks work closely with the state agricultural development fund that provides improved seeds and other subsidised materials to improve agricultural production systems**. They are the major financial entities accessed by smallholders. They hold very high repayment rates for their loan classes (approximately 95 percent), which has garnered regional attention as a potential model for other drought-affected countries.

During drought periods, these fin**ancial entities typically provide a special loan class for reconversion from fall wheat and barley to spring crops, and also provide credit to existing loan-holders and delay repayment condition**s. In addition, work creation programmes focus on replacing lost incomes while increasing long-term resilience. This can entail the creation and repair of water storage and irrigation infrastructure and represent a targeted and effective drought response strategy.

7.3.4 Water management interventions

In accordance with Water Law No 36-15, **basin plans and sectoral strategies govern water management interventions.** DRPE described these as following a three-tiered alert system with specific indicators for each city and basin. Interventions are specified according to the indicators and the particular area's exposure to risk, vulnerability to impacts and resilience. **Water allocation prioritises municipal supply, irrigation and then hydropower production**. Municipal water suppliers primarily focus on leakage and non-revenue water improvements and demand management during drought periods, with increased groundwater exploitation to cover surface water supply and demand gaps.

At the individual farm level, there is also variation in water management responses. **Moroccan farmers have various ways to cope depending on their farming type, income and land-ownership status**. Wealthier families are able to rely on stored grains, sell their sheep and goats, and receive subsidies from the state. Poorer farmers borrow money beyond the farm operation, are incentivised to sell large animals such as cattle, and may choose to lease their lands (Achy, 2012). **Frequently, these strategies are costly in the long run as they both increase the costs of restarting cultivation and can often struggle to recover from debt** – particularly if extended drought periods are experienced.

7.4 Management Needs

Reactive drought mitigation measures present a major cost burden. During the 1999 drought, public expenditure reached 3.18 billion dirham (~$318 million), of which 332 million dirham went to the drinking water component, 300 million dirham for livestock programs, 1.91 billion dirhams for job-creation in rural areas, and the rest covered agricultural credit sub-programmes (Ouassou, 2005). In 2016, the Moroccan government announced a planned public intervention package totalling approximately US$500 million (USDA, 2016). **Many planned interventions, however, were abandoned following late spring rains** (USDA-FAS, 2016).

Drought management needs, as understood my institutional stakeholders, revolve around institutional relationships and policy. While current technical capacity is largely adequate, institutions are not always able to access and use information effectively because of institutional and policy barriers. Drought management needs include several key themes:

- Clear and pre-determined **institutional roles** and coordination mechanisms;
- Tiered **intervention** and ease of declaration;
- Managing **overexploitation of groundwater;**
- Balancing **ABH capacity** across the country;
- **Connecting with other long-term projects;**
- Understanding changing **irrigation needs;**
- **Soil conservation.**

7.4.1 Clear and pre-determined institutional roles and coordination mechanisms

The lack of a regulatory text stipulating the role of specific government agencies in drought management precludes effective coordination. While agencies have overall remits in drought management, **there is not an operational framework to structure collaboration**, and no one agency is in charge of overall drought management and coordination. As a result, drought management planning does not begin until the crisis has arrived, and aside from knowing what interventions will be made, the coordination starts from a basis of weak information and leadership. **Ineffective information sharing, agency "territoriality" and weak coordination are core barriers to effective drought management**. Core drought monitoring agencies are not directly involved in decisions around drought declaration, and the separation of roles slows responses to drought, increasing the cost of mitigation efforts.

7.4.2 Tiered intervention and ease of declaration

Tiered drought declaration or sector-specific drought declarations depending on drought severity are also an area for potential improvement in current plans. Specific interventions require an official drought declaration, which often comes after drought impacts have begun to accumulate. **Having drought declarations tied to technical indicators and 'triggers' could greatly facilitate drought management for these reasons and improve coordination efforts**.

7.4.3 Assessing groundwater levels

Increased groundwater abstraction is the main drought mitigation tactic across large swathes of the country. However, **long-term resilience is undermined as aquifers are depleted or water quality degrades with unsustainable use**. In southern Morocco, especially in the *Souss Messa* Basin, the overexploitation of groundwater has become a critical growth limitation. **Integrating meteorological and groundwater recharge models – possibly through the development of a 'hydro-CDI' could improve long-**

term management efforts, and local understanding of drought impacts on groundwater aquifer recharge.

