CLIMATE VARIABILITY, DROUGHT, AND DROUGHT MANAGEMENT IN MOROCCO'S AGRICULTURAL SECTOR

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WORLD BANK GROUP

ACRONYMS AND ABBREVIATIONS

Exchange Rate

1 USD = 9.84 MAD = 0.91 EUR
1 MAD = 0.10 USD = 0.09 EUR

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABH	*Agences de Bassins Hydrauliques* (River Basin Agencies)
ADA	Agricultural Development Agency
AMS	American Meteorological Society
AR5	Fifth Assessment Report of the IPCC
BAMS	Bulletin of the American Meteorological Society
CAM	*Crédit Agricole Maroc* (Moroccan Agricultural Bank)
CDAS	Climate Data Assimilation System
CDI	Consolidated Drought Index
CEM	Country Economic Memorandum
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station
CHJ	Júcar Hydrographic Confederation (Spain)
CLIVAR	Climate and Ocean: Variability, Predictability and Change
CMIP3	Coupled Model Intercomparison Project 3
CMIP5	Coupled Model Intercomparison Project 5
CONAGUA	National Water Commission (Mexico)
CORDEX	Coordinated Regional Downscaling Experiment
CRTS	*Centre Royal de Télédétection Spatiale* (Royal Spatial Teledetection Center)
CRU	Climate Research Unit
CWSRF	Clean Water State Revolving Fund (California)
DJF	December, January, February
DMI	Danish Meteorological Institute
DNM	Directorate of National Meteorology
DRPE	*Direction de la Recherche et de la Planification de l'Eau* (Directorate for Water Research and Planning)
DSS	Decision Support System

ECMWF	European Centre for Medium-Range Weather Forecasts
ENSO	El Niño Southern Oscillation
E-OBS	ENSEMBLES daily gridded observational dataset for precipitation, temperature and sea level pressure in Europe
ERA-Interim	European Centre for Medium-Range Weather Forecasting Interim European Reanalysis
ETc	Full Water Use
EU	European Union
FAO	United Nations Food and Agriculture Organization
FMD	Farm Management Deposit (Australia)
FTE	Full-time Equivalent
CGMS-Maroc	Morocco Crop Growth Monitoring System
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GISS	Goddard Institute for Space Studies (NASA)
GISTEMP	Goddard Institute for Space Studies Surface Temperature Analysis
GMST	Global Mean Surface Temperature
GNI	Gross National Income
GoM	Government of Morocco
GWP	Global Water Partnership
HadCRUT4	Hadley Centre/Climate Research Unit gridded surface temperature dataset 4
HCEFLCD	*Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification* (High Commission for Water, Forests and the Fight against Desertification)
HMNDP	High Level Meeting on National Drought Policy
ICBA	International Center for Biosaline Agriculture
IDB	Islamic Development Bank
IDM	Integrated Drought Management
IDMP	Integrated Drought Management Program
IDMS	Integrated Drought Management System
IMF	International Monetary Fund
INRA	*Institut National de la Recherche Agronomique* (National Institute for Agricultural Research)
IOC	International Olive Council
IPCC	Intergovernmental Panel on Climate Change
JJL	June, July, August
KNMI	Koninklijk Nederlands Meteorologisch Intstituut (Royal Dutch Meteorological Institute)
MAD	Moroccan Dinar
MAM	March, April, May
MAMDA	*Mutuelle Agricole Marocaine d'Assurance*
MAPM	Ministry of Agriculture and Marine Fisheries
MCC	Millennium Challenge Corporation
MEF	Ministry of Economy and Finance
MO	Mediterranean Oscillation

MOI	Mediterranean Oscillation Index
MT	Metric Tons
MY	Marketing Year
NAO	North Atlantic Oscillation
NAOI	North Atlantic Oscillation Index
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NDMC	National Drought Mitigation Center (UNL)
NDO	National Drought Observatory
NDP	National Drought Policy
NDVI	Normalized Different Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
NRC	Climate, Energy, and Tenure Division (FAO)
NTIS	National System of Identification and Animal Traceability
ONI	Oceanic Niño Index
ONCA	National Office of Agricultural Extension Services
ONSSA	National Food Safety Office
ORMVA	Regional Offices of Agricultural Development
OSS	Observatory of Sahara and the Sahel
PDAIRE	Integrated Water Resource Development Plan
PDSI	Palmer Drought Severity Index
PMH	Small and Medium (Irrigation) Perimeters
PMV	*Plan Maroc Vert* (Green Morocco Plan)
PNEEI	National Program for Saving Water in Irrigation
PPI	*Périmètre Public Irrigué* (Public Irrigation Perimeter)
PPIC	Public Policy Institute of California
PRONACOSE	National Program Against the Drought (Mexico)
RCP	Representative Concentration Pathway (of Greenhouse Gas emissions)
RDMS	Regional Drought Management System
RFCS	Rural Finance Counselling Service (Australia)
RMSE	Root Mean Square Error
RPCA	Rotated Principal Component Analysis
RVCA	Rapid Value Chain Assessment
SGAA	Agricultural Crop Insurance Service
SMAS	Maghreb Drought Early Warning System
SODMI	Standardized Drought Monitoring Indicators
SON	September, October, November
SPEI	Standardized Precipitation-Evapotranspiration Index
SPI	Standardized Precipitation Index
SRES	IPCC Special Report on Emissions Scenarios
SWCB	State Water Control Board (California)
UKMO	United Kingdom Met Office

UNC	University of North Carolina
UNCCD	United Nations Convention to Combat Desertification
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction
UNL	University of Nebraska–Lincoln
USAID	United States Agency of International Development
USDA	United States Department of Agriculture
USDAFAS	United States Department of Agriculture Foreign Advisory Service
USDM	United States Drought Monitor
WeMO	Western Mediterranean Oscillation
WeMOI	Western Mediterranean Oscillation Index
WMO	World Meteorological Organization
WS&D	Water Scarcity and Drought
WUA	Water Users Association

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ABSTRACT

Droughts in Morocco are increasing in frequency and intensity. Associated with global climate change, this trend will likely be more evident in the future. Drought damage to the agricultural sector affects both rural livelihoods and the national economy as a whole. This report examines drought and climate variability impacts on agricultural and livestock activities in Morocco. It relies on original research on the citrus and olive value chains, which are both priorities in the government's current agricultural strategy, known as the "Green Plan" or *Plan Maroc Vert* (PMV). The report also considers drought impacts on cereal production, traces the government's efforts to address drought, and suggests actions to strength these efforts.

Long-term climate change is making Morocco, which already faces rural water scarcity, more vulnerable to extreme weather events. Recurrent atmospheric climate events, known as teleconnections, such as the El Niño Southern Oscillation (ENSO), may further exacerbate this situation. This study finds that ENSO had limited impacts on the 2015–2016 droughts in Morocco, but other teleconnections, specifically the North Atlantic Oscillation (NAO) and the Mediterranean Oscillation (MO), had greater impacts. Increased climate variability leads to stronger droughts, which adversely affect livestock and rainfed crops. Moreover, Morocco's average temperatures are rising and rainfall is becoming more sporadic, both affecting certain parts of the country more than others.

Agriculture and agribusiness activities generate over 30 percent of employment in Morocco. The agricultural sector also produces 20 percent of GDP and 35 percent of exports. Rainfed crops, like wheat, are critical for domestic food security and livestock survival, but are also most affected by climate variability. As such, increasing droughts represent a "contingent liability" for the Moroccan economy. This impacts Morocco's trade balance as agricultural exports fall and food and fodder imports rise to meet increased domestic demand.

This report suggests further drought management actions. Currently, the government is carrying out important monitoring and crop insurance programs, but more can be done to share information and strengthen inter-governmental and interagency coordination, especially with governments at the river basin level.

Addressing the increasingly adverse effects of climate variability is a key challenge for agriculture in Morocco. Adaptation pathways to raise agricultural incomes and productivity could focus on tree crops, especially citrus and olives, which are generally more resilient than field crops. However, with surface water becoming scarcer, water availability is the most important longer-term constraint.

Water scarcity forces farmers to pump more groundwater to irrigate crops and fruit trees. Survey data suggests farmers are well aware that climate change is happening so groundwater pumping is a short-term adaption measure. However, pumping only exacerbates water shortages. These actions call for better enforcement of water laws and regulations, particularly regarding well digging and irrigation water use. This could accompany improved water resource management in rural areas. International experience indicates effective water resource management addresses short-, medium-, and long-term water scarcity problems.

Thus, it becomes essential to link improved water resource management to drought risk management as both face similar challenges and share similar solutions. The Government could also revise and elevate its current drought management strategy into a more formal integrated drought management policy through a participatory process. This is recommended by the UN Food and Agricultural Organization (FAO) and the World Meteorological Organization (WMO) and has already been undertaken by other drought-prone countries such as Mexico and Australia. These actions will help Morocco anticipate and mitigate drought and climate variability impacts and achieve the PMV's goals of more sustainable benefits for farmers and the national economy.

OVERVIEW

0.1 INTRODUCTION

Droughts in Morocco are increasing in frequency and intensity. Associated with global climate change, this trend will likely be more evident in the future. Drought damage to the agricultural sector affects both rural livelihoods and the national economy as a whole. This report examines drought and climate variability impacts on agricultural and livestock activities in Morocco. It relies on original research on the citrus and olive value chains, which are both priorities in the government's current agricultural strategy, known as the "Green Plan" or *Plan Maroc Vert* (PMV). The report also considers drought impacts on cereal production, traces the government's efforts to address drought, and suggests actions to strength these efforts.

0.2 CLIMATE CHANGE, VARIABILITY, AND DROUGHTS IN MOROCCO

The Intergovernmental Panel on Climate Change (IPPC) says it is "unequivocal" that human activities contribute to global warming. 2017, in fact, was the hottest year on record, surpassing the previous high mark set in 2016. Similar trends have been recorded for Morocco and the Middle East and North Africa region, though there are year-to-year country-level variations from the global mean.

The IPPC projects a continued warming trend for Morocco. Every decade since 1970, there has been a 0.5 degrees Centigrade observed temperature increase, greatly exceeding the global average by about 0.15 degrees. Unless strong action is taken to mitigate this trend, additional temperature increases of as much as three to seven degrees Centigrade are projected for Morocco by 2100. The largest increases (four to seven degrees) are anticipated for the summer months (June, July, and August). Annual precipitation is projected to decline by 10–40 percent, including a 10-30 percent decrease during the wet season, from October to April, and a 10 to 40 percent decrease during the dry season, from May to September.

Over the next 20 years, Morocco will be more exposed to drought and other extreme weather events, unless action is taken. Unless strong preventive actions are taken at the global level, these trends and their adverse impacts are projected to become stronger during the rest of the century. Mitigating these impacts requires better adaptation and resource management at the national level, particularly for the agricultural sector.

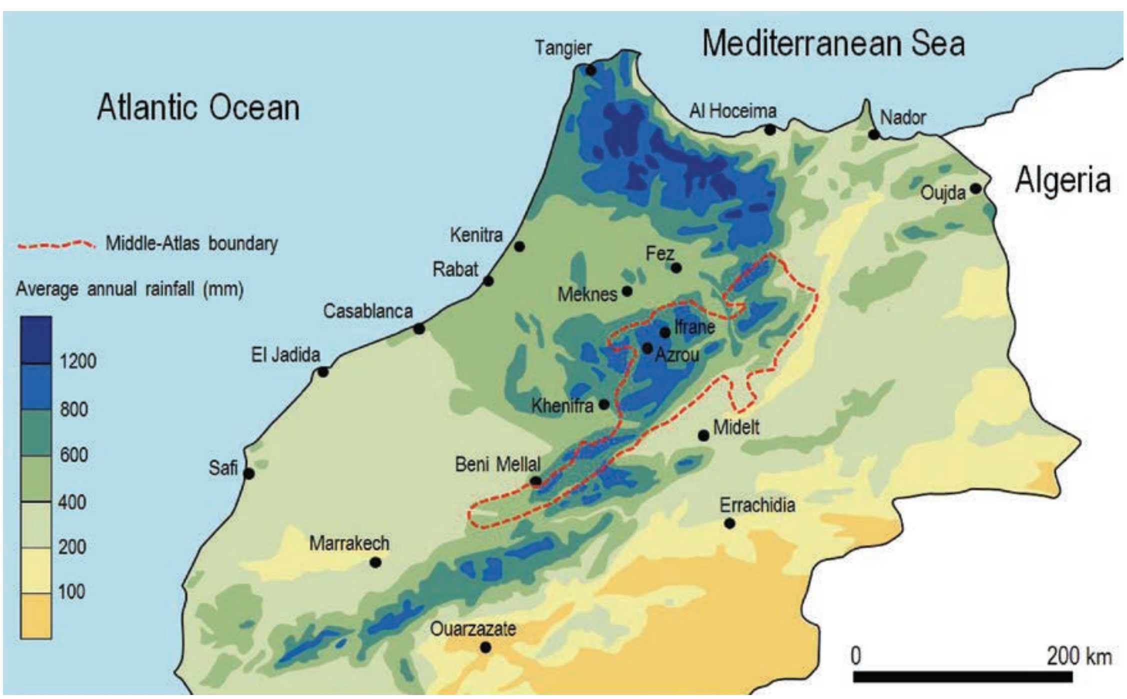
In Morocco, droughts are recurrent and becoming more frequent and, perhaps, more severe. Official drought declarations, triggering government emergency relief, were made in 1992–95, 1998–2001, 2005, 2007, and 2015–2016. The 1994–95 drought was particularly strong, leading to an estimated 7.6 percent GDP loss. The 1999 drought cost an estimated US$900 million and affected more than one million hectares of cropland.

0.3 MOROCCO'S CLIMATE AND THE LOCATION OF AGRICULTURAL ACTIVITIES

Morocco's climate varies considerably from north to south. Both rainfall and temperature are strongly influenced by the Atlantic Ocean to the west, the Mediterranean Sea to the north, and the Sahara Desert to the south and southeast. Most rainfall occurs between October and May. This is caused by the incursion of extratropical weather systems from Europe and the Atlantic Ocean, which brings colder air and cloudiness. This results in a declining rainfall gradient from north to south that is also influenced by the Atlas Mountains, where annual amounts of precipitation can surpass 1,000 mm. Temperatures in the arid and semi-arid southern and southeastern parts of the country are generally high, while rainfall and snow can occur in the northern mountainous areas between November and April. The high rainfall variability in north and central Morocco is illustrated in Figure 0.1.

Morocco's agricultural activities are located predominantly in the country's central and northern regions. The climate in these regions is characterized by hot, dry summers and cool, moist winters.

FIGURE 0.1 Mean Annual Precipitation over Northern and Central Morocco



Source: Royaume du Maroc 2000.

These seasons determine the growing period. However, rainfall here is irregular compared to the moist coast, the rain and snow-fed mountains, and the desert-like conditions south and east of the Atlas range. Other climate events - including droughts, heat waves, and occasional heavy rainfall and associated flooding - have varied significantly in Morocco and neighboring countries.

0.4 THE ROLE OF TELECONNECTIONS

This study examines the relative importance of teleconnections on Morocco's most recent droughts. A correlation analysis with Standardized Precipitation Index (SPI) data was used for this purpose. Drought is defined as extended periods of deficient precipitation compared to the statistical average, which result in water shortages for some group, activity, or environmental sector. Teleconnections, by contrast, are climate anomalies, or oscillations, related to each other at large distances.

ENSO's impacts on drought in 2015–16, while globally significant, did not conclusively affect Morocco. Other teleconnections, particularly the North Atlantic Oscillation (NAO) and, to a lesser extent, the Mediterranean Oscillation (MO), played a more dominant role. The NAO and MO affected Morocco's humid and semi-arid areas. However, more research is needed on the interactions between these teleconnections and the effects of local topographical conditions. This information would allow for a more complete assessment of ENSO, and other oscillations, on drought in Morocco.

0.5 DROUGHT IMPACTS ON MOROCCO'S AGRICULTURAL SECTOR

Drought's social and economic impacts on agricultural are significant in Morocco. Cereal production, which is critical for food security and livestock survival, varies according to annual precipitation levels and is particularly affected during drought years. This was the case for 2015–2016 as indicated in Table 0.1. Also, domestic output declines require more food imports, and lead to fewer agricultural

TABLE 0.1 Morocco: Annual Variations in Cereal Production by Crop, 2008–2016 (million tons)

Year/Crop	Durum Wheat	Common Wheat	Total Wheat	Barley	Total Production
2008/2009	2.1	4.3	6.4	3.8	10.2
2009/2010	1.6	3.2	4.8	2.5	7.3
2010/2011	1.8	4.1	5.9	2.3	8.2
2011/2012	1.1	2.7	3.8	1.2	5.0
2012/2013	1.9	5.1	7.0	2.7	9.7
2013/2014	1.4	3.7	5.1	1.7	6.8
2014/2015	2.4	5.6	8.0	3.5	11.5
2015/2016	0.9	1.9	2.7	0.6	3.4

Source: Adapted from Ministry of Agriculture, USDAFAS 2016.

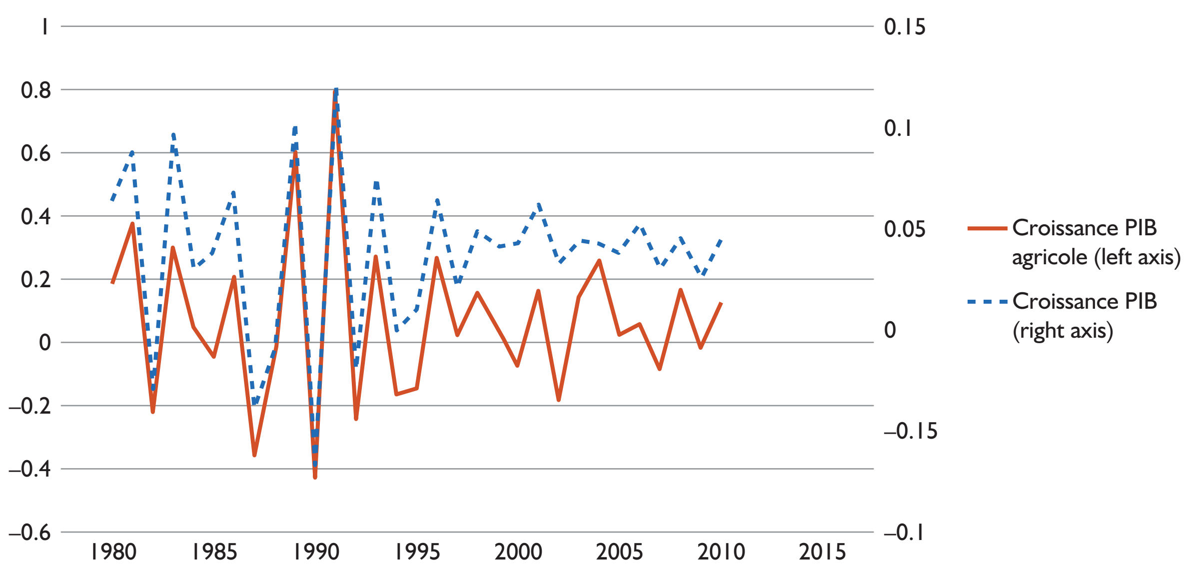
exports, disrupting the national trade balance. These impacts contribute to decreased economic growth. There are social impacts as well. Rural livelihoods, particularly for small-scale farmers and rural laborers, are harmed. This can occasionally raise political concerns.

Farmers interviewed for this study largely agreed that recent droughts have had the most important impacts on rainfed cereals and livestock. Livestock and agriculture, which are dominated by rangelands and rainfed croplands (83 percent), are important food sources for most Moroccans. There also appears to be regional discrepancies in drought resilience. The north is the most resilient, with more diversified crops, such as fruit trees, vegetables, annual crops, and small grain cereals. The center, which has cereals and the subsistence livestock production of chickens and small ruminants, is less resilient. The south's desert-like conditions means agriculture is not a dominant activity, with the exception of oases and greenhouses. As such, the south is much less sensitive to climate variability than the other major regions.

The most recent drought, from November 2015 to spring 2016, caused a three percent decline in economic growth. This was caused by decreased agricultural output, mainly in cereals production, and few mitigation actions, including crop insurance. The citrus and olive value chains saw output declines and sensitivity to water shortages from the 2015–16 drought.

Economic growth may be becoming less sensitive to the climate. Figure 0.2 shows the close relationship between national GDP variations and agricultural GDP variations. During the 1980s and 1990s, economic growth fluctuations were significant, varying between −4 and +13 percent. During this period, droughts were more severe and recurrent. Note also in Figure 0.2 that economic and agricultural growth were closely linked before the end of the 1990s. During the late 1990s and 2000s, however, economic growth diverged from agricultural growth, suggesting that annual economic performance may now be less dependent on agricultural outcomes. Still, the general relationship seems to persist as reflected in this study's value chain analyses.

FIGURE 0.2 Compared Evolution of Agricultural GDP Growth versus GDP Growth



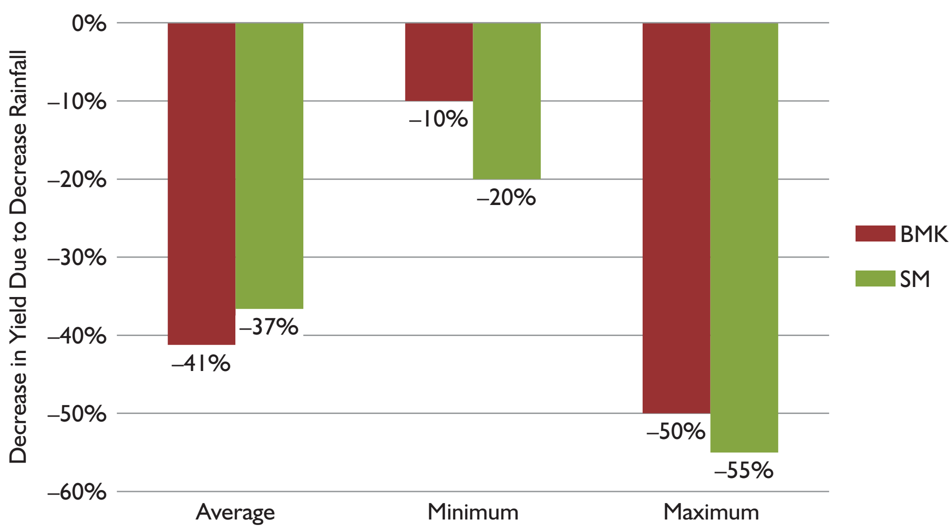
0.6 DROUGHT IMPACTS ON THE CITRUS SUBSECTOR

Increasing water scarcity is the most pressing medium- and long-term challenge for the citrus sector. Citrus trees require irrigation to produce quality fruit. Government programs partially reimburse farmers' investments in trees, irrigation, and other capital investment. Despite these programs, electricity costs for pumps and water charges from irrigation canals or other public utility sources can still be prohibitive.

Droughts and shifts in temperature and rainfall timing affect Morocco's citrus production. More specifically, it affects the timing of citrus blossoming and ripening, and other metrics. These changes reduce regional yields and shift harvest timing. As a result, citrus processors suffer from unreliable fruit quantity and quality, complicating their ability to meet export commitments.

Eighty percent of the citrus growers surveyed for this study reported declining or irregular yields over the past several years from decreased rainfall. Figure 0.3 illustrates this for both of this report's surveyed areas – Béni Mellal-Khénifra (BMK) and Souss-Massa (SM).

FIGURE 0.3 Reported Citrus Yield Rate Decline due to Decreased Rainfall



Source: World Bank data

A common farmer reaction to a changing climate and shifting growing conditions was to "do nothing," although this varied by region. Eighty percent of growers in the north have taken at least some adaptive measures, such as digging wells. Some have taken more innovative approaches such as using agrochemicals to improve drought resistance. By contrast, only 23 percent of growers in the south have taken any measures. Overall, the more developed northern region was more adaptive, with 30 percent of growers saying they reduced their water use. They cited cost-benefit reasons for this decision.

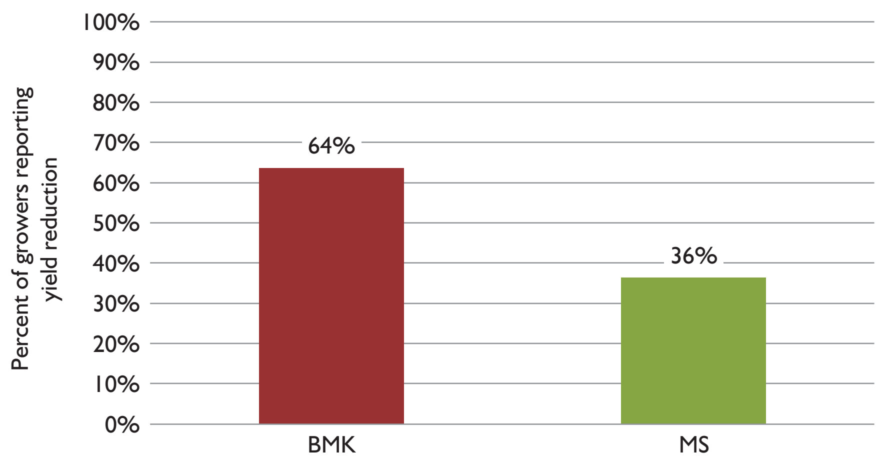
Morocco's citrus sector remains vulnerable to drought despite expected production increases. The increased production of citrus fruits is the result of expanding planted areas and improving irrigation systems. This study finds, however, that both large- and small-scale growers frequently lack sufficient skills to adapt to effects from drought and climate change. By taking steps now to reduce climate change vulnerability for citrus growers, Morocco will be better positioned to ensure citrus sector sustainability, meet its export and domestic consumption targets, and generally retain its success in the global citrus market.

0.7 DROUGHT IMPACTS ON THE OLIVES SUBSECTOR

Olives are more drought tolerant than citrus but water scarcity is still an issue. Reduced water, whether from reduced rainfall or irrigation, results in less, and lower quality olive oil. For smallholders, water scarcity adaptation consists largely of digging wells when existing wells dry up, or forgoing irrigation altogether. The study found that this was even the case when growers were incentivized to adapt. A Government of Morocco (GoM) and Millennium Challenge Corporation (MCC) scheme gives growers trees and funds for the first two years of irrigation and maintenance. After that, the program expects growers to continue tree maintenance on their own. However, this was not happening as irrigation costs from pumping or water charges tend to be prohibitive to small-scale landholders. Olive growers with larger drip irrigation farms maintain large retention ponds to store water for each irrigation cycle. This allows them to consistently irrigate their plantations, although it also reduces the surface area available for planting. Small-scale farmers have fewer options.

Half of surveyed olive growers reported irregular or declining yields from decreased rainfall over the past several years. Figure 0.4 shows grower responses from the BMK and Marrakech-Safi (MS) regions.

FIGURE 0.4 Olive Growers Experiencing Yield Rate Decline due to Decreased Rainfall



Source: World Bank data.

The intended use of olives affects harvest timing. Table olives are harvested earlier in the season than oil olives. Among oil olives, those destined for traditional mills are harvested earlier than those destined for modern mills. The early season olives are generally higher quality, albeit at a lower extraction rate, while the later season olives produce more oil per olive. As such, quantity-focused growers press later in the season. However, rainfall timing and distribution throughout the season, and extreme temperatures and weather events, such as hail, affect blossoming and ripening times. This disrupts preferred harvesting schedules and can require multiple harvest cycles. Thus, growers with only one olive variety have the highest vulnerability to drought and climate variability.

This study finds that olive growers lack coping mechanisms and incentives to adapt. As in the case of citrus growers, most olive growers (73 percent) said they "do nothing" to adapt to climate change. Morocco's olive sector is characterized by a traditionally low-maintenance approach to olive tree care, and concerned growers lack the skills to manage unprecedented climate effects. The growers who adapt use both labor and capital-intensive approaches. Some growers reported digging catchments at tree bases to retain water, others installed or improved drip irrigation systems. Some growers said they were likely to reduce their irrigation because of high costs. Low commercialization rates result in limited funds for irrigation and farm management.

Morocco's olive sector is vulnerable to drought despite the sector's proven resilience to climate factors. Historically, olive trees have been resistant to drought, providing growers, particularly small-scale landholders, with reliable incomes and household food supplies from minimum crop volumes, even under adverse conditions. However, weather variability is now compromising sector production. Both old and new trees are increasingly susceptible to extreme weather impacts, and growers are ill-equipped to cope with the unprecedented climate conditions. Processing mills are also affected. Traditional mills produce lower yields, which reduce worker incomes, and modern mills receive fewer, and lower quality, raw materials, which impacts their ability to plan production cycles.

Morocco can take action to protect the olive sector's long-term productivity. In recent years, Morocco has expanded olive production, initiated new plantings, and expanded irrigation access to support the olive sector's commercialization, but as in the cases of cereals and citrus, it remains vulnerable to drought and climate change. Most olive growers lack the skills to adapt to climate change. By taking steps now to improve cultivation techniques and reduce climate vulnerability for small-scale landholders, which comprise the majority of olive producers, Morocco will be better positioned to meet its output and export targets and retain its prominent position in international markets.

0.8 GOVERNMENT RESPONSE TO CLIMATE VARIABILITY AND DROUGHT IN THE AGRICULTURAL SECTOR

The Moroccan Government has adopted a more proactive stance in relation to drought management. This consists of both short- and longer-term measures that involve hydrological, agricultural, and meteorological monitoring activities. However, the sustainability of some of these measures has been variable. As an example, the innovative National Drought Observatory (NDO), established in 2001, was discontinued.

Several drought management interventions have been implemented over the past decade. This includes a multi-risk insurance program for rainfed cereal production launched in 2011. This program was subsequently expanded to an estimated 1.1 million hectares in 2016. Other recent measures include water allocation changes in public irrigation projects and commercial subsidies and direct provisions to ensure adequate livestock feed for livestock owners in officially declared drought-affected areas.

During the 2015-16 drought, the government prioritized three short-term actions. These included: (i) protecting animal resources by providing livestock feed, ensuring adequate livestock water supplies, and preventing animal diseases; (ii) protecting plant resources by irrigating young rainfed fruit plantations, multiplying certified seeds for the next planting season, securing irrigated plant production, and encouraging farmers to convert to spring crops; and (iii) maintaining a socio-economic equilibrium in rural areas by generating work and enhancing drinking water access for drought-affected populations. These actions were generally successful but their cost-effectiveness has never been assessed.

The GoM's longer-term actions prioritize increasing water supplies for agricultural activities. This approach started in the mid-1980s with dam and reservoir construction for water storage purposes.

BOX 0.1 Water Resources Management in Morocco

Morocco's groundwater resources are strategic to sustain stable agricultural revenues, including for small-scale farmers. In Morocco, renewable water resource potential is about 730 m3 per capita per year, well below the water stress threshold of 1,000 m3 per capita per year. With the exception of Sebou and Loukkos, all of Morocco's river basins are currently experiencing deficits in renewable water resources. A recent World Bank study on climate change in Morocco[1] shows precipitation will decrease by 10 to 35 percent, depending on the region and based on the A1B climate change scenario, for the 1971-2000 period to the 2035–2065 period.[2] Groundwater resources sustain irrigated agriculture's value-added, which averages 45 percent of total agricultural value-added in normal rainfall years, but falls to just seven percent in dry years. Over the past decade, abstraction has heavily impacted groundwater stocks. To ensure the productivity of irrigated agriculture during water deficit years, the government aims to improve sustainable groundwater resource planning. It is important to note that groundwater abstraction is made possible by subsidized energy, especially domestic butane, which was not targeted by recent petroleum product subsidy reforms.[3]

The Government of Morocco recently strengthened water sector legislation. The new Water Law, adopted in August 2016, improves sustainable groundwater management so farmers continue to benefit from increasingly limited water resource. Women in rural areas are also expected to benefit from the Water Law.

More recently, this approach has focused on drilling wells and promoting greater water use efficiency in irrigation projects. However, the drilling of new wells, which requires government permits, tends to exacerbate existing groundwater overdraft problems in arid and semi-arid zones. In some areas where aquifers are still in equilibrium, well drilling is less damaging. It is expected the government will establish new provisions to manage future shortages, including meter installations and well and borehole surveys, though these measures could meet social resistance. Box 0.1 summarizes the main water resource management issues, including the revised Water Law (No. 36-15) from August 2016, which strengthens state control over groundwater management.

The GoM has taken steps to reduce irrigation water use. During the PMV's inception in 2008, the GoM encouraged practices to reduce water use and local irrigation through the National Program for Saving Water in Irrigation (PNEEI). These are effective long-term actions to improve yields and stabilize agricultural incomes. They promote better water use, increase land-use intensity, and make labor resources more productive.

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[1] Impacts of Climate Change on Water Resource Management and Adaptation Measures in the Oum er Rbia River Basin, Morocco (World Bank 2013).

[2] The A1 scenario describes a future of rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. A1B refers to a scenario where energy sources are balanced (between fossil and non-fossil). Nakicenovic, N., Alcamo, J., Grubler, A., Riahi, K., Roehrl, R. A., Rogner, H. H., & Victor, N. (2000). *Special report on emissions scenarios (SRES), a special report of Working Group III of the intergovernmental panel on climate change*. Cambridge University Press.

[3] In June 2012, GoM introduced a one-off increase in the price for unleaded gasoline and diesel fuel of 20 and 16 percent respectively, the sharpest single increase in fuel prices in over the previous decade. In early 2014, the Government decided to remove all subsidies for unleaded gasoline and Heavy Fuel Oil and to gradually phase out subsidies for diesel, representing 64 percent of the total amount (MAD 35.9 billion, equal to US$ 4.3 billion) that GoM paid in subsidies for petroleum products in 2013. In the 2015 budget law, the Government announced the termination of all diesel subsidies and the liberalization of liquid fuel market by end 2015.

BOX 0.2 Summary and Lessons Learned from Conservation Agriculture Projects in Morocco

Four subprojects under the Project for the Integration of Climate Change in the Plan Maroc Vert (PICCPMV) support direct seeding of rainfed cereal-based systems. Although subprojects faced a number of hurdles, including a lack of direct seeders in the early years, the subprojects were mostly successful. The *Institut National de la Recherche Agronomique's* (INRA, National Institute for Agricultural Research) experimental station was a key element for effective implementation and sustainability. Direct seeding is now embedded into government programs through 2020.

Experience indicates this technology has the potential to raise yields, improve soil health, and reduce costs and labor relative to traditional tillage systems. It is important, however, for Morocco to maintain soil health and the soil-plant-water-nutrient system, while encouraging crop rotation,[4] maintaining residue, maximizing soil biomass, and minimizing external inputs. INRA researchers understand this concept but the PICCPMV has not aggressively pursued it, since the first priority was to overcome farmer resistance to new sustainable land management approaches.

One challenge in the broader transition to conservation agriculture remains subsidy policy, which favors wheat over other crops in the rotation system, specifically pulses, legumes, and oilseeds. These crops need more attention in government programs. Other actions to taken, include: improving seed access, improving pests and disease management, and establishing better value chains and marketing systems for these crops.

A second challenge is the cost of direct seeders, which despite subsidies remains high. Service providers have a role to play in machinery leasing, and the INRA is developing a local direct seeder (ECOSEEDER) that will soon be available on the market.

A third challenge is the availability of water, which will increasingly be a limiting factor. Seeding dates for different crops need to be tested on-site, as do different crop sequences to improve yields and produce more food, feed, and mulch biomass. More agro-meteorological services to provide relevant information will also help farmers adapt to local conditions.

Source: World Bank 2016e.

The GoM also introduced climate-smart agricultural practices. These can increase and stabilize yields in drought-prone areas through activities like conservation tilling. Pilots carried out for the World Bank–supported Project for the Integration of Climate Change in the Plan Maroc Vert (PICCPMV) project on rainfed wheat, for example, have increased and stabilized yields under conservation tillage compared to conventional methods. Box 0.2 describes these interventions, while Box 0.3 summarizes other long-term drought management measures in Morocco.

0.9 PERSISTING GAPS IN AND CHALLENGES FOR MOROCCO'S DROUGHT MANAGEMENT SYSTEM

There are several persistent weaknesses in Morocco's drought management system. The main concern among key informants is the lack of leadership or a clear institutional framework that addresses

[4] Rotation should be encouraged even before no-till systems are started, and straw should not be removed when no-till is introduced.

BOX 0.3 Longer-term Drought Management Measures in Morocco

The three pillars of Morocco's long-term drought management strategy consist of:

- **An integrated approach to water resource management** through mutually reinforcing policy and institutional reforms. This includes a long-term investment program to capture rainfall runoff and develop hydropower infrastructure to reduce energy imports.
- **Improved access to water and sanitation and increased wastewater treatment capacity** through increased budget support for public infrastructure for sanitation, pollution control, increased rural water supplies, and extension services in poor peri-urban areas. In this context, a National Sanitation Plan was established for 2006–2030 to abate water pollution by 60 percent.
- **Improved productivity, cost-effectiveness, water conservation and efficiency, and irrigated agriculture sustainability** through expanded investments in three areas. These include: (i) irrigation systems' hydraulic efficiency; (ii) irrigation agencies' strengthened managerial capacity; and (iii) increased water use productivity. To this end, the National Plan for Conservation of Irrigation Waters increases on-farm irrigation water use efficiency, improves water cost recovery and asset management in public irrigation perimeters, and promotes public-private partnerships for irrigation development and management.

Source: WMO and GWP 2014.

drought impacts. Currently, many government agencies are involved in drought-related activities, but no single agency is leading these efforts.[5] Informants also expressed concerns over insufficient budgets, and unclear drought declaration[6] and demarcation procedures.

Informants expressed added concerns over inadequate information-sharing. This includes concerns over the quality, timeliness, and dissemination of monitoring information. Some interviewees affirmed the need to better integrate and streamline the sharing of remote-sensing, hydrological, meteorological, and agricultural monitoring information. The systems that generate this information is generally considered technically strong, so the challenge is allowing stakeholders to use the information more productively. This information would inform drought declaration and demarcation decisions.

[5] Government of Morocco (2014) presents a complete map of the complex web of government institutions involved in drought management in terms of decision making, coordination, and implementation at the national, regional, and local levels. While the Ministry of Agriculture and Fisheries is responsible for coordination of these activities together with an Inter-ministerial Technical Commission and both Provincial Technical Committees, and Specialized Committees at the local level, six other Ministries (Water & Environment, Forestry, Interior, Health, Energy, and Finance) are also involved in the decision making and implementation processes, as well as an Advisory Board, Provincial Technical Boards, and Local Drought Committees in the decision making phase and specific implementation agencies, the Provincial Technical Committees, and elected representatives and non-governmental organizations (NGOs) at the local level.

[6] Official drought declarations and determination of the geographic areas eligible for particular drought relief interventions are made by a committee that includes the Ministries of Interior, Finance, Agriculture, and Water. While the ultimate decision-making criteria are not fixed, a mix of physical, social, and political factors are taken into account. In addition, little information is made public about how these decisions are actually made.

0.10 POLICY OPTIONS

The GoM has only partially succeeded in bringing lasting and sustainable solutions to drought and climate variability impacts. An example of this partial success was the innovative, but short-lived National Drought Observatory. Past experience shaped Morocco's current approach to drought management, which focuses on ensuring livestock survival. The country has also received assistance from external donors whose drought management-related projects have brought new insights and possibilities.

The GoM has implemented measures to address drought and climate variability. These include multi-risk cereal insurance and agricultural and meteorological monitoring. However, as illustrated above, more needs to be done, especially in the strategically important citrus and olive subsectors.

International experience suggests successful drought policy and management is based on Integrated Drought Management Planning (IDMP). IDMP emphasizes drought preparedness and involves three complementary pillars: (i) drought monitoring and early warning; (ii) vulnerability and impact assessment; and (iii) mitigation and response. This report proposes an expanded approach, based on the IDMP, to improve climate-resilient drought responses in Morocco. This approach covers the three IDMP pillars plus drought policy, planning, and risk management.

0.10.1 National Drought Policy

Morocco currently lacks a comprehensive national drought management strategy even though some elements are already in place. For example, Morocco has a well-defined institutional coordination mechanism, but other elements are lacking. To strengthen the government's strategy, policy could be developed through participatory consultations with key public- and private-sector stakeholders. Consultations can take place subnationally in geographic areas historically affected by drought. Government responses to drought can also be more proactive. In the past, drought response has not started until a crisis was declared. If more drought preparedness measures are taken beforehand, drought management will be more successful.

Drought management policy could link drought risk and climate change and variability. This includes short-term coping and longer-term climate change adaption. These linkages could be integrated into national drought policy and subnational drought management plans. Ongoing technical assistance, capacity building, and regular information exchange among national and international institutions in the Middle East and North Africa region and elsewhere could also prove helpful.

0.10.2 General Approach to Drought Planning and Management

It is recommended that Morocco proactively manage risk rather than reactively respond to crises as in the past. To be more proactive, more integrated drought monitoring and practical up-front drought planning and capacity development would help. These, and other institutional strengthening and investment activities, will become even more important as drought and water scarcity becomes more severe and widespread, affecting new sectors and communities. While some proactive drought risk management has taken place, its implementation has often proven problematic.

Drought risk management and water resource management go hand-in-hand and can be integrated into agricultural sector planning. Short-term benefits from increased, authorized and

BOX 0.4 Examples of Drought and Agricultural Production Monitoring in Morocco

Drought monitoring through remote sensing. Since 2014, the *Centre Royal de Télédétection Spatiale* (CRTS) has produced a monthly national drought map using a composite drought index (CDI). The CDI's values are produced from remotely sensed and modeled data at grid cells of a 25 × 25 kilometer resolution, which is relatively coarse. The resulting map is provided to partners and government stakeholders. These include the Ministry of Agriculture and Marine Fisheries (MAPM), Ministry of Interior, *Direction de la Recherche et de la Planification de l'Eau* (DRPE, Directorate for Water Research and Planning) and the *Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification* (HCEFLCD, High Commission for Water, Forests and the Fight against Desertification). Despite providing these maps to stakeholders, the maps are often not seen by technical staff.

Seasonal forecasting and observational monitoring. The National Meteorological Department (DNM) produces short-term and seasonal (3 month) forecasts through climate modeling and data from 206 automatic weather stations and 42 synoptic stations. Seasonal forecasts include information on Deciles, the Palmer Drought Severity Index (PDSI),[7] and the Standardized Precipitation Index (SPI).[8] The Standardized Precipitation-Evapotranspiration Index (SPEI),[9] an index that is produced for past periods only, is also forecasted. Forecasting information is provided to stakeholders every month at formal conventions. Through special requests, past SPI and land-surface temperature information may be shared. The DNM provides daily meteorological data to agricultural and water management stakeholders. This includes data on temperature, precipitation, solar irradiance, and actual evapotranspiration. In most cases, this information is provided automatically.