7.4.4 Addressing uneven ABH capacity

ABHs are taking increasingly prominent roles in drought management and the arbitration of competing sectoral water uses. Their role in water and drought management has expanded greatly under the new water law. However, some still lack the technical resources and staff to use all available information and the ability to gather all stakeholders effectively.

7.4.5 Connecting with other long-term projects

Several climate and development projects exist that could provide natural partnerships with the drought management system. Feasible mitigation efforts will build on existing work and projects. If the DMS is built with the understanding that there is a range of previous work encompassing drought monitoring and management, it will be more successful. Two examples include the following:

- The Adaptation of African Agriculture Initiative follows from the COP meetings in Morocco in 2016, aiming to encourage equitable adaptation and mitigation in response to climate change while strengthening agricultural capacity;
- The CGMS project has brought together three separate agencies for data integration quite successfully. Building on this momentum to pair agricultural, statistical, and meteorological information would be a major success for the DMS.

7.4.6 Understanding changing irrigation needs

Greater information of current crop types, irrigation needs, and agricultural markets could be used in conjunction with drought forecasting, real-time monitoring and early warning systems to assist water managers in the timely planning for water prioritisation during drought. Understanding which regions and seasons are likely to be affected, together with impacts on hydrological flows can allow for more cost-effective support in accordance to growing periods. Further consideration of irrigation needs would also require more regular well-siting and groundwater monitoring.

7.4.7 Soil conservation

Effective soil monitoring and management is important in proactively managing droughts. For smallholder farmers, soils can also provide a preliminary indicator of the onset of dry conditions. Additionally, water storage is tied to soil retention, as erosion into barrage areas can lead to dam siltation and can eventually clog irrigation supply lines. **Awareness of such connections, ground truthing and more effective soil management are key areas for drought management improvements**.

Ultimately, **an holistic approach fostering more integrated drought management, based on the proactive and preventive risk management**, rather than the current *ad-hoc* approach of crisis management, **offers promise of reducing the impacts of droughts across all sectors**.

8 Drought Governance

During a speech from the Throne in 2010, the King of Morocco reaffirmed **the priority of integrated political decision-making and the need for better inter-ministerial coordination**. ABHs and OMVRAs across the country are aware of the measures and intentions to move towards regional devolvement and decentralisation of watershed and drought impact mitigation and management. The shift to basin-level management represents a positive step toward recognizing the severity of a drought threat to multiple sectors and systems. Yet, **further integration of drought into a national hazard management plan will likely be necessary in the future.**

8.1.1 Institutional Stakeholders

The main institutional stakeholders involved in drought management include:

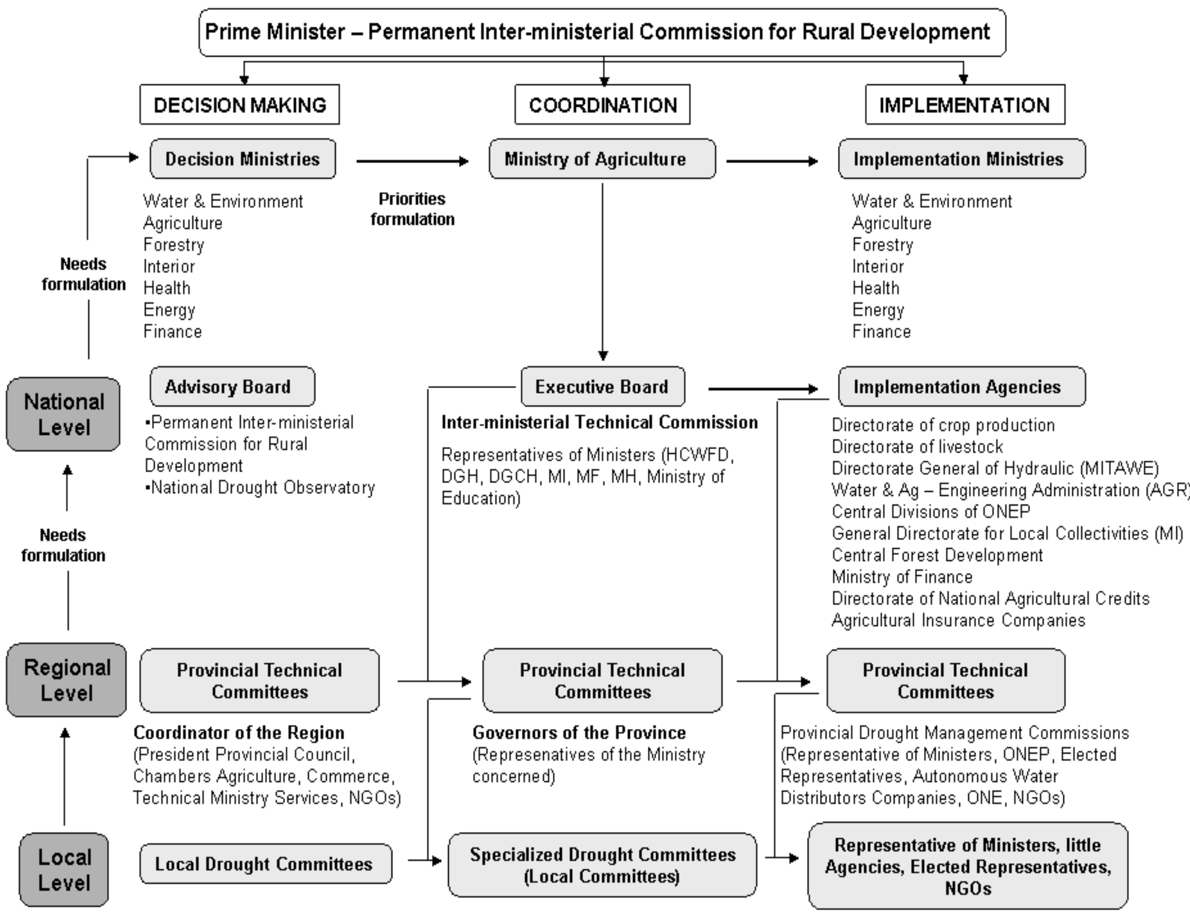
- **DMN** collaborates widely on drought monitoring activities including for forest fires and crop growth and yield monitoring. The forest climate risk management unit within the HCEFLCD produces a risk and impact map for forest fire intensity, severity, and spatial extent. This map is informed with climate information from the DMN and ground-truthed by foresters. Also, DMN contributes to the Crop Growth Modelling System platform, a tool developed in coordination with INRA and DSS that is used to estimate cereals yields.
- The **Ministry of Agriculture and Fisheries (MAPM)** plays a core role in drought monitoring and management, largely through the Directorate of Statistics and Strategies (DSS) and the Finance Directorate (DF) which, in collaboration with MAMDA, oversees the state-owned agricultural insurance firm, the climate risk insurance program. Recently the DSS began a programme of monitoring key bulk markets and regional markets to gather maximum, minimum and average prices of a basket of goods, livestock feeds and agricultural inputs. In collaboration with the national office for agricultural advice (ONCA) and INRA, the DSS also collects information on livestock and crop conditions in rural areas, and the DIAEA collects such information from irrigation districts.
- In addition to monitoring forest conditions, the **HCEFLCD** is establishing a desertification observatory to assess the intensity and extent of desertification through observation and modelling that

integrates climatic, environmental, socio-economic and demographic datasets. This requires uniform, timely and automated data inputs, and even before the completion of the project it has been cited as a successful example of collaboration and effective data-sharing.

- The **DRPE/DGE** oversees reservoir management and has a 4-tiered operation system for dam management linked to reservoir levels and the specific city and basin needs served by the reservoir. The 4 tiers - pre-alert through emergency - are defined by basin areas' exposure to risk, sensibility to impact and resilience in the fact of impact. DRPE/DGE work with the river basin authorities, ABHs, for collaborative management of water resources and as such are information providers to the regional and local decision-making bodies.
- Several **international agencies** have helped in different ways to strengthen the country coping capacity. These include FAO; UNDP; the Global Environment Facility (GEF); The World Food Programme (WFP); USAID; and IFAD. Some have helped to establish the Network on Drought Management for the Near East, Mediterranean and Central Asia ('NEMEDCA Drought Network').
- **Civil society institutions** and non-governmental organisations, research and academic institutions, and in some private sector entities are also working on elements of drought monitoring and impact assessments.
- **Universities and academic centres** play a major role in a DMS coalition. They have the potential to link a wide range of stakeholders through pre-existing relationships and research collaborations across disciplines. Also, they are largely impartial and politically neutral, which is one of the primary reasons the ONS was located at IAV – Hassan II (Hayes & Svoboda, 2008). These characteristics lend themselves to the type of dynamic and flexible arrangements needed in drought monitoring and management planning.

Figure 11, below, provides an existing – if dated – overview of the general governance structure for drought management in Morocco. Noticeably absent are the ABHs, which play a vital role in the regional management of water allocation and drought responses (Ouassou, 2005).