Agricultural and hydrological monitoring. Several agencies observe and monitor agricultural and hydrological drought conditions. These agencies include the MAPM, DRPE, basin authorities (ABHs), the *Institut National de la Recherche Agronomique* (INRA, National Institute for Agricultural Research), and the HCEFLCD for rangelands and forest areas. After official drought declarations, these monitoring activities inform management interventions, such as agricultural climate risk insurance payouts. Monitoring activities estimate the size of (i) cultivated areas by using irrigation district surveys, (ii) vegetative areas by using the Normalized Difference Vegetation Index (NDVI),[10] and (iii) livestock areas by using extension and veterinary services. Agricultural input and commodity prices, in both wholesale and commercial markets, are also monitored.

unauthorized, ground water extraction could be assessed against likely long-term costs. This critical trade-off requires a long-term, cross-sectoral approach.

0.10.3 Drought Monitoring and Early Warning

National institutions could develop scientifically rigorous drought onset indicators for Morocco. Once defined, these indicators could be the starting point for improved coordination and cooperation efforts among the various agencies responsible for drought management. This would build on other successful drought monitoring initiatives in the country (see Box 0.4). In preparing the World

[7] This index uses readily available temperature and precipitation data to measure relative dryness.

[8] This is a widely used index to characterize meteorological drought. It allows an analyst to determine the rarity of a drought at a given time scale (temporal resolution) of interest for any rainfall station with historical data.

[9] As its name suggests, this index is designed to take both precipitation and evapotranspiration into account in determining the onset, duration, and magnitude of drought conditions.

[10] This index measures the "greenness" and vigor of vegetation over a seven-day period as a way of identifying drought-induced stress.

Bank's Inclusive Green Growth Development Policy Loan in 2015, agrometeorological information was shared between the National Meteorological Agency (DNM) and the Ministry of Agriculture, Water Fisheries, Rural Development, and Forests (MAPMDREF). This improved the coordination between these two agencies. Increased line ministry collaboration will help strengthen Morocco's overall drought preparedness.

There is a need to better involve local experts who can identify and verify drought conditions. Developing expert networks generates feedback and strengthens drought monitoring efforts. This information would help mapping accuracy. Linking drought maps and related data to seasonal forecasts and hydrological modeling systems' scenario planning supports short- and longer-term decision making. Expert networks can improve local ownership over drought risk management processes. More local links and improved mapping could also improve coordination among the national and water basin levels, as promoted under the new water law.

0.10.4 Vulnerability and Impact Assessments

Up-front impact and vulnerability assessments in drought-prone areas also build preparedness. Assessments can be undertaken at varying spatial scales, including at the regional and river basin levels, and inform local drought preparedness plans. A successful example of this relationship took place in arid Northeast Brazil, where a regional Drought Monitor is now fully operational.

0.10.5 Drought Mitigation and Response

Morocco would benefit from establishing strong institutional coordination mechanisms. A single authority could allocate resources, coordinate agency roles, and generally lead drought management-related decision making. This could improve information-sharing and help establish "triggers." Triggers would use accurate information on an area's drought sensitivity, and the predicted severity and duration of droughts, to initiate drought management actions.

The GoM could explicitly recognize the link between droughts and global climate change and variability. Morocco's national climate change adaptation plan, submitted in 2015 to the United Nations Framework Convention of Climate Change (UNFCCC), includes various measures to manage both floods and water scarcity. These measures listed in the plan include: constructing dams to prevent foods, converting surface and sprinkler irrigation to drip irrigation; and replacing a million hectares of grain crops with fruit plantations. However, the plan never specifically mentions droughts. This further underscores the need for Morocco to integrate drought management and climate change adaptation with water resource management and agricultural sector planning.

CHAPTER
ONE

INTRODUCTION

This report explores the impacts of climate variability,[11] including the 2015–2016 El Niño and other teleconnections, and of the associated increasingly frequent and severe droughts on the agricultural (including livestock) sector in Morocco. It will also examine past and present efforts by the Moroccan Government to address these impacts, including both good practices and gaps that still need to be filled. And it will make recommendations for future actions that the country could consider taking in order to strengthen its approach to drought management, again with a particular focus on agriculture and associated water resource management concerns. Climate-related impacts on two key value chains – citrus and olives – will provide more specific examples of these effects. These value chains were considered more specifically at the request of the Moroccan Government. In carrying out this analysis, this report builds on and updates information for the Middle East and North Africa region as a whole and Morocco in particular that was provided in the earlier World Bank publication, *Adaptation to a Changing Climate in the Arab Countries: A Case for Adaptation Governance and Leadership in Building Climate Resilience* (Verner 2012).

Droughts often have severe impacts on agricultural production and yields, and, thus, on people's livelihoods and welfare. Poor small farmers, rural workers, and their communities are generally the most adversely affected. However, droughts can have significant macroeconomic impacts as well, as national food security needs frequently require increased imports to offset domestic output declines, and the same may be true of crops used for animal fodder. Agricultural exports are also likely to be reduced as a result. Insufficient and/or highly variable rainfall likewise tends to result in increased pressure on, often already declining, groundwater resources, especially for irrigated agriculture, which has serious implications for their long-run sustainability. Thus, drought events can have a very broad range of social, economic, and environmental impacts.

As the main concern of this report is with making drought management more effective in the face of increasing climate variability and change, this introductory chapter will briefly describe the nature

[11] It is important to differentiate between climate variability and climate change. Climate variability refers to variations in the mean state of precipitation and other climate statistics on all temporal and spatial scales, while climate change is generally understood to mean long-term change in the earth's climate, especially a change due to an increase in the average atmospheric temperature, which is often commonly referred to as global warming. Drought events are examples of climate variability but also appear to be increasing in frequency and severity as the result of global climate change.

of droughts and the recommended approach to national drought policy and interventions based on evolving international experience. This experience was reviewed for selected developed and developing countries, including elsewhere in Middle East and North Africa,[12] as part of the present study and has been summarized in a background paper (Redwood 2017). This experience is also reflected in recently published World Bank–supported books on drought management challenges and opportunities in Sub-Saharan Africa (Cervigni and Morris 2016) and Brazil (De Nys, Engle, and Magalhães 2017).

Following this Introduction, the balance of this report will be divided into four chapters. Chapter 2 and its annexes will consider recent evidence regarding climate change and variability and drought in Morocco, including the possible impact of the recent El Niño and other relevant climate phenomena known as teleconnections. Chapter 3 and its annexes will examine the impact of recent droughts on the agricultural sector in Morocco, including their effects on two economically important agricultural value chains, citrus and olives, which are assessed in greater detail in other Bank analytical work (World Bank 2017). Chapter 4 will describe the evolution and nature of Morocco's efforts to address droughts and their impacts on the agricultural sector, and Chapter 5 will present the study's principal suggested policy options.

The nature of droughts. A drought can be defined as "an extended period of deficient precipitation compared to the statistical average for a particular region which results in water shortages for some activity, group, or environmental sector".[13] However, numerous definitions exist. Some of the main alternatives are presented in Box 1.1 below. According to the United Nations Food and Agriculture Organization (FAO) and other specialists, there are various types of droughts and differing ways of measuring them:

- **Meteorological drought** is defined by the lack of precipitation over a region for a period of time. Analyses can concentrate on monthly precipitation (e.g., Gibbs 1975) or on cumulative precipitation shortages (e.g., Estrela et al. 2000).
- **Hydrological drought** results from a period with inadequate surface and subsurface water resources for established water uses. Streamflow data is generally applied to hydrological drought analysis (Clausen and Pearson 1995; Dracup et al. 1980). Geology is one of the main factors influencing hydrological droughts (e.g., Vogel and Kroll 1992). Reservoir levels are also an important consideration.
- **Agricultural drought** refers to periods with declining soil moisture and consequent crop failure, or **alternatively**, when there is insufficient soil moisture to meet the needs of a particular crop at a particular time. This typically occurs after a meteorological drought but before a hydrological one. Since crop water demands depend on specific plant characteristics, stage of growth, type and state of soil, and weather conditions, several drought indices, based on a combination of factors (e.g., precipitation, temperature, and soil moisture) have been devised.
- **Socio-economic drought** occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply (AMS 2004), or alternatively, when human activities are affected by reduced precipitation and related water availability and which associates human activities with elements of meteorological, agricultural, and hydrological drought (FAO, n.d.).

[12] Specifically, recent drought management experience was reviewed for Australia, Brazil, India, Iran, Jordan, Lebanon, Mexico, Morocco, Spain, Tunisia, and the United States.

[13] See, for example, FAO and NDMC(2008), 5, and FAO (n.d.).

BOX 1.1 Alternative Definitions of Drought

There is no universal definition of drought, leading to possible confusion as to how to predict them, individuate them while they occur, and respond to them promptly. One of the problems associated with drought is that the nature of water availability and differing demands in various parts of the world have historically resulted in many different views and definitions of drought. However, two main classes of drought definitions exist (Mishra and Singh 2010):

1. Conceptual definitions, which are stated in relative terms, e.g., drought is a long dry period. It is obvious that the understanding of a long-time period will differ in different areas of the world, say, the Northeastern United States, Southern Italy, or the Sahel.
2. Operational definitions, which attempt to identify the onset, severity, and termination of drought periods, leading thus to analysis of drought frequency, severity, and duration for a given return period.

Mishra and Singh (2010) present a number of drought definitions, to show how different they can be:

- drought is "a significant deviation from the normal hydrologic conditions of an area" (Palmer 1965);
- a drought hazard is "the percentage of years when crops fail from the lack of moisture" (FAO 1983);
- drought is a "sustained, extended deficiency in precipitation" (WMO 1986);
- drought is "the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems" (UNCCD 1994);
- drought is "an extended period – a season, a year, or several years – of deficient rainfall relative to the statistical multi-year mean for a region" (Schneider 1996).

Most of the time, but not always, meteorological drought will be the trigger for other types of drought. In addition, some experts also refer to a more specific type of hydrological drought as **groundwater drought**, which can be defined by the decrease of groundwater level (Eltahir and Yeh 1999), of groundwater recharge (Marsh et al. 1994), or of groundwater discharge (Peters et al., 2001). Overexploitation may create a groundwater drought and is a problem especially in arid and semi-arid zones where groundwater has formed over very long time scales due to little to no precipitation throughout the year. This is of particular relevance to countries in the Middle East and North Africa region, including Morocco, as one of the typical responses of farmers to agricultural drought, especially those depending on irrigation, is increased exploitation of groundwater, which is already in comparatively scarce supply.

Over the past few decades, droughts have become more frequent and intense worldwide, affecting both developed and developing countries. Projections by the Intergovernmental Panel on Climate Change (IPCC) indicate that they are likely to become even more so in the future due to global climate change. This source affirms that, while regional droughts have occurred in the past, the widespread extent of drought conditions in various parts of the world is broadly consistent with the expected changes in the hydrological cycle under global warming. Droughts in some areas are often more severe in El Niño years such as 2016 although the certainty and severity of their effects vary in accordance with countries' geographic location as will be further assessed in the next chapter.

Drought Impacts. Droughts, which have also been described as "a slow, creeping natural disaster," often have significant direct and indirect economic, social, and environmental impacts. They particularly affect agriculture and related sectors, such as livestock, forestry, and inland fisheries, because of their strong reliance on surface and subsurface water supplies. Direct generic impacts of drought include, *inter alia*: (i) reduced crop, rangeland, and forest productivity; (ii) reduced water levels in rivers, lakes, and reservoirs and, thus, increased water shortages; (iii) increased fire hazards; (iv) damage to wildlife and fish habitats; (iv) higher livestock and wildlife mortality rates; (v) insect infestations; (vi) increased plant disease; and (vii) greater wind and soil erosion. Increased erosion often leads to increasing desertification, which is defined as "the degradation of land in arid, semi-arid, and other areas with a dry season caused primarily by over-exploitation and inappropriate [land] use interacting with climate variance" (FAO and NDMC 2008). Potential indirect impacts include: (i) reduced income for farmers and agro-businesses; (ii) increased prices for food and other primary products; (iii) rural unemployment; (iv) lower tax revenues; (v) increased crime and insecurity; and (vi) stepped-up migration to urban areas and elsewhere.

Even though the incidence and intensity of droughts appear to be increasing worldwide in association with climate change, developing countries are generally more vulnerable than higher income ones to their adverse effects. Among the reasons for this is that dryland populations tend to be concentrated to a greater extent in developing countries and employed to a relatively greater extent in the agricultural sector. This is particularly the case in low and lower middle income countries like many of those in Sub-Saharan Africa, South Asia, and Middle East and North Africa, where agriculture is also responsible for a comparatively high share of total freshwater extraction that also clearly varies by country income level (see Table 1.1 below). Drought-related economic losses likewise tend to be significantly higher as a proportion of Gross National Income (GNI) in the developing world, according to FAO. In general, moreover, developing nations and their poor rural populations in particular are comparatively less well prepared to confront droughts and their impacts.

International Response. Over the past several decades, the international community has increasingly recognized the economic, social, and environmental risks associated with droughts as well as the likelihood that their future impacts will be exacerbated by climate change. Among other responses, this led to convening a High-Level Meeting on National Drought Policy (HMNDP) by the World Meteorological Organization (WMO), the United Nations Convention to Combat Desertification (UNCCD), and FAO in collaboration with other UN agencies in Geneva in March 2013. The Final Declaration from this Meeting encouraged all Governments "to develop and implement National Drought Management Policies, consistent with their national development laws, conditions, capabilities and objectives," accompanied *inter alia* by the following:

- Development of proactive drought impact mitigation, preventive and planning measures; risk management; fostering of science, appropriate technology, and innovation; public outreach; and resource management.
- Promotion of greater collaboration to enhance the quality of local/national/regional/global observation networks and delivery systems.
- Improvement of public awareness about drought risk and preparedness for drought.
- Consideration, where possible within the legal framework of each country, of economic instruments and financial strategies, including risk reduction, risk sharing, and risk transfer tools in drought management plans.
- Establishment of emergency response plans based on sound management of natural resources and self-help at appropriate governance levels.
- Integration of drought management plans with local and national development policies. (HMNDP 2012).

TABLE 1.1 Per Capita Gross National Income, Rural Population, and Share of Labor Force in Agriculture and Agriculture as a Share of Water Withdrawal for Selected Countries, Regions, and Income Groups

Country/Region	Per Capita GNI (US$) (World Bank Atlas Method)	Rural Population Share (%)	Share of Labor Force in Agriculture		Agriculture as a Share of Total Freshwater Withdrawal (%)
			Male (%)	Female (%)	
United States	55,230	18.6	2.3	0.9	40
Spain	29,390	20.6	6.0	2.1	64
Australia	64,600	10.7	3.5	1.7	66
India	1,570	67.6	NA	NA	90
Mexico	9,870	21.0	18.8	3.7	77
Brazil	11,790	14.6	17.5	10.7	60
Iran	7,120	27.1	NA	NA	92
Jordan	5,160	16.6	NA	NA	65
Lebanon	10,030	12.3	NA	NA	60
Morocco	3,070	40.3	NA*	NA*	88
Tunisia	4,230	33.4	NA*	NA*	80
North America	54,879	18.5	2.3	0.9	38
Europe & Central Asia	26,424	29.3	8.6	7.1	36
Latin America & Caribbean	9,912	20.4	17.9	8.1	72
East Asia & Pacific	9,731	44.3	NA	NA	72
Middle East & North Africa	8,722	36.3	NA	NA	85
Sub-Saharan Africa	1,646	62.8	NA	NA	81
South Asia	1,496	67.4	NA	NA	91
Low Income	628	70.2	NA	NA	90
Lower Middle Income	2,018	61.5	NA	NA	88
Upper Middle Income	7,926	38.2	NA	NA	49
High Income	38,301	19.3	4.0	2.2	43

Sources: World Bank 2016a, 2016d.
Note: Gender disaggregated information was not available (NA) in the *World Development Indicators* for the Middle East and North Africa countries and India for 2013–16. However, according to this source 37.2 percent of the total Moroccan labor force in 2014 and 15.3 percent of that in Tunisia in 2013 was employed in the agricultural sector.

Following the HMNDP, WMO and the Global Water Partnership (GWP), together with the National Drought Mitigation Center (NDMC) at the University of Nebraska–Lincoln (UNL), established an Integrated Drought Management Program (IDMP), which soon thereafter published the rationale and a set of guidelines for development of a National Drought Policy (NDP) or Strategy (NDS). This document lays out a ten-step process for countries to follow in order to prepare a NDP or NDS, which is summarized in Box 1.2 below. This useful framework, which emphasizes the importance of stakeholder participation, can also be used to assess the extent to which specific countries have currently progressed along the recommended path, which contains three main pillars: (i) drought monitoring and early warning; (ii) vulnerability and impact assessment; and (iii) mitigation and response.

BOX 1.2 Proposed Steps in the National Drought Policy/Strategy and Preparedness Process

1. Appoint a national drought management policy/strategy committee.
2. State or define the goals and objectives of a risk-based national drought management policy/strategy.
3. Seek stakeholder participation; define and resolve conflicts between key water use sectors, considering also transboundary implications.
4. Inventory data and financial resources available and identify groups at risk.
5. Prepare/write the key tenets of the national drought management policy/strategy and preparedness plans, including the following elements: monitoring; early warning and prediction; risk and impact assessment; and mitigation and response.
6. Identify research needs and fill institutional gaps.
7. Integrate science and policy aspects of drought management.
8. Publicize the national drought management policy/strategy and preparedness plans and build public awareness and consensus.
9. Develop education programs for all age and stakeholder groups.
10. Evaluate and revise national drought management policy/strategy and supporting preparedness plans.

Source: Adapted from WMO and GWP 2014.

According to this source, governments have traditionally responded to droughts primarily with, often *ad hoc,* emergency assistance measures. However, it argues that this approach is "seriously flawed" from the standpoint of vulnerability reduction since the recipients of government support "are not expected to change behaviors or resource management practices as a condition of the assistance." Instead, it affirms that governments should develop national drought policies/strategies and preparedness plans that focus on risk reduction. It recommends, moreover, that such documents should include organizational frameworks and operational arrangements and that they should be developed "in advance of drought and maintained between drought episodes by governments or other entities," with the complementary objective of generating "improved coordination and collaboration within and between levels of government, stakeholders in the primary impact sectors, and the plethora of private organizations with a vested interest in drought management (i.e., communities, natural resource or irrigation districts or managers, utilities, agribusinesses, farmers' organizations, and others)" (WMO and GWP 2014).

The WMO and GWP, finally, have developed a useful checklist of historical, current, and potential drought impacts, which are broken down into economic, environmental, and social categories. These impacts include the following subcategories, which are of particular relevance for the agricultural, livestock, forestry, and fisheries sectors and for rural areas more generally:

- Economic
  - Losses from crop production
  - Losses from dairy and livestock production
  - Losses from timber production
  - Losses from fisheries production
  - Income losses for farmers and others directly affected
  - Unemployment from drought-related production declines
  - Decline in food production/disrupted food supply

        - Increased groundwater depletion, land subsidence
        - Decreased land prices
    - Environmental
        - Damage to plant species
        - Increased number and severity of fires
        - Wind and water erosion of soils
        - Reservoir, lake and drawdown/reduced levels (including farm pods)
        - Water quality effects (e.g., salt concentration, increased water temperature, etc.)
    - Social
        - Reductions in nutrition (e.g., high-cost food limitations, stress-related dietary deficiencies)
        - Increased conflicts, including with respect to water use, etc.
        - Inequity in drought impacts
        - Reduced quality of life, changes in lifestyle in rural areas
        - Population migration from rural areas.

Overview of the Moroccan Case. Long-term climate change and shorter-term recurrent climate events, such as the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) known as teleconnections, are already making water-scarce countries like Morocco more vulnerable and their dryland agriculture even drier. As a result, an existing problem for farmers is becoming even worse as temperatures rise and rainfall is becoming more sporadic. Morocco's farmers are already experiencing and will continue to suffer from increasing climate variability. Droughts are one of the most significant outcomes of these climate phenomena, and farmers are particularly vulnerable to them as they negatively affect both key rainfed crops, such as wheat and barley, and livestock.

Agriculture and agribusiness/agroindustry are important both for rural communities and the overall Moroccan economy as more than 30 percent of the population is employed in these sectors and they contribute, on average, 20 percent of the country's GDP and 35 percent of its total exports. Wheat and other rainfed crops are among the crops most affected by climate variability, and they are critical for food security and livestock survival in the country. With the increasingly adverse impacts of climate change-associated droughts, their effects translate into a contingent liability for the Moroccan macro economy, including both GDP growth and the balance of payments, as agricultural and agro-industrial outputs and exports fall and food and fodder imports need to rise in order to meet domestic needs. This is why the present report suggests additional action with respect to integrated drought management (IDM) on top of what the Government is already doing.

Multi-year drought and general rainfall variability is a key issue for agriculture in Morocco. Water availability is the most important underlying issue as surface water is becoming scarcer ant this has led farmers to pump more groundwater to supplement irrigation of crops and fruit trees, including citrus and olives, as a way of adapting to the changing climate. This calls for improved water resource management and supervision and better enforcement of existing laws and regulations. International experience in both developed and developing countries reveals that this can be an effective way of addressing both short- and longer-term water scarcity problems.

While the negative effects of ENSO are clearly important from a global perspective, based on original research, this study finds that they were less important than other teleconnections with respect to the most recent (i.e., 2015–16) drought experienced in Morocco and elsewhere in the Middle East and

North Africa region. This report also examines two important crops, citrus and olives, which the Government is currently promoting under its *Plan Vert Maroc* (PMV) in order to determine how and how well they are currently adapting to climate variability and change. The adaptation pathways chosen to secure and increase productivity and incomes in the agricultural sector rightly focus on tree crops that are generally more resilient than field crops. However, improved water management is also an essential part of this adaptation plan.

With improved collaboration across and coordination among public sector institutions and better information access and sharing, farmers will make more effective investments, agribusinesses can become more profitable, and, in combination, this will also contribute to greater income and employment. In addition, the Government could consider elevating and revising its current integrated drought management strategy (IDMS) into a more formal integrated drought management policy (IDMP), as recommended by international organizations including the UN Food and Agricultural Agency (FAO) and the World Meteorological Organization (WMO) and undertaken by numerous countries such as Australia and Mexico. Taking such actions will help Morocco reduce the contingent liability associated with increasing climate variability and drought and help PMV to achieve greater and more sustainable impacts for farmers and the national economy.

CHAPTER
TWO

CLIMATE VARIABILITY AND DROUGHT IN MOROCCO

This chapter reviews the scientific evidence regarding the increasing incidence of climate variability and drought in recent years in Morocco. In doing so, it will focus on the possible contributions of several important teleconnections, including the strong El Niño Southern Oscillation (ENSO) that significantly affected climate conditions in various parts of the world in 2015–2016. It will also begin to consider the implications of increasing climate variability and drought for the agricultural sector in Morocco, whose impacts will be examined in greater detail in Chapter 3.

2.1 OVERVIEW

Climate in Morocco is changing and the country has experienced a large annual mean temperature increase of ~0.5°C per decade since about 1970. This is well above the global mean trend of ~0.15°C per decade over the same period. Recent years have been particularly warm and several temperature records have been broken. Along with the recent warm years a number of very dry wet-seasons have occurred. Although no long-term trend in precipitation amounts presently appears to be detectable, the recent strong year-to-year fluctuations in rainfall have resulted in several years over the past decade in which low precipitation amounts have exacerbated already severe water scarcity. This climate variability, together with its impacts on the agricultural sector, will be discussed in more detail below and in the next chapter. Annex 2.1 provides background information on recent climate variability and change in the Middle East and North Africa region more generally.

With the co-occurrence of the strong El Niño in 2015–16 and drought conditions in parts of the Middle East and North Africa region, it has been hypothesized that the onset of El Niño can be seen as an early warning mechanism for drought-like conditions, including in Morocco. Using a long time series of various climate records, however, no strong linkage between ENSO and drought in Morocco can yet be confirmed. Thus, the information currently available is inconclusive in explaining ENSO's role on Morocco's weather. However, it does highlight the influences of the North Atlantic Oscillation (NAO) and the Mediterranean Oscillation (MO), about which more will be said below. For more definitive results, studies of greater complexity that take correlations between these different modes of climate variability and their interplay with regional geographical features into account are needed.

Climate projections nonetheless indicate that Morocco will continue to experience warming well above the global mean rate. Projections also indicate that winter precipitation will be reduced as warming increases. Even with no change in precipitation, evaporation will increase due to rising temperatures, and surface soil moisture will tend to decrease. Similarly, the availability of water for irrigation using mountain streams and reservoirs will continue to be stressed at an increasing rate. Taken together, the chances are high that widespread drought conditions will occur more frequently and become more severe in Morocco, challenging local agriculture.

Drought, while the principal focus of the present study, is not the only climate-related risk to agriculture. As the climate warms, there is also an increased risk of flash floods from heavy precipitation, resulting in landslides and loss of infrastructure, crops, and arable land. Likewise, very dry conditions enhance the risk of wildfires and the associated loss of property, livestock, and crops. Agricultural practices in Morocco therefore need to be able to better respond to the long-term trends associated with global warming and teleconnections such as NAO, MO, and ENSO. They also need to take into account that annual to decadal fluctuations will occur on top of the mean overall warming trend.

Large-scale international efforts to improve long-term climate and short-term weather predictions are ongoing. Thus, it remains essential for Moroccan authorities to be aware of this work and remain engaged with the specialists focusing on these issues. If the precision of ENSO, NAO, and MO predictions on seasonal multi-year to decadal time scales can be improved, planning crop selections and timing of plantation can also be enhanced.

2.2 THE CLIMATE OF MOROCCO

Morocco's climate is strongly and differentially influenced by its position at the center of three major geographical regions: the Atlantic Ocean to the west, the Mediterranean Sea to the north, and the Sahara Desert to the south. The country's climate is largely typical of that in the Mediterranean Basin more generally with temperatures and precipitation out-of-phase, as hot and dry periods coincide with summer, whereas the winter (October to March) rainfall season is associated with mild temperatures (Xoplaki 2002). Precipitation is slightly bimodal in distribution, with a first peak in late November and a second, smaller one in April (Jlidene and Balaghi 2009). Like other Mediterranean countries, Morocco shares a high inter-annual variability of precipitation. Within the country, the range of physiographic conditions leads to three zones being delineated:

a) The Rif and Atlas Mountains with the highest summit in the latter range, Toubkal, rising to 4,165 meters above sea level;
b) The broad coastal plains inward from the Atlantic Ocean, framed by the arc of the Rif and the Atlas Mountains; and,
c) Plains and valleys south of the Atlas Mountains, which merge with the Sahara Desert along the southern, south-eastern and south-western borders of the country.

The presence of the Sahara together with the local orography make for complex and heterogeneous rainfall patterns, as total annual precipitation ranges from 200 mm in the South to 900 mm in the North (Lamb and Peppler 1987). Precipitation variability extends from 25 percent along the western Atlantic coast to 100 percent in the semi-arid South (Knippertz et al. 2003). Given these variations, three contrasting climatic regions within Morocco are defined by total precipitation levels (see www.worldclim.org): (i) semi-arid superior to subhumid (precipitation: 450-1050 mm, delimited by High Tellian Atlas); (ii) semi-arid (precipitation: 300-450 mm, delimited by Middle Atlas); and, (iii) arid (precipitation: 10–300 mm, delimited by Anti-Saharan Atlas).

Most of the Western Mediterranean rainfall occurs between October and May due to extratropical weather system incursions from the Atlantic Ocean and to a lesser extent from Europe, bringing cold air and cloudiness. The typical rainfall distribution is characterized by a negative gradient from north to south. It is also affected by the barrier from the high Atlas Mountain chain, which receives high amounts of precipitation exceeding one meter annually and efficiently shadowing the eastern part of the country, while the Sahara Desert begins at the southwestern edge of the mountain chain.

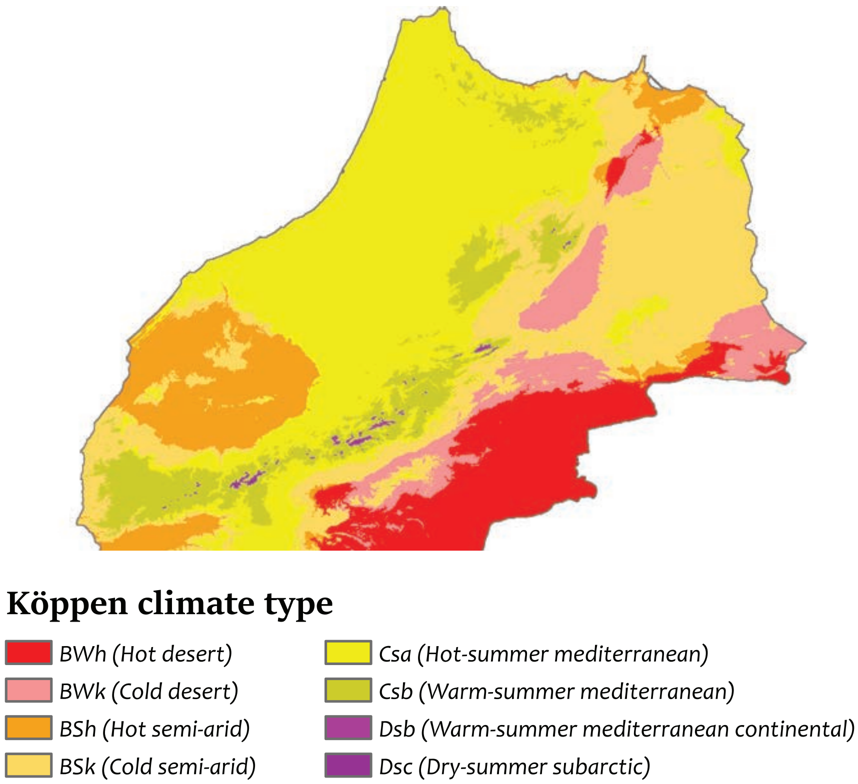
In summary, coastal Morocco has a moderate, subtropical climate with cool sea breezes from the Atlantic Ocean and the Mediterranean. Temperatures in the interior are more extreme. Climate and temperature also vary with the terrain. In the desert region in the south and southeastern part of Morocco temperatures are high, while in the mountain ranges it can be freezing at night time and mountain peaks are sometimes snowcapped throughout the year. While winters are cold and rough, summers are moderately warm here. On the western slopes of the Central and High Atlas Mountains rainfall and snow are significant from November to April. Nevertheless, some convective clouds occasionally develop even during the dry season when subtropical maritime air masses converge in the region. Summer is generally dry and hot and daily maximum temperatures exceeding 40°C are a common feature of the continental areas towards the Sahara.

Figure 2.1 below depicts the general climatological setting of Morocco using the Köppen classification (e.g., Kottek et al. 2006) that depicts temperature and precipitation information in combination. Note in particular the steep climatological gradient between the Mediterranean and the southern and southeastern parts of the country, from warm Mediterranean to hot dessert climate. The high and dense Atlas Mountains elongated perpendicular to the general atmospheric flow makes this part of Morocco not only fertile and extremely important for agriculture but also functions as a water reservoir that enables irrigation and furthers agricultural practices in the lowlands within the mountains and to the north and west.

The climate of the arable part of Morocco thus is Mediterranean, characterized by hot dry summers and cool moist winters that determine the growing period. Precipitation is irregular and rainfall varies considerably from the relatively moist coast over the generally rain- or snow-fed mountains to the desert-like conditions south and to the east of the Atlas mountain range. Although little precipitation reaches the Sahara Desert on the eastern side of the Atlas and into Algeria, the region receives its moisture from river streams originating in the mountains. Figure 2.2 portrays the seasonality of precipitation for Morocco and the geographical setting emphasizing the complex topographical setting of the Atlas Mountains.

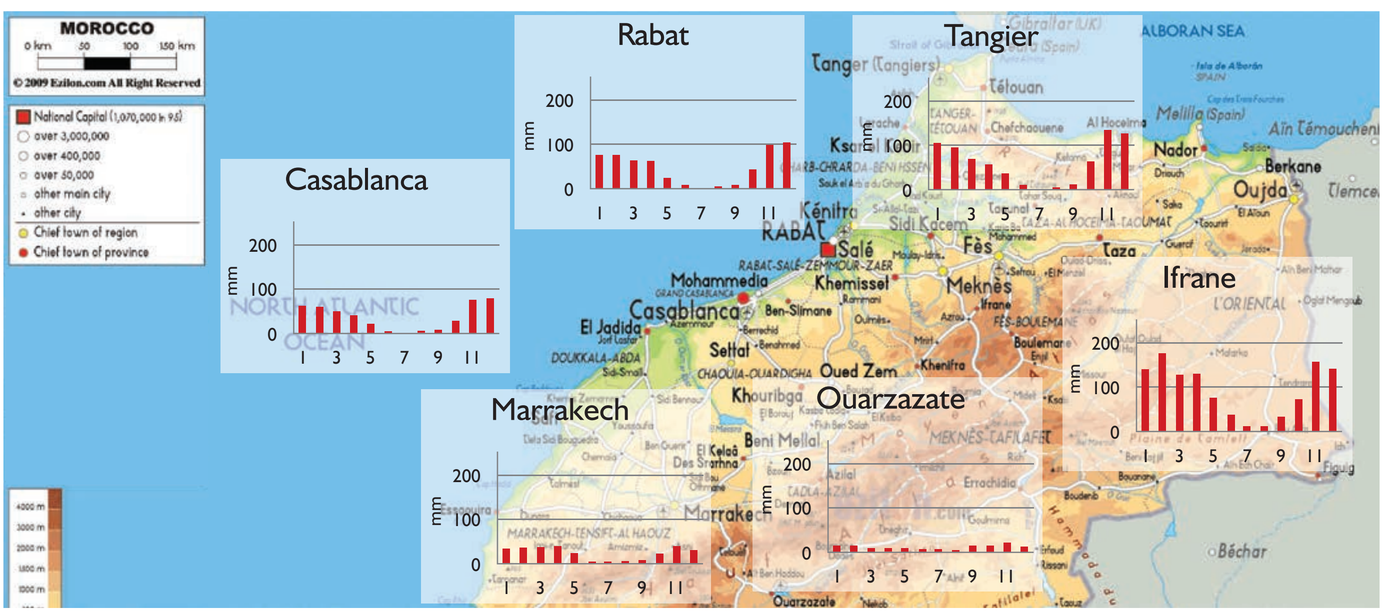
The fertile areas near the Atlantic and Mediterranean coastlines, in short, are hydrated by their proximity to the sea. The Atlas Mountains form a high barrier that virtually wrings water from the clouds, due to the effect of ascending moist air being cooled and then released as precipitation. This rain (and during winters regularly snow) creates rivers and streams that run through the mountain villages and water the valley farms. Precipitation data from representative stations over a 30 year period (1961–1990), interpreted using a topographical height-dependent interpolation algorithm,

FIGURE 2.1 Morocco Natural Climate Zones according to the Köppen Classification



Source: Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Morocco_koppen.svg.

FIGURE 2.2 Monthly Mean Precipitation in mm (1961–1990) for Eight Quality-checked and Homogenized Data Series Representing the Moroccan Climate



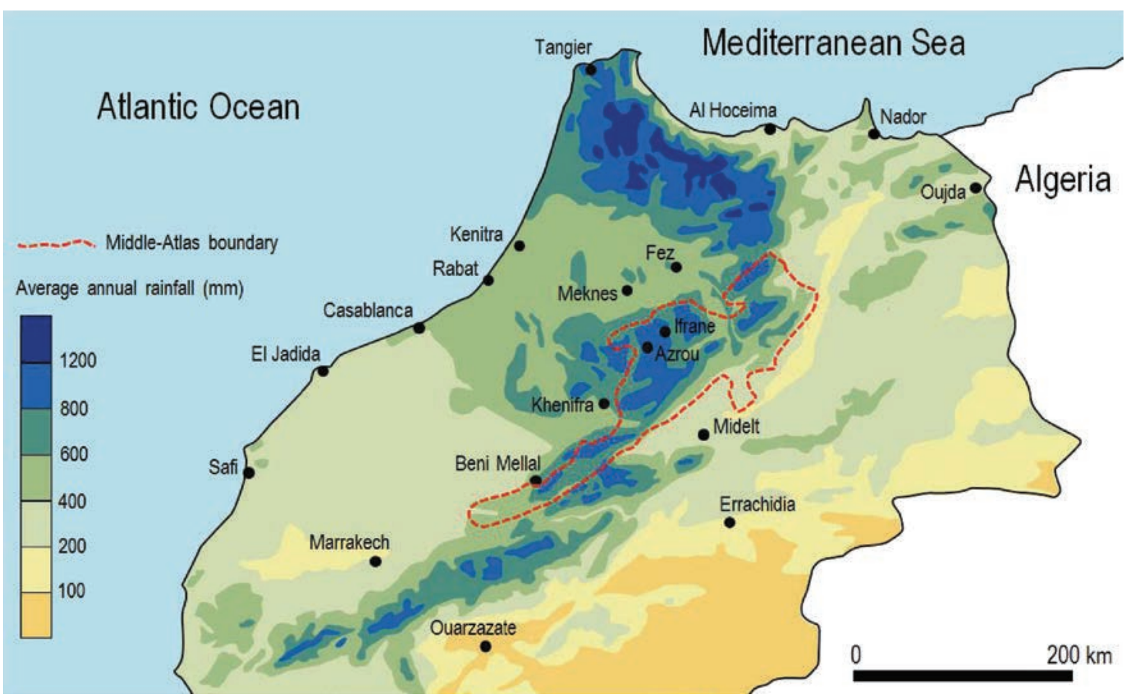
Source: KNMI Climate Explorer, https://climexp.knmi.nl/selectstation.cgi?id=someone@somewhere.

are depicted in Figure 2.3 (from Royaume du Maroc 2000). Moroccan agriculture is greatly dependent on rainfall. The rainfed area represents 85 percent of total arable land, which is about 87,000 km^2, concentrated in the northwest part of the country (e.g., European Union FP7 project E-AGRI, http://www.e- agri.info/study_area_01.html).

The Mediterranean-like climates of the Earth, however, are among the most vulnerable to the pressure from ongoing and projected future global climate change. This has been pointed out in several Intergovernmental Panel on Climate Change (IPCC) reports (Christensen et al. 2007, 2013). It is also reflected in the temperature trends experienced in the region. Annex 2.2 portrays the annual mean temperature and precipitation trends for four climate monitoring stations in Morocco, with a reasonably complete time span coverage to illustrate these temperature trends.[14] As is also evident from the IPCC's fifth Annual Report (AR5, Hartman et al. 2013), Morocco has experienced a warming trend of ~0.5 °C per decade since about 1970, which is well above the global mean trend of ~0.15 °C per decade for the same period. It should be noted, however, that temperature trends may differ substantially due to local conditions, and the overall trend across the entirety of Morocco may actually have been realized, as depicted differently from that observed at the four geographically well-distributed stations considered in Annex 2.2.

While temperature changes worldwide appear to be evolving in a largely coherent fashion with the global mean temperature (although with varying amplitude), precipitation trends and long-term changes are much less clear. Rainfall variations are often a complex consequence of changes in large-scale drivers

FIGURE 2.3 Climate Setting: Mean Annual Precipitation over Northern and Central Morocco



Source: Royaume du Maroc 2000.

[14] Casablanca and Marrakech have the most complete series and span nearly 100 years of data with the most recent data being from 2015.

(e.g., radiative forcing due to enhanced greenhouse effect) together with local and regional feedbacks that may well operate in opposing directions. Hartman et al. (2013) have reported, for instance, that most of the Mediterranean region has experienced a drying trend between 1950 and 2010. But station data from Morocco (although incomplete) are inconclusive in confirming such an overall trend. Rather, the time series indicates large inter-annual and decadal variations that cannot be directly linked to global or even regional warming trends.

2.3 DROUGHTS AND THEIR CAUSES IN MOROCCO

The increasing shortage of available water is a significant constraint for economic and social development in Morocco. This is a result both of natural conditions (aridity and drought) and poor water management practices and decision-making (water scarcity and desertification) leading to increased water insecurity (see Figure 2.4). Political unrest, economic dislocation, growing population, the lack of international agreements over shared water resources, and poor water management all pose threats to the country against a background of increasing risks from the present and predicted future meteorological and climatological characteristics of the region (Gleick 2014).

Over the last decade, population growth, through both natural increase and forced migration, together with the expansion of agricultural, energy, and industrial activities has increased the demand for water in Morocco at a time of growing contamination of water supplies and limited investment in water and sanitation services. Rapid urbanization also contributes to increasing water scarcity, as the development of adequate infrastructure to respond to human needs has frequently not kept up with the growth of population. At the same time, natural water availability is affected by aridity and droughts, particularly in more humid and semi-arid areas where agriculture is predominantly rainfed. Aridity denotes a permanent or semi-permanent local condition in which precipitation is reduced and so are natural water resources. In addition, parts of coastal Morocco have experienced increasing salinity of both groundwater and soils in recent decades.

Beyond increasing aridity, Morocco is projected to experience an increased risk of summer drought. Drylands (i.e., arid and semi-arid areas) are particularly prone to drought, because their rainfall amounts critically depend on a few events, and there is often little stored renewable water available to offset resource deficits (Sun et al. 2006). These regions also typically show strong spatial and temporal variability in rainfall. A drought is distinct from a heat wave, as the latter typically occurs over the time scale of a week, while droughts often persist for months or years (Chang and Wallace 1987). Droughts are slower to develop, longer lasting with impacts increasing over time, and less predictable than other climate extremes, such as floods. Furthermore, drought is not necessarily related to an increase in temperature. Several recent research papers have shown, however, that climate change is resulting in an increase in drought frequency and intensity in the Mediterranean region, especially through the

FIGURE 2.4 Limited Water Availability across Different Time Scales and Causes Are Defined Using Specific Terms

	Short-/Mid-Time Scale or Temporary	Long-Time Scale or Quasi-Permanent
Natural	Drought	Aridity
Human-made	Water Scarcity	Desertification

Source: Pereira et al. 2002; Van Loon and Van Lanen 2013.

effects of reduced winter rainfall and increasing evapotranspiration (Hoerling et. al. 2012; Mathbout and Skaf 2010; Romanou et al. 2010).

Teleconnections. Understanding why droughts occur is one of the first steps to being able to predict such events in the future and to take action to prevent their negative impacts on people's incomes and wellbeing. The underlying atmospheric conditions that cause drought are large-scale high pressure systems over an area for a period of time that prevent low pressure rain-bearing frontal systems from moving into this area or for convectional uplift conditions to persist. The changes in large-scale atmospheric dynamics that bring about these more local conditions are still poorly understood, including the role of the influences known as teleconnections (from the Greek word for "faraway", and the English word "connection"). They are defined as recurring and persistent large-scale patterns of pressure and circulation anomalies over vast geographical areas, or, more simply, as atmospheric interactions between widely separated regions of the Earth (Glantz 1994).

Teleconnections can last from weeks to months at a time. They can appear for several consecutive years, and, thus, they can play a major role in inter-annual and inter-decadal atmospheric variability. Since they can affect temperature, precipitation, storm tracks, and jet stream location and intensity, they are often responsible for abnormal weather patterns, simultaneously affecting distant areas (Barnston and Livezey 1987; Barnston and Livezey 1991; Mo and Livezey 1986). Different teleconnections are found around the globe, and their strengths and phases are often characterized by particular indexes, about which more will be said below. The most important teleconnections for the Middle East and North Africa region are the North Atlantic Oscillation (NAO, MO, and ENSO.