Figure 11 Drought Management under the Commission for Rural Development



The development and implementation of government management is the responsibility of the MDCE. This Department is also **responsible for coordinating environmental protection actions at the national level, whilst ensuring the coordination of environmental actions between various national actors**. The MDCE has tools for environmental monitoring such as the National Observatory for the Environment of Morocco (ONEM), Regional Observatories for the Environment and Sustainable Development (OREDD), the National Laboratory of Environment (LNE), and an Impact Studies Department (SEI).

The **ONEM and the OREDDs are responsible for improving environmental knowledge and developing decision support tools for environmental protection** at the national and regional levels, respectively. LNE is responsible for monitoring the state of the environment, mainly water and air. The SEI coordinates impact study commissions in which different government authorities and other stakeholders are represented. The environmental monitoring system assesses only air and bathing water regularly, but still not systematically. The freshwater quality monitoring system is conducted periodically although not on a regular basis. The current structure of the Department of the Environment is not adequate for this monitoring, especially since a legal framework is lacking in this area of environmental monitoring and assessment.

The **Ministry of Energy, Mines, Water and the Environment, in charge of water (MDC Water) is entrusted with the responsibility for planning and management of water resources and development of weather forecasting and climate change information**. Several other ministries are also involved in the implementation of environmental programs or have regulatory and compliance control responsibilities, each within the limits of its remit and expertise. These agencies include the Ministry of the Interior, the High Commission for Water and Forests and the Fight Against Desertification, the Ministry of Agriculture and Maritime Fisheries, the Ministry of Health, the Ministry of Housing, Town Planning and City Policy, the Ministry of Tourism, the Royal Gendarmerie, the Merchant Navy, etc. However, **with this multitude of actors, there is a dispersion of efforts and sometimes an absence of harmony in decision-making**.

The **National Council for the Environment and Sustainable Development** (CNEDD), a body **tasked with guiding the various actors in environmental action**, is coordinated by the MDCE. In addition to the CNE, other consultative bodies exist at the national level, such as the Higher Council for Water and Climate (CSEC) and the National Forestry Council (CNF), while underlining the strategic importance of Economic, Social and Environmental Council (CESE) which provides an advisory role to the government, the House of Representatives and the House of Councillors. **These councils must act as coordination mechanisms within and between public institutions. However, the activity of some boards is limited**. As an indication, the CNE has met only seven times since 1995, approximately once every three years; and the CSEC has never met since the year 2001.

Most of the institutional stakeholder listed above have been involved to varying degrees in forging policies, strategies, laws, by-laws and temporary laws for governing surface and groundwater, agriculture, land use, livestock and rangelands management, and elements touching upon drought management.

8.1.2 National Drought Observatory

There is currently political interest and buy-in to revitalise the function of the ONS in some form. The failure of the former ONS highlights the very limitations that need considering in any future iteration. In the wake of the disastrous droughts at the turn of the millennium, the Moroccan government set up the ONS at the Agricultural and Veterinary Institute - Hassan II roughly following the model of the NDMC in the United States. Partners were supposed to provide or assign staff to the ONS, and MAPM was primarily supposed to provide resources with the intention that the ONS would be independent of the government. Its overall remit was to conduct research and implement programs on drought monitoring, impact assessment and planning. However, **the ONS did not continue to function as intended long after its establishmen**t. Hayes and Svoboda (2008) identify **four issues that have substantially limited the core functions of the ONS over the years**.

1. The ONS did not receive the **financial and personnel resources** it expected and needed to accomplish its objectives, and this occurred for a variety of reasons, many of which were understood to be political. Possibly owing to its being housed within a university setting, it did not receive adequate exposure to key decision-makers and agency heads.
2. The perception exists that **communication and dissemination shortcomings** repeatedly interfered between the ONS and its stakeholders.
3. **Data sharing** and attribution have been, and remain, major obstacles.
4. The fear existed that **tasks and activities** would be reassigned from other agencies.

These are core issues that any future iteration of a Moroccan national drought centre must address through specific legal status, institutional setup, mandate to coordinate information sharing and mode of operation with collaborating agencies. **A dedicated national drought observatory can greatly facilitate the coordination of drought governance** by providing the following key services:

- **Actively monitor drought conditions** and provide information to aid drought planning and coordination activities undertaken by government agencies.
- **Operate as a communications hub** – provide information to and from officials at all levels of governance, as well as to the media and public.
- **Coordinate outreach and research efforts** and connect and communicate them effectively. This includes training officials on drought risk management and mitigation.
- **Evaluate drought risk policies and mitigation programmes** for effectiveness.
- **Identify, communicate and facilitate peer learning** from successful drought management efforts from different parts of the country and abroad.