El Niño is the best known coupled ocean-atmosphere phenomenon that causes global climate variability on seasonal to inter-annual time scales (Wolter and Timlin 2011). While ENSO clearly influences areas in Asia and Africa, as well as North and South America, its impact on North Africa is generally weak. Simulations by Merkel and Latif (2002) using a fully coupled climate model suggest that El Niño could weaken the North Atlantic mean meridional pressure gradient, causing a southward shift of the North Atlantic storm-track that, in turn, has been shown to produce a weakening of the NAO and generate wetter conditions over central Europe and the western Mediterranean (Hurrell and van Loon 1997). Research has revealed possible links between European and Mediterranean climate and ENSO (Lloyd-Hughes and Saunders 2002; Shaman 2014), as well as with drought in Morocco (Mariotti et. al. 2002). However, evidence remains sparse, and not much work has been carried out or is available in the literature with respect to the effects of ENSO on North Africa and its relationship with other teleconnections influencing the region.

The NAO is among the most prominent teleconnection patterns that are known to affect large parts of the Middle East and North Africa region, especially Morocco, throughout the year (Barnston and Livezey 1987). The NAO consists of a north-south dipole of air pressure anomalies, with one center located south of Iceland and the other, of opposite sign, situated over the Azores (between 35°N and 40°N). The positive phase of the NAO indicates below-normal pressure across the high latitudes of the North Atlantic and above-normal pressure over the central North Atlantic, the eastern United States, and Western Europe. The negative phase indicates an opposite pattern of pressure anomalies over these regions.

Observations, reanalysis, and climate reconstruction over decades and centuries suggest that the NAO is the dominant influence on large-scale patterns of winter precipitation, river flow, and surface temperatures across the Middle and Near East. The NAO is also a very important driver for western and southern Mediterranean precipitation. Winter rainfall over southern Europe and North Africa has declined since the 1970s because of a strongly positive phase in the NAO. The North Atlantic Oscillation Index (NAOI) is calculated through a technique known as the Rotated Principal Component Analysis (Barnston and Livezey 1987) applied to monthly mean standardized 500-mb height anomalies obtained from the Climate Data Assimilation System (CDAS) in the 20°N–90°N region between January 1950 and December 2000. For each month, teleconnection indices are calculated as the solution to the Least Squares system of equations that explains the most spatial variance of the observed standardized height anomaly field.[15] The MO and Western Mediterranean Oscillations (WeMO), which are described in Box 2.1 below, also impact parts of the Middle East and North Africa region, but affect Morocco to a lesser extent than the NAO.

Droughts in Morocco. Inter-year climate variability, including drought, is an increasingly common phenomenon in Morocco. To understand this more fully, meteorological data for 38 synoptic stations covering the broad latitudinal, orographic, and agro-climatic diversity within Morocco, provided by the Direction de la Meteorologie Nationale (DNM), were analyzed. For a number of representative stations within the main climatic zones where agriculture is important, 9-month Standard Precipitation

BOX 2.1 The Mediterranean and Western Mediterranean Oscillations

Conte et al. (1989) introduced the concept of Mediterranean Oscillation (MO), studying the presence of synchronized, but opposed, atmospheric behavior between its eastern and western sub-basins. The low-frequency pattern of the MO produces opposed anomalies between the extremities across the basin, affecting pressure, temperature, and precipitation regimes. The influence of the MO on Mediterranean climate variability has been studied by many researchers (Baldi et al. 2004; Corte-Real et al. 1995; Kutiel and Paz 1998; Maheras et al. 1999b; Palmieri et al. 2001; Palutikof et al. 1996; Piervitali et al. 1997; Xoplaki et al. 2003). With specific reference to precipitation, research has highlighted that the MO is the most important low-frequency driver (Douguédroit 1998; Dünkeloh and Jacobeit 2003; Kutiel et al. 1996; Maheras et al. 1999;). Several methods have been used to measure the Mediterranean Oscillation. The Mediterranean Oscillation Index (MOI), given by Conte et al. (1989) and Palutikof et al. (1996), is defined as the normalized pressure difference between Algiers (36.4°N, 3.1°E) and Cairo (30.1°N, 31.4°E). The MOI data are calculated through 16 point Bessel interpolation of National Center for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) reanalysis of pressure data and provided by the Climate Research Unit (CRU).

In addition to the MO, Martin-Vide and Lopez-Bustins (2006) proposed a new regional teleconnection pattern, the Western Mediterranean Oscillation (WeMO), initially to try to explain the poor relationship between the weather patterns in the eastern Iberian Peninsula and the North Atlantic Oscillation (NAO). It was defined as the difference in pressure between the Po plain, in the north of the Italian peninsula, and the Gulf of Cadiz in the southwest of the Iberian Peninsula, with its positive phase being when pressure in Cadiz is higher than in the Po region. The Western Mediterranean Oscillation Index (WeMOI) has been used in studies to explain daily time scale to heavy rainfall events (Martin-Vide and Lopez-Bustins 2006; Martin-Vide et al. 2008), convective rainfall (López-Bustins and Azorín-Molina 2004), sea-breeze occurrence (Azorin-Molina and Lopez-Bustins 2008), urban heat island (Lopez-Bustins et al. 2006), sunshine variability (Lopez-Bustins and Sanchez-Lorenzo 2006), and winter rainfall trends (Lopez-Bustins et al. 2008; Oliva et al. 2006). These teleconnections or circulation indices will be used in detail to attribute the likely large-scale cause for agricultural droughts in Morocco later in this chapter.

[15] For more information on the RPCA technique, see www.cpc.ncep.noaa.gov/data/teledoc/teleindcalc.shtml.

Indices (SPIs) for the rainy season were generated (September to May for the lower elevation areas and September to June for the North and the mountains). The results, which are presented in Annex 2.3, illustrate the high variability throughout the country and even between meteorological stations in the same zones. Some of the greatest variability is in the humid and east semi-arid areas, which are zones of rainfed agricultural significance, so these dynamics are highly likely to impact production.

Analyzing possible links between teleconnections and Morocco drought. The abnormal atmospheric conditions that bring drought are characterized by high-pressure systems remaining over an area that suppress rainfall. These changes can be linked to variations in large-scale atmospheric systems (oscillations) that result from pressure, wind, temperature, and precipitation dynamics. The causes of these natural variations are not always well understood, with some linked to abnormal terrestrial or oceanic warming and cooling. The links between droughts in Morocco and atmospheric variations have been analyzed by some researchers with, as indicated above, the NAO found to be a strong influence. Xoplaki et al. (2004) attributed dry conditions over the Mediterranean area since the late 1970s to the persistence of the positive phase of the NAO, while Lamb and Peppler (1987) showed the connection between the NAO and winter precipitation over the Atlantic coast of Morocco. Trigo et al. (2004), among others, have shown that negative phases of NAO have had strong influences on precipitation anomalies over this region during winter months.

In the present study, correlations between teleconnection indexes and agro-climatic regions' Standard Precipitation index (SPI) values were analyzed to further explore the possible links between different teleconnections and precipitation anomalies in Morocco. The analysis examined links between drought precipitation anomalies in Morocco and teleconnections from 1990–2014 (the available meteorological station data) and their correlation with ENSO, NAO, MO, and WeMO.[16] For Morocco, the correlation between each teleconnection index and the 3-month SPI[17] was undertaken. Given that the agricultural season in Morocco is from October to June, the correlation was calculated with respect to nine three-month periods, which are displayed in Figures 2.5 and 2.6. The first shows the correlation of SPI and teleconnection indexes when the latter is positive and the second the results when teleconnection indices are in the negative phase.

As the severe drought of 2015–2016 took place during a strong ENSO event, the pertinent index was included in the analysis. However, this study confirms that the evidence is sketchy at best, with a weak negative correlation during La Niña phases the most prominent in the humid region of the country. The influences of the two major teleconnections operating in the area, the MO and NAO, are much clearer in both the humid and the semi-arid areas. The MO positive phase correlates with negative precipitation anomalies in particular during December and February. The NAO during its positive phase affects late autumn positive precipitation anomalies, and the negative phase influences in the sub-humid areas in early spring.

Additional analysis was undertaken at a more localized station level to identify influences. The results are presented in Annex 2.4, which highlights the strong negative precipitation anomaly correlation to the

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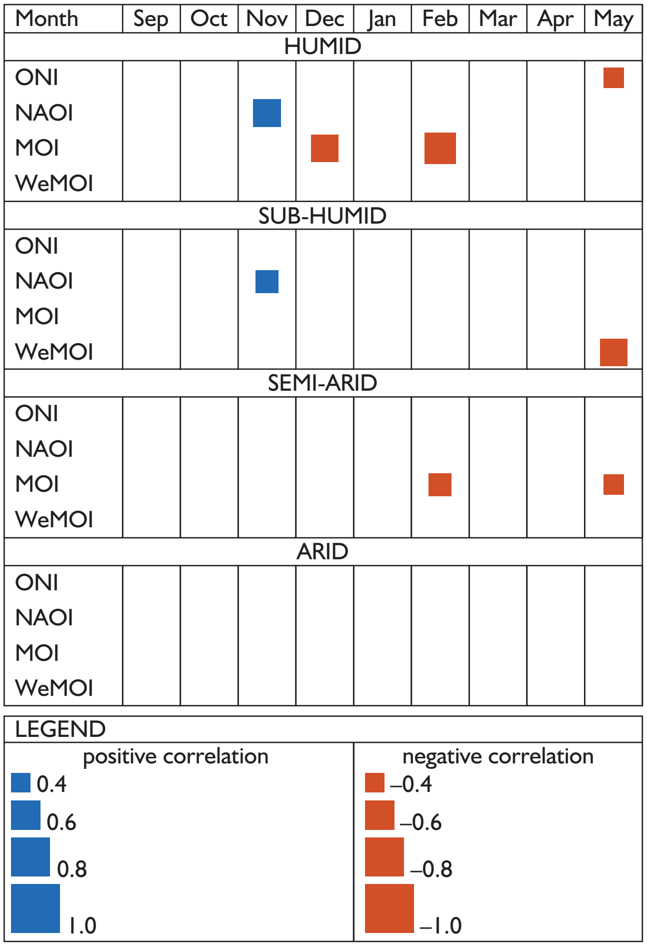
[16] The Oceanic Niño Index (ONI) was used to capture the variations and phases in ENSO and the NAO Index (NAOI), the MO Index (MOI), and the WeMO index (WeMOI) to capture those for NOA, MO, and WeMO, respectively.

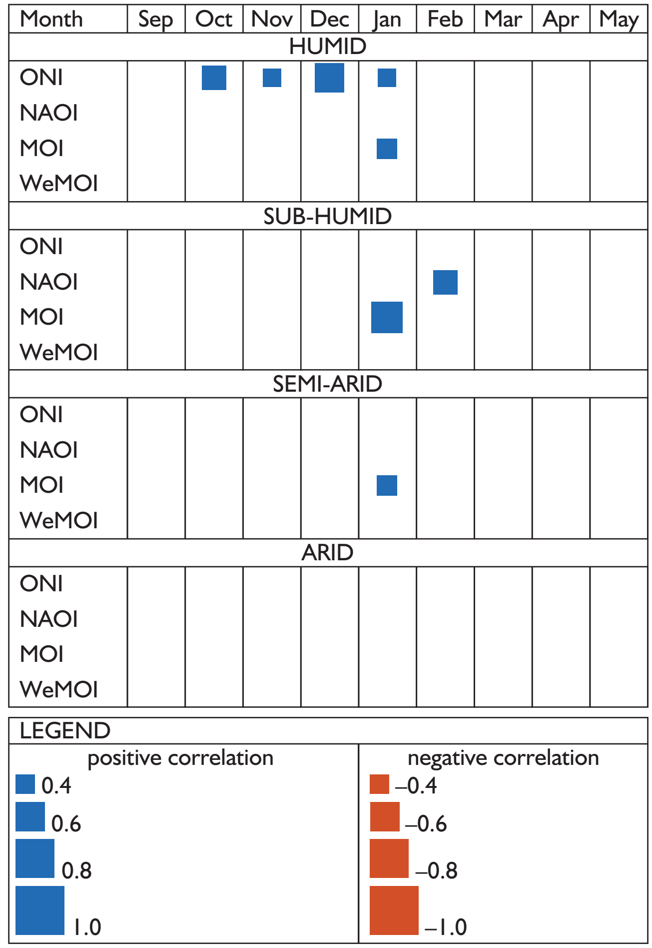
[17] The World Meteorological Organization (WMO) regards the 3-month SPI as the most effective index to establish moisture availability for agricultural purposes. From the climatological point of view, drought is defined as five consecutive months of negative 3-months SPI.

FIGURE 2.5 Correlation Values for the Positive Phases of the Teleconnection Indexes



Source: Original research by ICBA Climate Change & Adaption Team.
Note: Correlations with at least an 80 percent confidence interval and a 0.40 correlation. Positive correlation, resulting in increased positive precipitation anomaly, indicated in blue; negative correlation in red. The size of the squares indicates the correlation value and ranges from 0.40 to 0.67. ONI = Oceanic Niño Index; NAOI = North Atlantic Oscillation Index; MOI = Mediterranean Oscillation Index; WeMOI = Western Mediterranean Oscillation Index.

FIGURE 2.6 Correlation Values for Negative Phases of the Teleconnection Indexes



Source: Original research by ICBA Climate Change & Adaption Team.
Note. Correlations with at least 80 percent of confidence interval. Negative correlations, resulting in increased positive precipitation anomaly, is indicated in blue; positive correlation in red. The size of the squares indicates the correlation value and ranges from 0.40 to 0.64. ONI = Oceanic Niño Index; NAOI = North Atlantic Oscillation Index; MOI = Mediterranean Oscillation Index; WeMOI = Western Mediterranean Oscillation Index.

negative phase of the NAO across many stations, especially on the western Moroccan coast. Similarly, this Annex shows the influences of the MO on precipitation. At the station level, the MO positive phase connections to precipitation anomalies are much clearer, with both positive and negative links to drier and wetter months. The winter period is particularly affected by a decrease in precipitation, whereas April-May is linked to wetter conditions.

In summary, the results of this analysis are inconclusive in explaining ENSO's impact on Morocco's weather and climate, but they do highlight the influences of the NAO and MO. There is a need for more

[18] Rossby waves are a natural phenomenon in the atmosphere and consist of giant meanders in high altitude winds that have a major influence on weather. They are associated with pressure systems and the jet stream.

complex studies that would take into account both how the different teleconnections influence each other and the role of orography. Many studies point towards the need to examine the complex interconnection between ENSO, NAO, and MO. Shaman and Tziperman (2011), for instance, suggest that El Niño conditions can increase fall convection over the Pacific Ocean, triggering Rossby waves[18] over North America and from there to the North Atlantic, where the resulting increase in onshore moisture can influence precipitation in the Northwestern Mediterranean.

Recent observed events. The most recent climate-related developments in Morocco and neighboring countries, primarily Algeria, are presented in Annex 2.5 for the last 10 calendar years through 2015 (2016 not yet being available). Taking a broader view than simply referring to Morocco was chosen in order to reflect the more general class of events that appear to have dominated the regional climate influenced by the vicinity of the Atlas Mountains and divided between the Atlantic Ocean and the Mediterranean Sea, all of which clearly affect Morocco. This information is extracted from the annual Bulletins of the American Meteorological Society (BAMS 2008–2016), which provide the most comprehensive peer reviewed global update on the state of the climate for any individual year. These reports date a couple of decades back, but only for the last decade or so has attention to all populated regions of the world been given comprehensively.[19]

2.4 IPCC PROJECTIONS FOR MOROCCO

The IPPC projections are expressed as anomalies with respect to the 1986–2005 reference period (i.e., differences between the future period and the reference period). Thus, the observed variations are relative to the climate change that has already occurred since the pre-industrial period. The IPCC-type models are made available through the Coupled Model Intercomparison Project Phase 5 (CMIP5, Taylor 2012) database. Following the same procedures used to produce the maps in the IPCC report, Koninklijk Nederlands Meteorologisch Intstituut (KNMI) Climate Explorer (https://climexp.knmi.nl) has developed an on-line database to produce maps on a country-by-country scale. As global climate models are by and large unable to represent details relevant to country scales, such maps are indicative at best of things that may come. Figure 2.7 shows the projected annual mean end of century temperature changes for Morocco for the RCP8.5 scenario,[20] while the annual mean relative precipitation change is depicted in Figure 2.8. In both cases, the values represent the median values based on all available simulations.[21]

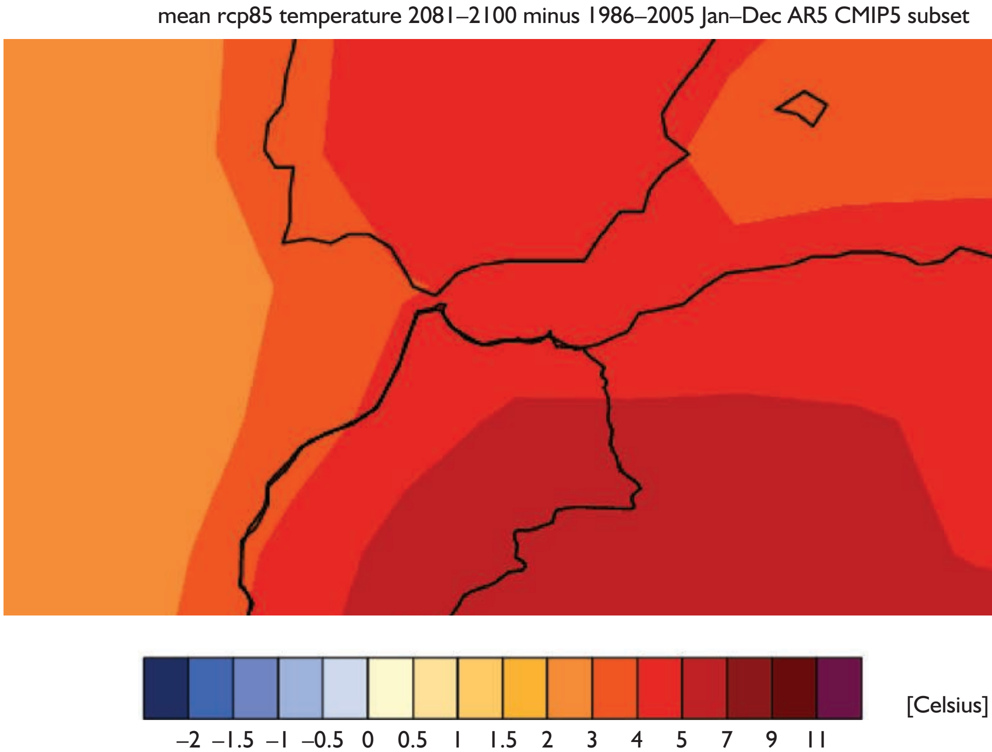
In summary, the CMPI5 models indicate that, for the RCP8.5 scenario, country scale temperatures by the end of the 21st century could increase by 3–6 °C, 3–6 °C, 4–7 °C, and 3.5–6 °C during

[19] They also consider the fact that some parts of the world are not able to provide all the meteorological information collected within any given country, mostly due to internal conflicts and the remoteness of many meteorological stations as well commercial considerations by some meteorological services. Therefore, increasingly the reports also utilize re-analysis products from major weather centers such as the National Center for Environmental Prediction (NCEP) and the European Centre for Medium Range Forecasting (ECMWF).

[20] The IPCC (2013) maps for four different future Representative Concentration Pathway (RCP) scenarios (RCP2.6, RCP4.5, RCP6.0, and RCP8.5) have been elaborated. These scenarios represent increased forcing from the strongly mitigated scenario RCP2.6 (constructed to keep temperatures below 2.0°C) to a non-mitigated business as usual scenario RCP8.5. Only RCP8.5 is shown here. For each modeled grid point, the 25th, 50th and 75th percentiles of the distribution of the CMIP5 ensemble are shown, as only the 50th percentile and the resulting climate change represents the years 2081–2100 versus 1986–2005. This includes both natural variability and inter-model spread.

[21] For a better sense of projection uncertainties, however, the regional maps should be consulted.

FIGURE 2.7 Annual Mean Temperature Change (2081–2100) versus (1986–2005)



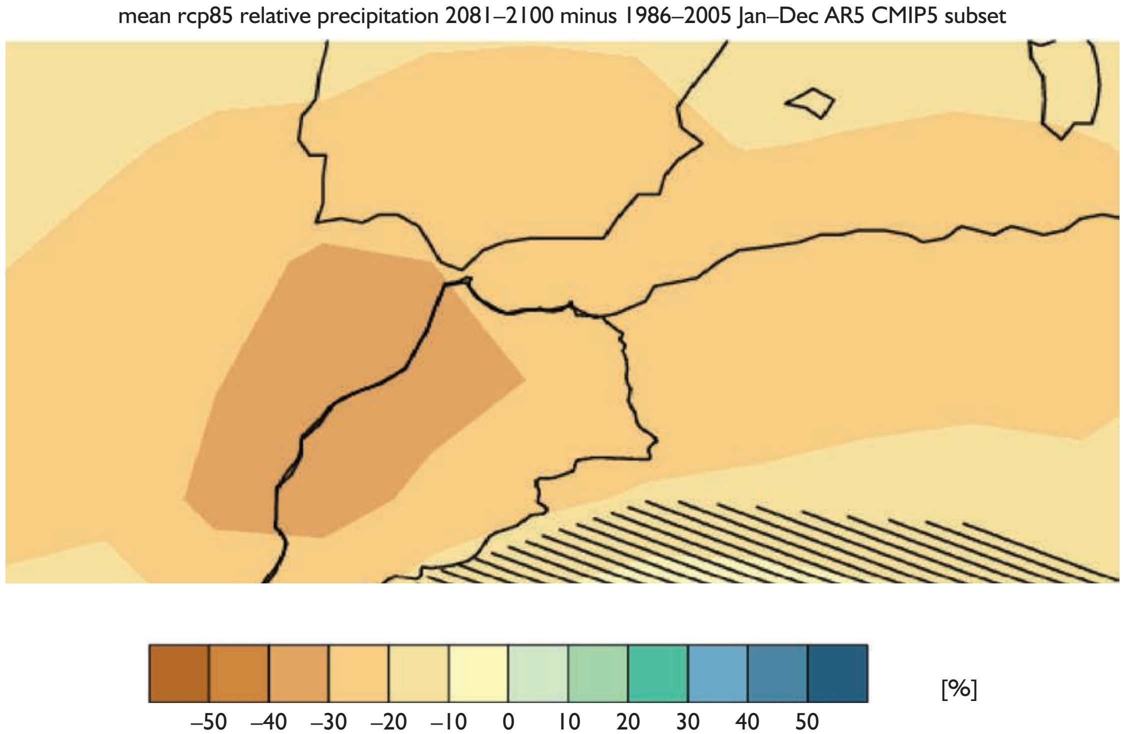
Source: KNMI Climate Explorer, https://climexp.knmi.nl/plot_atlas_form.py.

December, January, February (DJF), March, April, May (MAM), June, July, August (JJA), and September, October, November (SON), respectively. Precipitation amounts may be reduced by 10–40 percent annually, 10–30 percent in the wet season (October–April), and 10-40 percent in the dry season (May–September).[22]

Figure 2.9 below displays consistent model mean projected change for the end of century (2081–2100) versus 1986-2005 for the RCP8.5 scenario for the winter months October through April of precipitation, net water flux (precipitation minus evaporation), near surface soil moisture, and near surface atmospheric relative humidity. All of these components of the hydrological cycle clearly indicate that Morocco and its neighboring countries are projected to experience substantially drier conditions with enhanced risks for droughts throughout and towards the end of the 21st Century and under high-end emissions scenarios in particular. The small projected increase in soil moisture content in southern Morocco is so small that it does not have any impact due to the prevailing very dry conditions. With a strongly reduced hydrological cycle, runoff from the mountains and the related storage in support of the dry season (May through September) are also going to be adversely influenced. In short, the water available for irrigation will be considerably less abundant than at present. Taking year-to-year variability into account also suggests that drought conditions in Morocco will occur relatively regularly in the future.

[22] For other scenarios or other time slices, see IPCC (2013).

FIGURE 2.8 Annual Mean Relative Precipitation Change (2081–2100) versus (1986–2005)



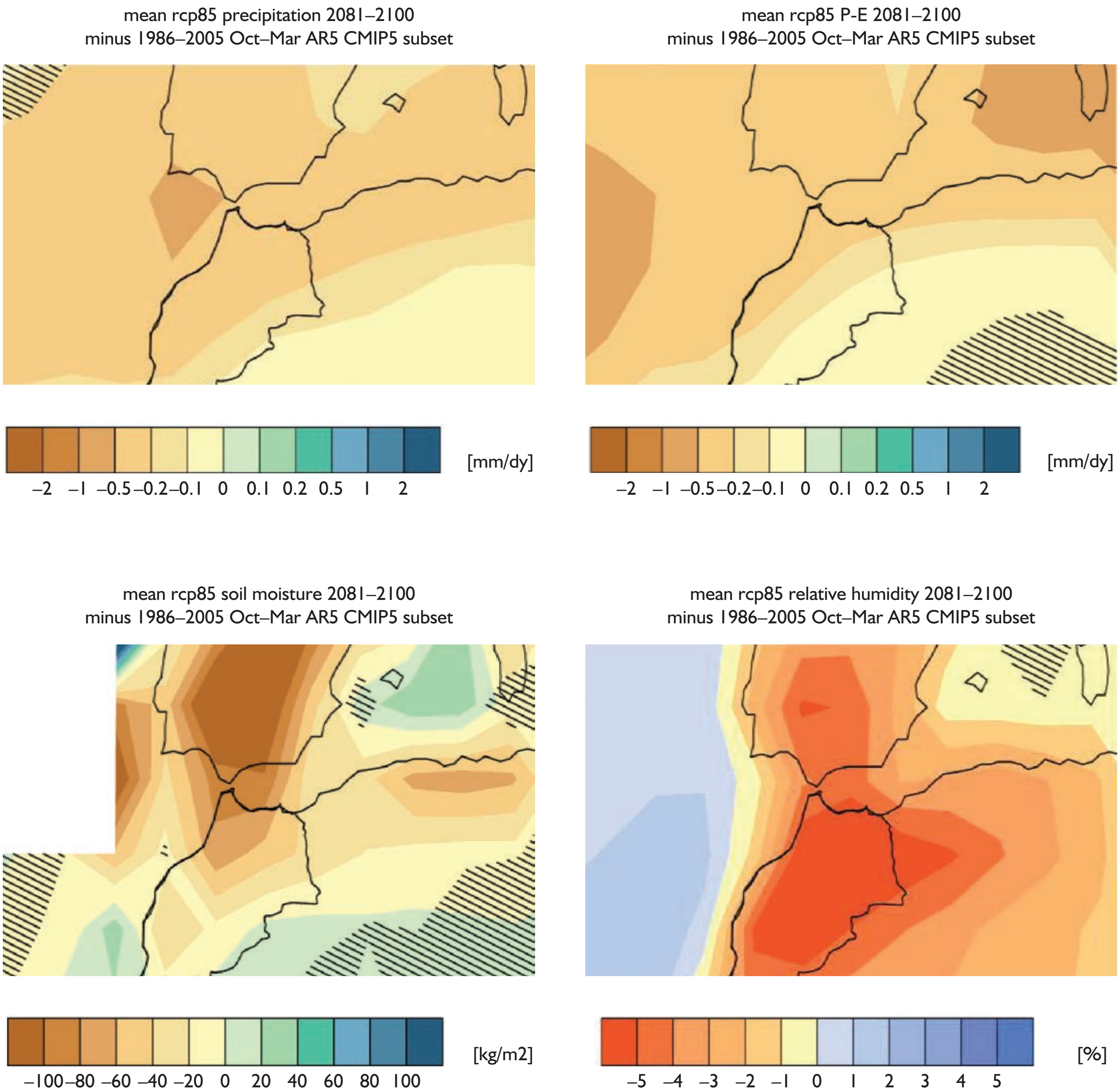
Source: KNMI Climate Explorer; https://climexp.knmi.nl/plot_atlas_form.py.
Note: Projected by CMIP5 Models for the RCP8.5 scenario.[23]

Considered together, it is evident that, even for the next 20 year period (2016–2035), the general trend for Morocco is for higher exposure to drought conditions. Equally important, the chances are high for the entire country, suggesting that widespread drought conditions may occur more frequently and become more severe, challenging local small- and even large-scale agriculture. For the near term, the actual RCP scenario is not relevant as the climate system is basically still adjusting to the enhanced levels of greenhouse gases that have already been reached. But after the middle of the present century, the scenarios start to differentiate among the RCPs.

Extreme events not related to droughts. The risk of flash floods and related hazards, such as hail storms and landslides, should likewise be considered. In general, it is to be expected that that such events may occur throughout the year in the future as well. As is evident from Annex 2.5 on recent observed events, severe precipitation amounts during relatively short time periods already pose a challenge to Morocco and hence to its conditions for agriculture. Information from both on-the-ground observations and modeling shows that rainfall intensity may increase in some areas and seasons even as total rainfall decreases for the country considered as a whole. Thus, the same area may be subject both to drier conditions and to more flooding. Annex 2.6 illustrates this on the global scale.

[23] In addition to the observations contained in the preceding footnote, the hatching in this Figure denotes areas where the 20-year mean differences of the percentiles are less than the standard deviation of model-estimated present-day natural variability of 20-year mean differences – a measure of robustness of the results. Hatching also indicates that the change is not statistically significant, yet the sign and magnitude may still be relevant given the geographical pattern of the overall changes.

FIGURE 2.9 Mean Projected Change for Winter (October–April)



Note: Upper left: precipitation [mm/day]; upper right: net water flux (precipitation – evaporation) [mm/day]; lower left: near surface soil moisture [kg/m2]; lower right: relative humidity [%]. (2081–2100) versus (1986–2005) as projected by the CMIP5 models for the RCP8.5 scenario.

2.5 FUTURE DROUGHT PROSPECTS IN MOROCCO

According to stakeholder observations in focal group sessions and interviews undertaken in 2016 as part of an ongoing USAID-funded regional drought management project by the International Center for Biosaline Agriculture (ICBA), the University of Nebraska–Lincoln (UNL), and FAO, climate variability and change are already affecting Morocco at both the national and the farm levels. From anecdotal evidence, the participants reported that drying has occurred over the last 30 years with a northward movement of more humid conditions increased aridity in the central parts of the country. For agriculture, changes in the water deficit are causing increased risks for several staple crops, as will be further discussed in the next chapter. In recent climate change research, moreover, Elkharrim and Bahi (2014), using statistical downscaling methods for the Bouregreg Basin in northwest Morocco, have found that the annual mean maximum temperature for this area could rise by 1.5-2.6 °C and annual precipitation could vary between a 5 percent increase and a 20 percent decline.

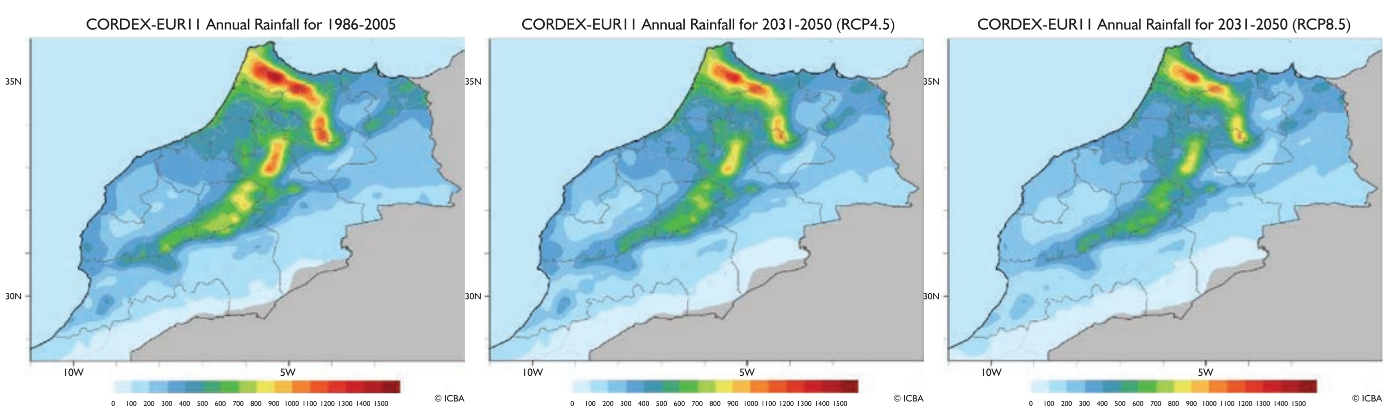
To gain better insight into likely future drought conditions in Morocco, downscaled climate change data downloaded from the seven regional models listed in Table 2.1 below, made available through the Coordinated Regional Climate Downscaling Experiment (CORDEX)[24] project, were analyzed for this study. The CORDEX-Europe domain was chosen at a 110 x 110 km grid resolution to provide the most detailed insight in spatial terms. Data from the greenhouse gas (GHG) emissions scenarios RCP4.5 and RCP8.5 were used to reflect optimistic and business-as-usual trends.

TABLE 2.1 List of CORDEX-EUR11 Regional Models Used

Modeling Center Name	Global Model	Regional Model
CNRM-CERFACS	CNRM-CM5	CCLM4-8-17
ICHEC	ICHEC-EC-EARTH	CCLM4-8-17
ICHEC	ICHEC-EC-EARTH	RACMO22E
IPSL	IPSL-CM5A-MR	WRF331F
MOHC	HadGEM2-ES	CCLM4-8-17
MOHC	HadGEM2-ES	RACMO22E
MPI	MPI-ESM-LR	CCLM4-8-17

The amalgamated data for total projected rainfall during the cropping season for 2031–2050 and 2066–2095 were compared with the historical data for 1976–2005 in order to characterize potential changes in precipitation patterns in the near and longer term future. The analysis focused on the main agricultural areas of the country. Figure 2.10 indicates

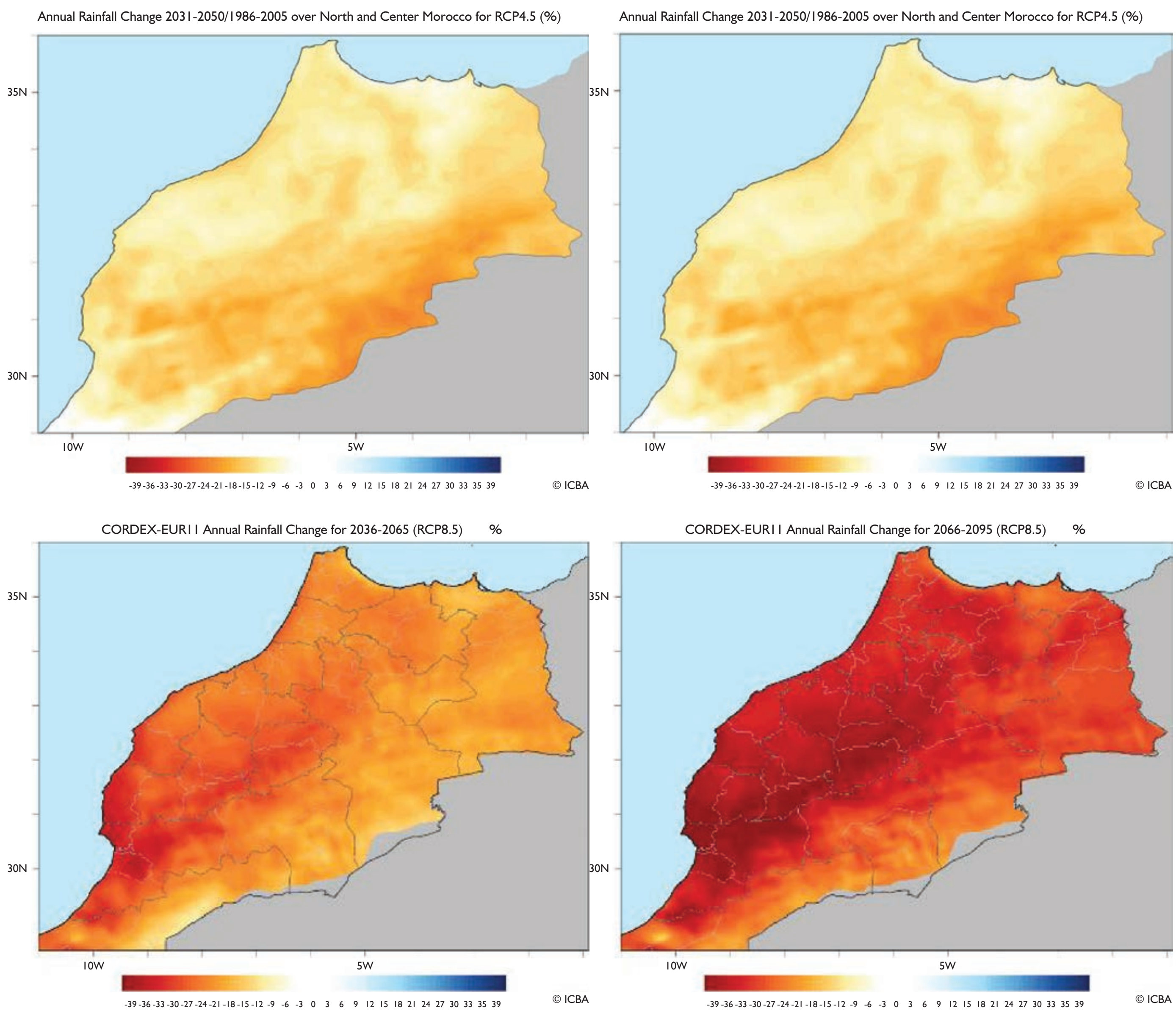
FIGURE 2.10 Total Annual Rainfall for the Periods 1976-2005 (left panel), 2031-2050 – RCP4.5 (middle panel) and 2031-2050 – RCP8.5 (right panel)



[24] See http://www.cordex.org/.

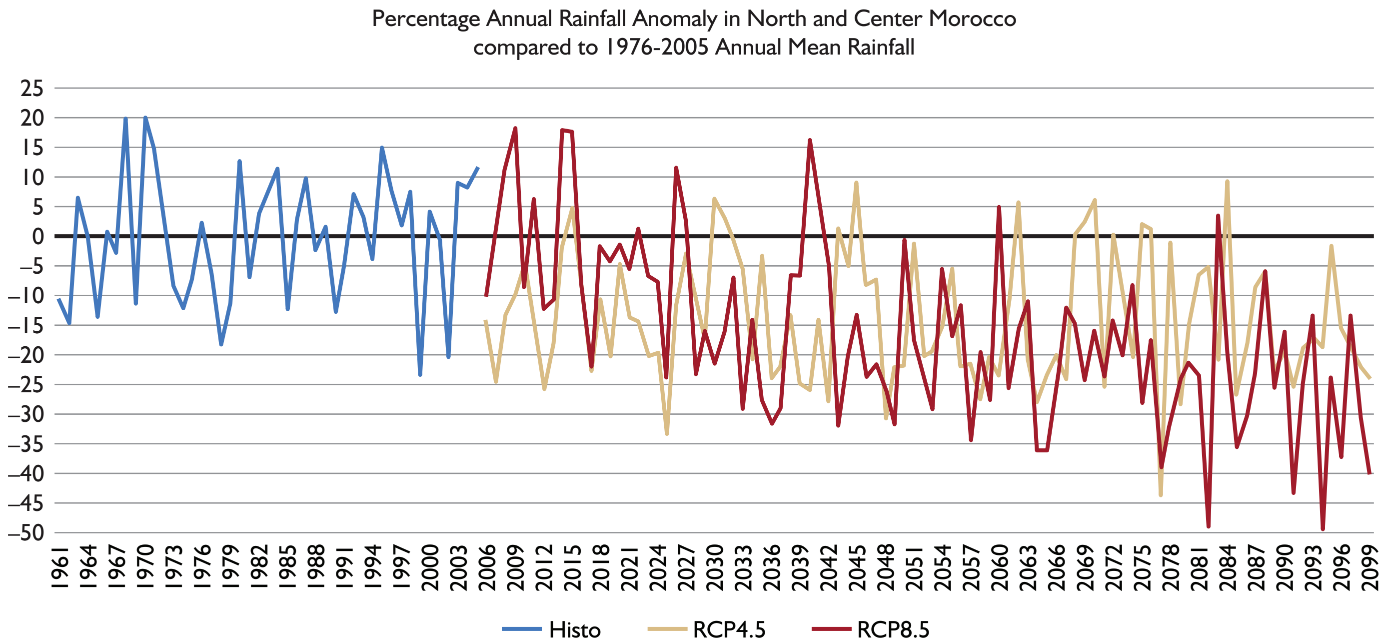
the changes in total annual precipitation (shown in green, yellow and red) in the mountain areas. The wettest areas remain the mountainous zones receiving the most rainfall going forward, but there is a noticeable reduction. The percentage change maps in Figure 2.11 highlight that, under both RCP4.5 and RCP8.5 scenarios, all areas are predicted to receive reduced rainfall. Rainfall is projected to decrease by 20 to 30 percent in the RCP4.5 scenario and by 30 to 45 percent in the RCP8.5 one by the end of the century. The climate regime in some fertile regions will shift from semi-arid to arid and in the extreme northern part of the country it will shift from a sub-humid to a semi-arid one. These are significant changes. The humid, sub-humid, and semi-arid zones have all been shrinking since 1970s, and the climate projections are showing that these zones will continue to decrease and move toward the north.

FIGURE 2.11 Annual Rainfall Percentage Change in North and Central Morocco Compared to 1976–2005 for RCP4.5 (top panels) and RCP8.5 (bottom panels)



Note: The periods shown are 2036–2065 (left panels) and 2066–2095 (right panels).

FIGURE 2.12 Annual Rainfall Anomaly in North and Central Morocco Compared to the Annual Total Mean Rainfall for the Period 1976–2005

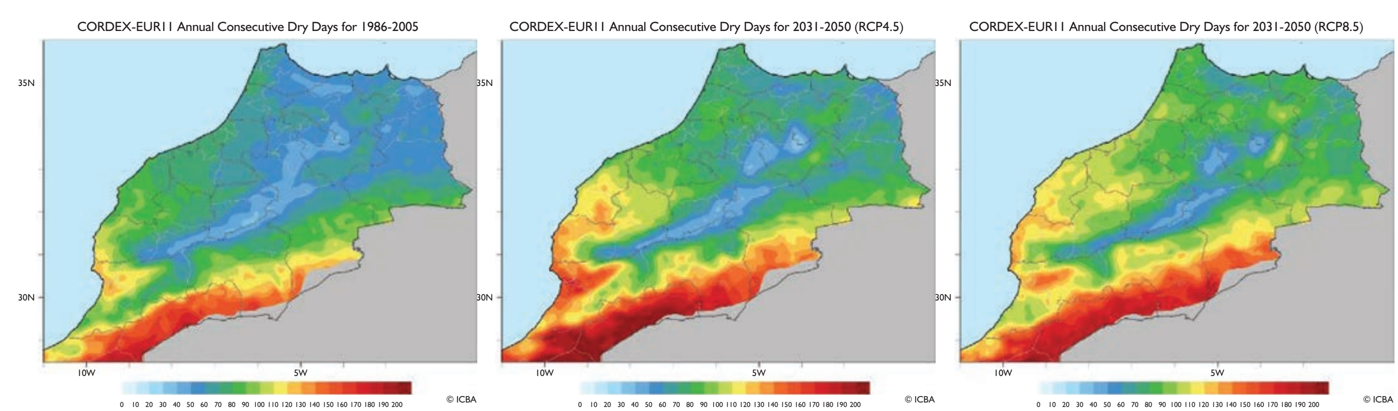


Note: The blue line represents the average of all models for the historical period, the yellow line is the average of all models.