8.1.3 Water Sector Governance

National capacity in drought awareness, response and mitigation can often be tempered by the institutional and procedural capacity of national water policy and governance. Since 1995, water policy in Morocco has been governed by a single law (Law No. 10-95). Although replaced by Water Law 36-15 in 2016, the regulatory system put in place by Law 10-95 remains in force pending the implementation of the application texts of Law 36-15. The law aims to **create harmonious and flexible planning systems for both national and regional water us**e. It prioritises increasing water mobilisation, rational management of water resources at the basin level, and the protection and enhancement of the public water sector. This law has provisions regulating the quality of water to be provided by the Basin Agencies: Decree No. 2-97-787 on water quality standards and the inventory of water pollution was published in 1998. This decree is accompanied by joint orders defining the quality standards for surface water, irrigation, water used for fish farming, and surface water used for municipal supplies.

Importantly, **the law introduced the principles of "user-pays" and "polluter-pays", and the treatment of water as an economic and social good for steering optimal allocation**. These principles are implemented through the following decrees:

i. Decree No. 2-97-787 of 4 February 1998 on water quality standards and the inventory of water pollution, which defines water quality standards;
ii. Decree No. 2-04-553 of 24 January 2005 on spills, discharges, direct or indirect deposits in surface or groundwater, which also broadly covers development of standards for the effective protection of available water resources;
iii. Decree No. 2-05-1533 of 13 February 2006 on autonomous sanitation aimed at improving the livelihood of the rural population and the protection of water resources;
iv. Decree No. 2-05-1326 of 25 July 2006 on water for food use, which established the regulatory basis for sanitary control and monitoring the quality of water for food use.

In parallel with the legislation, a **National Water Strategy (NWS) was put in place in 2009, with aims to meet future needs in the short-, medium- and long-term (2030).** This strategy is organised around supply and demand management, the preservation and protection of water resources and the environment, and the pursuit of regulatory and institutional reforms.

The new water law (Law 36-15) focussed on the public water domain and the management of private rights to water. It

…sets the rules for integrated, decentralised and participatory management of water resources to guarantee citizens' right to access to water, for rational and sustainable use, for better quantitative and qualitative valuation of water, aquatic environments and the public water domain in general, as well as water-related risk prevention rules to ensure the protection and safety of people, property and the environment. It also aims to put in place rules and tools for water planning including wastewater, desalinated seawater, and others to increase the national water potential taking climate change into account in order to adapt to it."

This law preserves water rights for private operators and historic collective rights whilst affirming the public nature of most water resources available in the territory. According to Article 5,

…the public water domain consists of all inland waters, whether superficial, subterranean, fresh, brackish, salty, mineral or wastewater, as well as desalinated seawater discharged into the public water domain and hydraulic infrastructure and their annexes for public use.

The law provides ample opportunities for **the private use of groundwater and its economic development**. However, this is subject to the sustainability of water resource use, the establishment of a planning system and mobilisation infrastructure, and a fee payment scheme. Thus, in the private domain, the use of groundwater is free. However, it is required on the one hand to be authorised, and on the other hand it is subject to the payment of a fee according to a general rule specified by Article 27. Access to groundwater is granted only after an investigation has been conducted by the watershed agency, and it lasts for 10 years and fixes the flow, the volume or the area to be used, and the measures to be taken by the granter of the authorisation to avoid degradation of the public water resources that it uses. Article 31 stipulates that the authorisation decision must present:

- Water metering equipment, sampling regime, conditions of installation, maintenance, and repair, which is especially emphasised for pumping infrastructure;
- Deadlines for reporting volumes of water abstracted, or the materials used and the method of calculation, and payment terms of the fees and surcharges to be applied if the fee is not paid under the terms set.

The use of irrigation water is subject to the submission of a project plan to the watershed agency or the competent governmental authorities that complies with the associated standards and includes an application for authorisation or concession for the use of water. The law has also planned for the establishment of a water police force to record offenses as well as sanctions against offenders. Compliance is monitored by judicial police officers, water police officers commissioned by the administration, watershed agencies and other concerned public institutions.

The mechanisms, commitments and measures outlined in national water policy provide strong institutional mandates for the effective and holistic governance of drought mitigation and management efforts. What remains to be done is develop clearly defined and agreed upon action plans across ministries that ensure such benefits are translated into effective, timely, and actionable responsibilities.