The temporal variability of likely future precipitation values was also explored to gain insight on changes in the potential frequency and duration of droughts. The frequency of dry years, calculated for both RCP4.5 and RCP8.5 scenarios, is presented in Figure 2.12, which shows the negative rainfall anomalies for North and Central Morocco compared to historical conditions for 1976-2005. The frequency of dry years will increase markedly under both scenarios (Figure 2.13).

These projections indicate that Morocco will be impacted by longer periods of consecutive dry days in the future. This will put more pressure on water for irrigation and cause additional crop water stress

FIGURE 2.13 Spatial Distribution of the Annual Consecutive Dry Days in Northern Morocco for the Periods 1976–2005 (left panel), 2036–2065 – RCP4.5 (middle panel) and 2036–2065 – RCP8.5 (right panel)



in rainfed areas. Consecutive dry years could reach as many as five with high impacts both on vulnerable rural areas and urban populations in term of the availability of drinking water. It can thus be concluded that future droughts in Morocco are likely to be more frequent and severe under both the RCP4.5 and RCP8.5 climate change scenarios. The central and southern parts of the country, moreover, will be affected to a greater extent than the north and mountainous regions.

2.6 IMPLICATIONS FOR AGRICULTURE

Agricultural practices around the world typically adapt to changing local climate conditions, although frequently with a lag. However, over the past decades, it has increasingly been realized that local climate conditions are often less stable than perceived by society. Not only does the climate vary on decadal time scales, resulting in quite variable year-to-year agricultural yields, it also results in greater vulnerability to trends that have not been perceived either because of a lack of long-term quality controlled observational data sets or due to an inadequate response to existing information. Yet local agricultural practices in many places appear to adjust if the information about changes is demonstrated to be robust. Thus, ensuring information robustness is a major requirement for effective corrective action.

Climate records of temperature and precipitation from the past century, together with climate simulations for detection and attribution studies and future projections, all show large variations at the regional scale. Consequently, all information about climate variability at the scale of small to moderate sized countries, such as Morocco, is at best indicative and cannot yet be used for predictions. In this context, the IPCC (2013) distinguishes between climate *predictions* and *projections* as follows:

> ***Predictions:*** A climate prediction or forecast is the result of an attempt to produce (starting from a particular state of the climate system) an estimate of the actual evolution of the climate in the future, for example, at seasonal, inter-annual or decadal time scales. Because the future evolution of the climate system may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature.
>
> ***Projections:*** A climate projection is the simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the particular emissions/concentration/radiative forcing scenario used, which, in turn is based on assumptions concerning, for example, future socio-economic and technological developments that may or may not occur in practice.

This formally clear separation between predicted (with a certain likelihood estimate) future and projected story lines that may or may not be realized, however, becomes blurred once the interest is in estimating agricultural yields in the near-term future. Instead of assessing vulnerability to plausible future scenarios, the interest is often related to an actual prediction of regional and/or local climatic conditions. This is one of the reasons why studies addressing ENSO and other large scale climate drivers have intensified in recent years. With some demonstrated greater seasonal to multi-annual ability to predict the state of ENSO, there is a prospect that predictability of droughts, or chances for flash floods or larger scale flooding, can be made with acceptable credibility. This also reveals why large international funding programs (e.g., EU's Horizon 2020) are directed towards these research needs.

This chapter has confirmed that there is an overall widespread annual mean warming (~2.5 °C/century) trend for Morocco. Yet, the country's complex terrain with very its high mountains and very sharp climate gradient between the Atlantic Ocean, the Mediterranean Sea, and the more continental desert-like climate in the southeast, suggest that local patterns of change may deviate from what can be extracted from the few climate monitoring stations represented here. The same can be said about information about actual precipitation in any non-gauged location. However, by viewing local development in a broader regional context, it is evident that all known climate-related challenges to both modern and traditional agriculture are already influencing the sector in Morocco. Most severely among these is the occurrence of local and regional droughts or very dry conditions, whose impacts on the agricultural sector are the subject of the next chapter. It is likewise clear that, with rising temperatures and the projected reduction in the net hydrological cycle, Morocco will be increasingly challenged in terms of its future water availability. Both rainfed and irrigated crops are, in fact, already undergoing increasing pressure from a climatic viewpoint.

Agricultural practices in Morocco need to be able to respond to both the short–term trends related to climate variability and the longer-term ones associated with climate change. Furthermore, this needs to be based on the understanding that annual to decadal fluctuations will occur on top of the mean trend. Along with the temperature variations, moreover, there will be modulations in the hydrological cycle. Although no clear overall trend in precipitation is presently apparent from the records, it is nonetheless evident that rising temperatures enhance evaporation and hence that net water fluxes at the surface are shifting. Similarly, the availability of water for irrigation using mountain streams and reservoirs will continue to be stressed at an increasing rate. While drying is the long term trend, the year-to-year variability will remain high. If predictive ability on seasonal multi-year to decadal time scales, as well as those for the NAO, MO, and ENSO, can be improved, planning crop selections and the timing of crop planting can be enhanced. The aforementioned large-scale efforts to improve longer-term predictions are thus important for Morocco to be fully cognizant of in the years ahead.

CHAPTER
THREE

CLIMATE VARIABILITY AND DROUGHT IMPACTS ON THE AGRICULTURAL SECTOR IN MOROCCO

This chapter examines the impact of increasing climate variability and more frequent and intense droughts on agricultural and livestock activities in Morocco. It will give particular attention to their effects on two important value chains, citrus and olives, which are critical for the country's agricultural export economy, as well as for the livelihoods of a substantial share of its rural population. It will also consider their impacts on cereals production which is vital for domestic food security and the production of animal fodder. Their drought-related declines generally require increased imports of these goods, and, thus also have an adverse influence on Morocco's external trade balance and its overall macroeconomic performance, as well as on the social wellbeing of its rural communities.

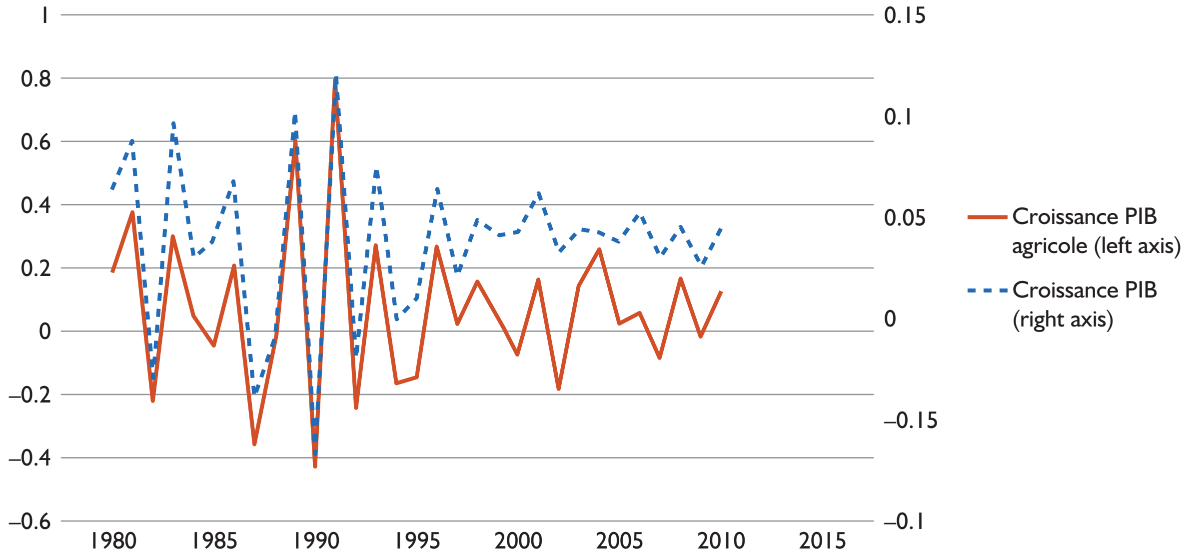
3.1 THE AGRICULTURAL SECTOR, GEOGRAPHY, AND CLIMATE[25]

The agricultural (including livestock) sector presently accounts for roughly 15 percent of Morocco's gross domestic product (GDP), 23 percent of its exports, and close to 30 percent of its total employment. From 2000 to 2015, agriculture was the fastest growing sector in the country (World Bank 2016b). Agro-industry is the country's second-largest industrial subsector. It represents 27 percent of industrial GDP and 5 percent of total GDP. The sector's value-added is around MAD 30 billion (US$ 3 billion). Agribusiness employs up to 143,000 people and is composed of 2,050 industrial units (mainly small and medium-sized companies). Agribusiness output is mostly destined for the domestic market, with exported goods accounting for only 12 percent of total industrial exports.

Economic growth has overall become more resilient to the climate. Agricultural value added currently accounts for less than 14 percent of national GDP. It remains dependent on climate variability. Figure 3.1 below clearly shows the close relationship between the variations in the national GDP in conjunction with the variability of agricultural GDP. The decline in the impact of agricultural economic outcomes on economic growth is also the result of the overall diversification of the economy, which has reduced the share of agriculture in GDP. Graph 3.2 below shows that agriculture's share of total GDP

[25] This overview is largely drawn from World Bank (2017) and Our Africa, *Morocco – Climate and Agriculture*, http://www.our-africa.org/morocco/climate-agriculture. For an earlier World Bank study with respect to climate change and the agricultural sector in Morocco, see World Bank (2011).

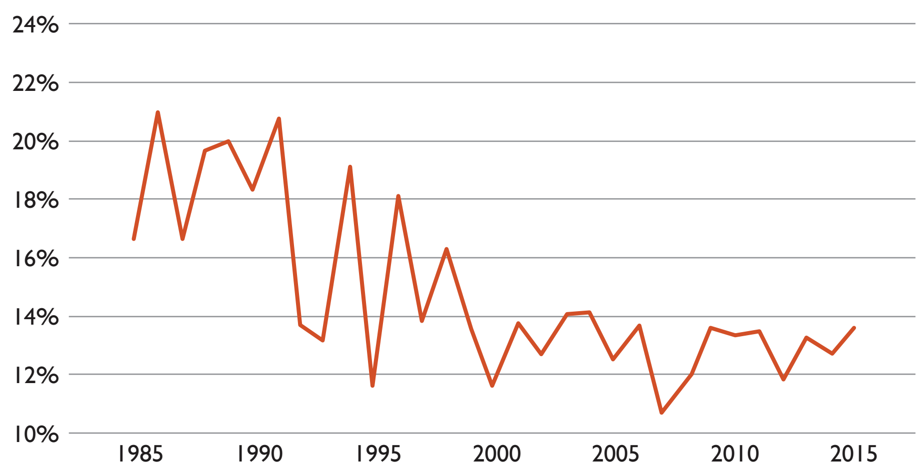
FIGURE 3.1 Evolution of Agriculture (Ag) GDP Growth versus GDP Growth



Source: Adapted from GoM data, 2014.

decreased from almost 20 percent during the 1980s to 15 percent on average during the 1990s and then from 12 to 13 percent since 2007. Indeed, during the 1980s and 1990s, fluctuations in economic growth, and consequently in income, were significant with amplitudes varying between −4 percent and +13 percent. During this period, droughts were more recurrent and severe. Note also that agricultural growth and economic growth were linked (superimposed curves) before the end of the 1990s, which means that they were perfectly correlated. Since the late 1990s and during the 2000s, economic growth has stood out from agricultural growth, making economic performance less dependent on agricultural outcomes and with fewer fluctuations.

FIGURE 3.2 Morocco: Agricultural Value Added as a Share of GDP, 1985–2015



Source: World Bank 2016d.

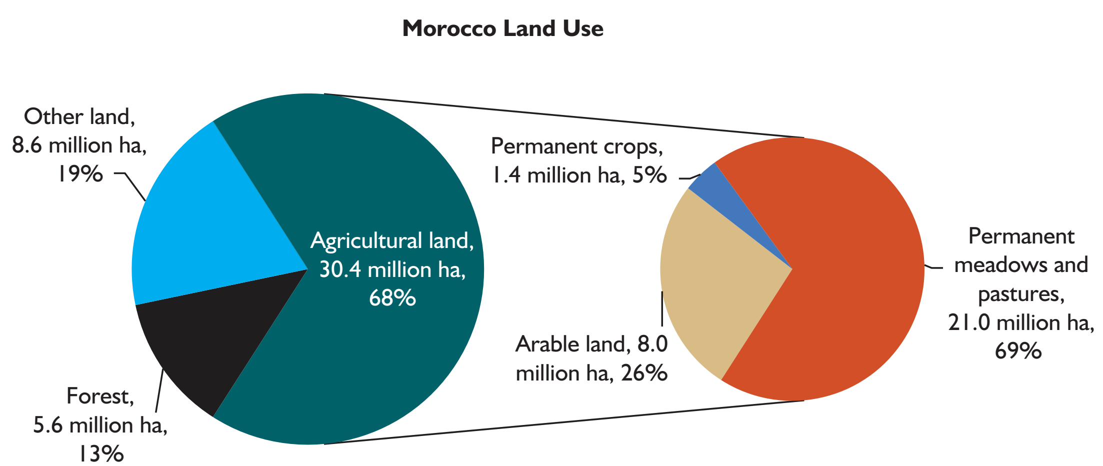
As suggested in the previous chapter, Morocco has three main environmental zones:

- The highland areas of the Rif (to the north) and Atlas (to the east) Mountains – the climate varies with altitude in the mountainous areas of the country, which make up 80 percent of the national territory; the more elevated mountain regions have higher rainfall (over 2,000 mm) and colder temperatures, with winter snows common in areas over 2,000 meters.
- The coastal plains and plateaus – the coastal region to the north enjoys a Mediterranean-style climate, with hot dry summers and mild wet winters; rainfall decreases progressively down the coast (e.g., the Gharb plain receives around 800 mm, the Sous valley in the south only 200 mm).
- Desert to the south, southeast and southwest – in the southern region, the semi-arid conditions beyond the Atlas Mountains soon become desert; this part of the country has virtually no rain, very hot summer daytime temperatures and, very cold nights.

The coastal plains and plateaus provide the main growing areas for Morocco's commercial agriculture, with the warm climate and rains allowing for production of winter wheat and barley, with vegetables, fruits, grapes, olives, and pulses grown during the summers. Dates are produced in oases in the dry south of the country, fed mostly by underground tunnels from the mountains. Expanding irrigation is supporting growing production of export crops such as tea, sugarcane, cotton, tobacco, sunflowers, and soybeans. Livestock-rearing (sheep, cattle, and goats) is widespread, providing local consumers with meat and dairy goods. While the country produces a broad range of food products both for the domestic market and export, recurrent droughts present a threat to both internal food security and the balance of payments, as primary exports generally decline and the need for food imports rises when severe droughts lower local agricultural output and yields.

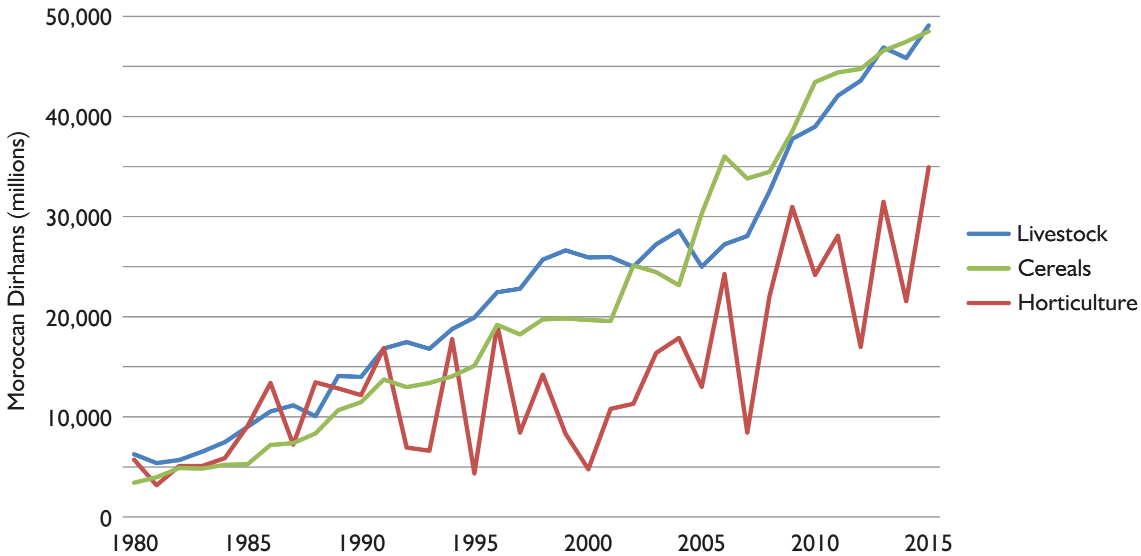
As Figure 3.3 shows, the majority of the arable land in Morocco is devoted to agriculture, with the rest in forest or other uses. Agricultural land use statistics reveal that some 8.0 million hectares are

FIGURE 3.3 Agricultural Land Use in Morocco



Source: FAOSTAT 2013.
Note: ha = hectares.

FIGURE 3.4 Indicators of Long-term Diversification of Agriculture, 1980–2015.



Source: FAOSTAT 2015.

arable, while 1.4 million hectares are dedicated to permanent crops and 21.0 million hectares are in permanent meadows and/or pastures. Permanent crop area in the country increased by 46 percent between 2008 and 2013 in response to Government efforts to promote higher value and commercial agriculture, including citrus and olives.

Among the main crops grown in Morocco, cereals are planted on nearly 43 percent of the area, 3 percent is dedicated to pulses (beans, etc.), 7 percent to commercial plantation type crops (such as almonds, grapes, citrus, olives, and dates), 2 percent to industrial crops (cotton, sugar beets and oilseeds, sugar cane), 2 percent to forage, and 2 percent to vegetables, while 42 percent of the land generally remains fallow.[26] The country's key agricultural exports include citrus fruit (especially oranges), vegetables (e.g., pepper, tomato, green bean), almonds, table olives and olive oil, dairy products (e.g., cheese), and, more recently, blueberries, cherries and asparagus. More specifically, Morocco was the world's second largest exporter of table olives, fourth largest exporter of tangerines/mandarins, fifth largest exporter of olive oil, and eleventh largest exporters of oranges in 2013.[27] Early season vegetables and specialty crops such as Argan, however, have the highest value for export.

Faced with climate variability and the process of climate change, Moroccan agriculture has adapted through diversification and rising yields. Although cereal production remains dominant, there is an increasing trend towards horticulture and livestock production.

The graph in Figure 3.4 shows the change in value of cereal production (in red), of animal production (in green) and tree crop production (blue). Cereal production, measured in monetary units, is characterized by strong fluctuations, despite a marked increase in growth over the years 2000s. Its growth rate

[26] Global Yield Gap Atlas, *Country Profile: The Kingdom of Morocco*, http://www.yieldgap.org/morocco.

[27] Morocco produced some 1.6 million tons of olives and 2.2 million tons of citrus in 2014, while between 2008 and 2014 the harvested area in olives increased by 74 percent and that in citrus by 24 percent (World Bank 2017).

is clearly lower than that of horticultural and arboricultural production. This is also the case in livestock production, driven by the performance of (irrigated) milk production, the development of red meat production—especially bovine meat—and the development of poultry farming.

Despite significant agricultural area and employment, Morocco still depends significantly on imported food, especially when drought conditions prevail. Key agricultural imports include sugar, grains, tea, and coffee, as well as basic food grains and fodder during drought years. Even in non-drought years, Morocco spends about 20 percent of its export revenues on food imports, which is roughly four times higher than the world average.[28] Export revenues thus play a crucial role in food security, as do cereal imports in drought years. To stimulate production and benefit growers, agriculture production is fully exempted from taxes.[29]

Approximately one million small farms (70 percent of total landholdings) cover 74 percent of agricultural land and contribute 50 percent of agricultural GDP. While there are a large variety of small family farms having an average size of 1.6 hectares, they are often characterized by low-productivity and limited market integration. Many of these farms are operated by aging household heads with low education levels. These small farms generally use rainfed production systems, make limited use of modern technologies, lack technical know-how, and are particularly vulnerable to recurrent droughts. They also typically produce low-value agricultural commodities, such as wheat and barley, for which government incentives are provided in the form of subsidies and market protection.

Smallholders co-exist with a much smaller, but efficient, group of commercial farmers who produce high-value export crops. This subsector of mainly irrigated farms, which occupy only 4.6 percent of total agricultural land (World Bank 2016a), accounts for 7 percent of total GDP, 50 percent of agriculture GDP, and 75 percent of agricultural exports. It is estimated to provide employment for 50 percent of the rural labor force (World Bank 2013). Morocco has a comparative advantage in certain crops, including grapes, citrus, melons, peppers, tomatoes, and strawberries, particularly for export to African and European markets.