8.1.4 Institutional Challenges

Despite the significant advances in Moroccan drought governance capacity, **there remains a need for an effective information sharing platform to collate and disseminate drought monitoring information**. A lack of clear information sharing has represented a core barrier to effective drought management in the past. In response, there remains a great local interest in creating an information sharing platform on which they can compile and share relevant drought-related information, including the CDI. The OSS is the current institutional focal point for hosting the now operational CDI and is currently sharing drought maps monthly on its government webpage. Considerations for the continued development of an information sharing platform could consider the following prerequisites:

- **Accessibility** to core stakeholders;
- **Automation** of data provision;
- **Formal mechanisms** requiring data provision;
- **Uniformity of inputs** format, type and timing;
- Common **indicators** within sectors; and
- **Technical specifications** for each agency’s provision.

A common perception across institutional stakeholders suggests that agencies retain a reluctance in providing information if they were unable to retrieve data themselves, and thus formal institutional agreements were necessary. **The following factors could be considered as potential barriers to effective information sharing**:

- **Drought data sensitivity**: Drought data is considered politically sensitive, which exacerbates the other barriers described below. This limits its exposure and prohibits more general reporting on and circulation of climatic and agro-meteorological conditions. This includes the CDI map produced by CRTS. With the OSS now managing CDI map dissemination there is a greater availability of the maps and discussion of inputs. Awareness among non-governmental agencies remains low.
- **Formality and data purchase**: Government agencies typically share information only with designated partner agencies through formal conventions. Without such conventions, data, if its provision is permitted, must be purchased at high cost.
- **Lack of information 'percolation'**: When inter-agency data-sharing occurs, often information only reaches the top managers of the receiving agency and pertinent data does not reach technical staff. This prevents the incorporation of shared information into monitoring, management and modelling systems. Without the expectation of regular and timely receipt of information products – including the CDI drought map – technical staff are unable to evaluate information products and examine potential utilisation in daily activities.
- **Uniform standards**: A wide variety of information sources are pertinent to drought monitoring and management and stakeholders said that lack of uniform standards for data collection, reporting and frequency of update are major obstacles to monitoring and planning. In some cases, paper records are still used complicating information exchange.

An integrated, inter-agency information sharing platform with regularly updated data on meteorological, agricultural and hydrological conditions would help overcome many of these challenges. These information streams cross multiple ministries and agencies, and at present the primary data platforms are functionally linked to individual agencies and specific modelling systems, and they have limited access points. **Sharing drought related information, especially the CDI on a shared platform**, similar to the website currently used by the OSS, **would improve the mobilisation, validation and potential social implications of drought data by a broader group of institutional stakeholders in the effective execution of drought plans**.

9 Conclusions

Morocco has taken significant strides towards the effective, comprehensive and pro-active management and mitigation of droughts. As Morocco faces increasing water scarcity and development pressures, optimising resource use to reduce drought vulnerability and to improve the effectiveness and efficiency of drought mitigations becomes increasingly important and challenging. Improving drought monitoring and drought management planning is vital to inform the timing and form of resource allocation decision-making. Of the priority areas to consider during future planning, the following issues should remain under consideration:

- **Understanding of drought development, impacts and vulnerability** for rainfed cereals in core agricultural areas is very well-developed; there is considerable awareness of the importance of improving understanding of drought relationships with other **biomass** production (particularly to support sustainable rangeland exploitation); other **sectors** beyond agriculture, and in other **regions**, especially those targeted in long-term development plans.
- Technical drought monitoring capacity is not seen as the primary need to improve overall drought monitoring capabilities in Morocco; there is a need to **improve information sharing mechanisms** as far and away the most important drought monitoring need now.
- Drought monitoring information feeds up to decision-makers efficiently, but agencies are unable to integrate data streams and therefore cannot integrate over-arching findings effectively.
- **Intra- and inter-ministerial coordination mechanisms** prior to official drought declaration are not well-established leading to costly, time-consuming delays when drought management plans are initiated.
- More formal agreements on technically derived indicators of drought onset and their formal incorporation in management plans, together with the budgetary allocation in a tiered manner to accompany them.
- Enhancing understanding of the **relationship between drought and groundwater resources** given their role in mitigating drought impacts, the significant effects of drought on groundwater usage and resource condition, and in many areas the increasing reliance on unsustainable groundwater use even in wet years.

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