While Morocco has made significant progress in recent years to expand irrigation for commercial agriculture, many farmers still lack access to irrigated, arable land and thus produce poor quality goods and have low yield rates. The main irrigated areas are the Rharb and Loukkos in the northwest, the Tadla in the center-north of the Atlas Mountain region, Al Haouz in the Marrakech region, the Souss-Massa (SM) in the Agadir region, the Ouarzazate and Tafilalet south of the Atlas Mountains, and the Low Moulouya in the northeast.

Moroccan agriculture and livestock also remain vulnerable to droughts. As the full impact of the fall 2015 drought and resultant poor harvests comes to light, for example, Morocco's GDP growth is expected to slow to 1.5 percent in 2016, with agricultural GDP projected to contract by 9.5 percent (see the next section below for further details on recent drought impacts on the sector).[30] To exacerbate matters, farmers often do not formally own land or are unable to provide notarized land title, which makes it difficult for them to obtain credit or permits (e.g., for digging wells), thereby limiting investment for irrigation and other needed inputs.

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[28] Hafez Ghanem, *Agriculture and Rural Development for Inclusive Growth and Food Security in Morocco*, Working Paper 82, Brookings Institute, February 2015, https://www.brookings.edu/wp-content/uploads/2016/07/Agriculture_WEB_Revised.pdf.

[29] Morokko-Info, *Agriculture and Fishery*, http://www.marokko-info.nl/english/agriculture-and-fishery.

[30] World Bank (2016).

Livestock production is likewise important in Morocco with more than 2.7 million cattle, 17 million sheep and 5.3 million goats, in addition to 0.2 million camels, 0.51 million mules and 0.98 million donkeys (FAOSTAT). Collectively these animals contribute more than 1.35 million metric tons of milk and 300,000 tons of meat with chicken and game adding a further 600,000 tons. Imports of meat have declined since 2000 with only milk and its sub-products increasing (more than double). Only 18 percent of farmers gain their incomes solely from animal husbandry, but livestock constitutes a significant financial reserve for the majority of farmers, in particular for those who have difficult access to agricultural loans. The historical drought of 1982–1985 caused the most impacts on livestock with losses of cattle and sheep herds reaching 25 and 40 percent and partial recovery took almost 7 years.

As indicated in the previous chapter, like many other countries around the world, Morocco appears to be increasingly susceptible to chronic drought. Climate variability and change is likely to further aggravate water scarcity, reduce yields, and increase the volatility of agricultural production, with substantial variation between regions within the country.[31] The 2010 *World Development Report* (World Bank 2009), for example, ranks Morocco among the countries for which climate change will have the greatest impact on agricultural yields. As will be further elaborated below, improved land and water management, including water and soil moisture conservation, and the development of crop and livestock systems resilient to drought and extreme weather conditions are priorities, especially for the small farmers whose production systems are largely rainfed and who often lack the technical know-how and financial resources to adapt (World Bank 2015). In the irrigated areas, in turn, climate change is expected to reduce the availability of surface water and increase overexploitation of groundwater. Agriculture is already responsible for 88 percent of all freshwater withdrawal in the country (World Bank 2016a). Weather and rainfall variability, moreover, have major spillover effects on the rest of the economy. Thus, when drought affects agriculture, the whole economy suffers. This has implications for efforts to combat rural poverty as well.

Poverty in Morocco remains largely rural, where 40 percent of its 34.4 million people live. Rural poverty is linked to poor access to basic services, deteriorating infrastructure, low literacy rates and educational skills, limited formal employment opportunities, and difficult geographical conditions, including mountainous areas. In 2014, poverty rates were roughly six times higher in rural than in urban areas. In addition, more than 19 percent of the rural population is vulnerable to poverty.[32] Consequently, the rural population accounts for more than 79 percent of the poor and 64 percent of the vulnerable, particularly women and youth. Women's work on subsistence farms, moreover, is often unpaid or unrecognized. About 73 percent of female labor in the primary sector is unpaid, a share that is even higher than the 60 percent unpaid labor rate for youth.

Improving the prospects of the rural poor in Morocco requires higher household and farm incomes, sustainable farming practices, and more diverse income opportunities. Farming is the main source of income in rural areas, and the majority of farms have low quality, low productivity, semi-subsistence farming on small lands. As suggested above, small farmers face significant constraints. These include marginalized land, land titling issues, land fragmentation, unpredictable rainfall, limited access to markets, limited farmer organization. Several activities would ensure that better sector performance translates into higher incomes, including extension service reforms, using value added crops and irrigation, local

[31] Gommes et al. 2009. This was an input for the earlier World Bank (2011) study on climate change on climate and agriculture in Morocco (see footnote 18 above).

[32] Vulnerability to poverty is the share of the population whose per capita consumption is in the range between the poverty line and one and a half times that threshold.

transformation through agroindustry, and improving agriculture value chain management and commercialization practices.

In part in response to these challenges, in 2008, the Moroccan Government developed "the Green Morocco Plan" or *Plan Maroc Vert* (PMV) (2008–2020) to maximize the potential of the agri-food sector and integrate smallholder farming into a growth-oriented strategy. It seeks to consolidate the agricultural sector as a source of growth, competitiveness, and broad-based economic development through increased investments and systemic public sector reforms. The PMV embodies a shift from a protected sector towards open market agriculture that integrates value addition into the agri-food chain and smallholders into the commercial agricultural economy. It aims to double agricultural value-added, create 1.5 million jobs and halve rural poverty by 2020. It is complemented by the National Program for Saving Water in Irrigation (PNEEI), which seeks more productive water use by promoting higher value crops in irrigated areas, improving water service in public irrigation perimeters, and introducing more efficient irrigation technologies (mainly drip irrigation) in 555,000 new hectares by 2020.

3.2 DROUGHT IMPACTS ON THE AGRICULTURAL AND LIVESTOCK SECTOR

Against this general sectoral background, the focus now turns to droughts and their impacts. According to a report by the World Meteorological Organization and the Global Water Partnership, a dendrochronological (i.e., tree-ring dating) study in the early 1980s reconstructed the history of drought in Morocco over the past millennium. It showed that there were some 89 droughts lasting one to six years over this period, with an average interval between them of roughly 11 years. The average duration of these droughts was about 1.6 years, with the 20th Century having been one of the driest over the last nine centuries (WMO and GWP 2014). Box 3.1 below provides additional information on the history of droughts and drought-related famines in Morocco. As indicated in the previous chapter, rainfall in Morocco decreases from north to south and from west to east. Thus, there is important spatial and temporal variability in precipitation, as well as in terms of both surface and groundwater potential, with the highest surface water concentration occurring in the northwestern part of the country.

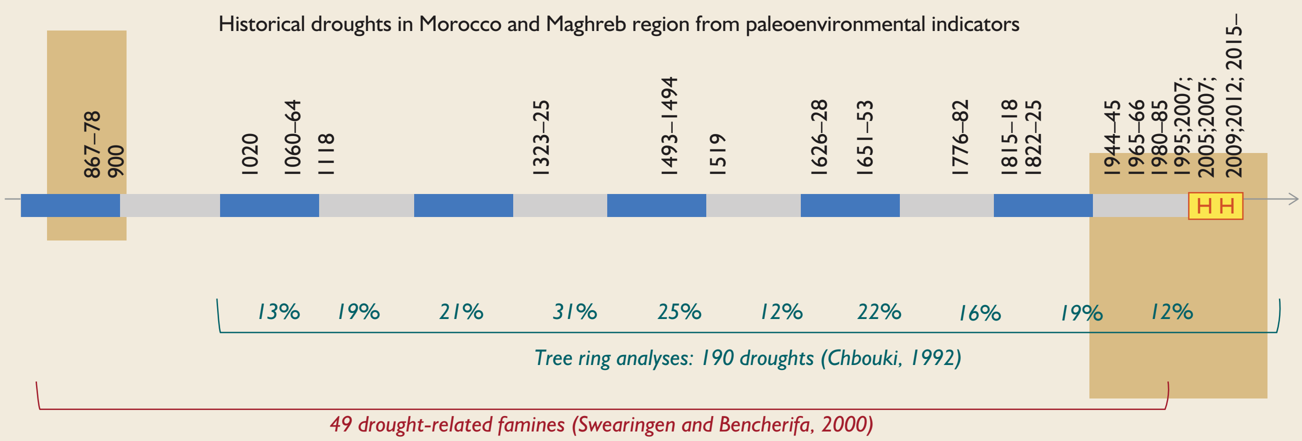
In recent times, Morocco has experienced more than 20 years of drought in the last 40 years with overall rainfall deficit ranging from 30 to 100 percent in the various departments (see Figure 3.3). From the early 1970s the data suggests a clear climate shift in drought severity/frequency with a series of consecutive dry years. Benassi (2008) highlighted an increase in the frequency, intensity, and duration of droughts leading to greater temporal persistence, especially in the Spring months. The economic costs resulting from drought conditions have also risen over time. Those from the 1999 drought, for example, were estimated by the insurance sector to be on the order of US$ 900 million, with local communities that were dependent on rainfed agriculture the most adversely affected (see http://www.emdat.be/). A large number of farmers reportedly lacked insurance, so they suffered even more as there was little compensation for their losses.

The Directorate of National Meteorology (DNM) in Casablanca confirms that Morocco has been experiencing more frequent droughts over the past two decades, rising from one event every ten years at the beginning of the last century to 5 to 6 per decade at the start of the present one. These dry periods are also becoming more severe in terms of their impacts. In 2000–2001, for example, drought conditions

BOX 3.1 Drought and Famines over the Centuries in Morocco

Droughts are recurring climatic extreme events in Morocco. The long-term reconstruction of past events over centuries using various data sources such as tree-rings and alluvial sediments, gives context to the current drought study. (Chbouki 1992; Chbouki et al. 1995; Cook et al. 2016; Esper et al. 2007; Stour and Agoumi 2008; Swearingen and Bencherifa 2000; Touchan et al. 2008, 2011). Over 65 severe hydrological droughts were found using carbon dating of alluvial sediments with some of the most severe and frequent in the 9th century. Tree ring analyses identified from the 11th century, 190 agricultural droughts (Chbouki, 1992). These data show a significant increase in hydrological deficits from the start of the 17th century, with another noted trend in increased frequency since the start of the 20th century. Famines are often a consequence of droughts and it is notable that 49 major famines occurred over the last 1,200 years. Major historical famines were experienced in 1779 in Rabat (http://www.ub.edu/geocrit/locust.htm) and in 1940–48 with the devastating impacts of the latter partly the result actions involving the exporting of grain out of the country (http://www.orlok.com/timenine.html).

Historical droughts in Morocco and Maghreb region from paleoenvironmental indicators

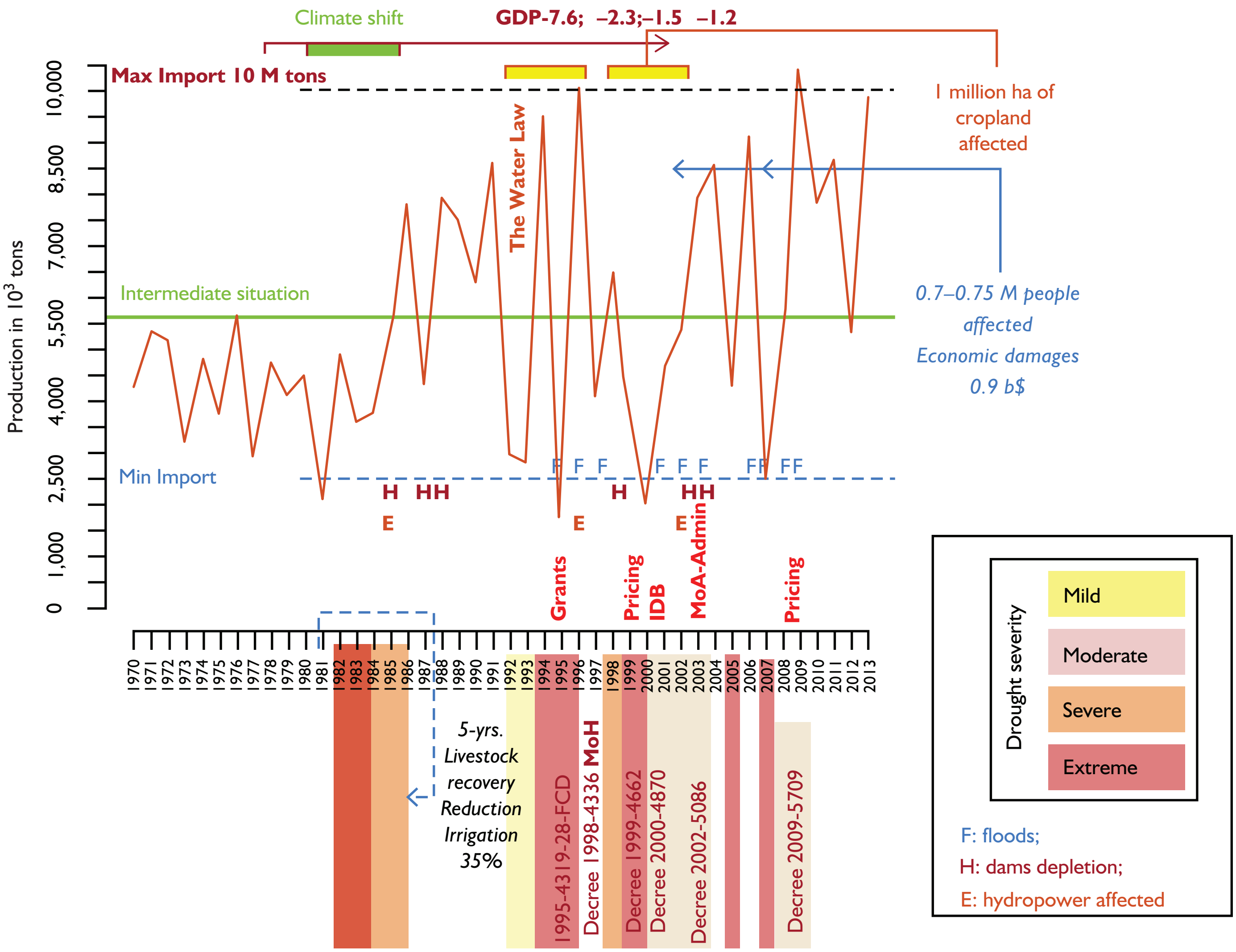


Source: ICBA (2017.) from Chbouki 1992 and Swearningen and Benchifera 2000.

required the country to import about 5 million tons of wheat in the latter year, which was more than twice that imported on average in non-drought years. Again in 2006–07, national grain production was only half of a normal rainfall year's levels and an estimated 700,000 people were adversely affected. According to this source, droughts have had "considerable negative impacts on the economy and people of Morocco in terms of crop production losses, reductions in GDP, and loss to livelihood" as well as being "a major obstacle for agriculture and food security." As the periodic droughts are expected to have even greater impacts in the future, this study concluded that policymakers needed to take heed of their severe implications, "especially for the most vulnerable in society, such as resource-poor, small-scale farmers, and poorer urban households" (El Khatri and El Hairech n.d.).

As in other countries in the Middle East and North Africa region and elsewhere, droughts in Morocco also have significant environmental, as well as economic and social, impacts. These include biodiversity losses in ecosystems associated with water, increases in the number and severity of fires, decreases in lake and reservoir levels, growing groundwater depletion, increased animal and plant diseases, and greater stress on endangered species and other wildlife (Government of Morocco 2014). They also contribute to rising desertification in parts of what is already an increasingly water stressed country.

FIGURE 3.5 Cereals Production in Morocco (000 tons)

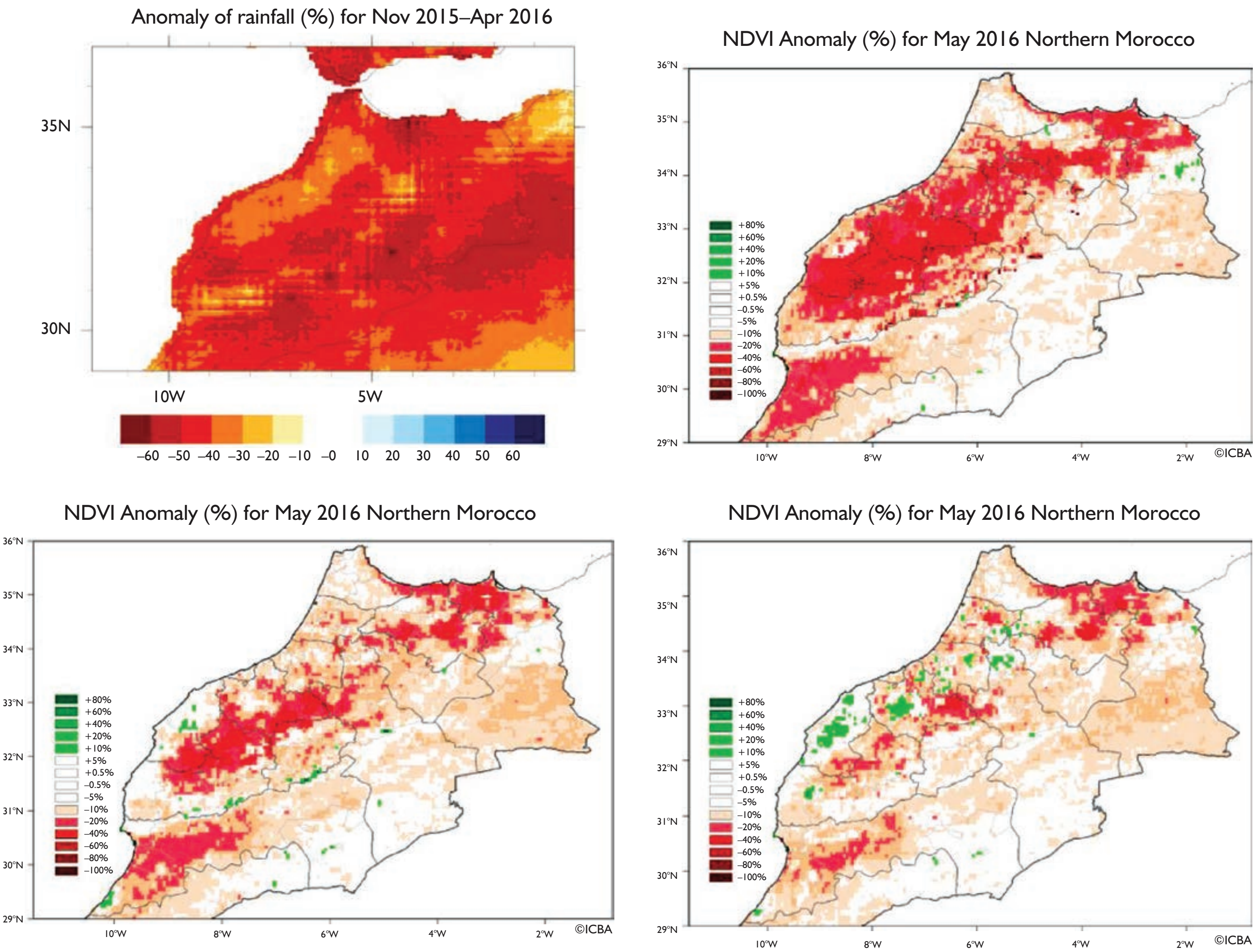


Note: Maximum production (dashed line), average production (line in green) and minimum production (line in blue). Dry years are colored according to severity as reported by the Government and reports by outside organizations. Decrees of reaction to drought are the following sequence: 1995-4319 (water law and official funding), 1998-4336 (Ministry of Health), 1999-4662 (water pricing), 2000-4870 (use of the Islamic Development Bank (IDB) fund), 2002-5086 (MAPM, administrative responsibilities for managing the IDB fund), 2009-5709 (water pricing). H = reported hydrological drought (dams depletion); E = major electric disruption from failures of hydro-power system; F = reported river basin flooding GDP = gross domestic production depression rate (in %).

Sekkat (2004) emphasizes that droughts have led to a volatile economic growth rate in the country. Highlighting this impact, the 2015–2016 drought was again devastating for Morocco from a macroeconomic standpoint, causing a drop in national economic growth of more than 3 percentage points as a result of the decrease in agricultural production and needed emergency relief measures (Economists Intelligence Unit 2016). The next chapter will discuss the various instruments used by the Government of Morocco in an effort to address drought impacts in greater detail.

As concerns the most recent drought, below average rainfall levels began in November 2015 and by the end of the 2016 growing season the precipitation deficit was more than 60% over much of the country (see Figure 3.6a). The impacts were offset to begin with by residual soil moisture levels that resulted from the above-average levels of precipitation in the preceding season. The drought-induced

FIGURE 3.6 Rainfall and Vegetation Anomaly Data for Morocco, 2015–16



Source: ICBA (2017).

Note: (a) The rainfall anomaly data for Morocco for November 2015–April 2016 showing the areas most affected by drought. (b) Normalized Difference Vegetation Index (NDVI) anomaly data for March 2016 showing parts of the main agricultural areas suffering stress. (c) NDVI anomaly data showing the slight easing of vegetation stress conditions following rain in April 2016. (d) NDVI anomaly data showing the areas still experiencing vegetation stress but also an easing of conditions following precipitation which helped to save summer cropping.

vegetation stress throughout the spring of 2016 is clearly shown in Figures 3.6 b, c, and d for the main crop production areas of the country. However, the rain that came in the late spring brought a greening in some areas and helped to save some of the summer crops as Figure 3.6d illustrates.

In stakeholder interviews carried out by the International Center for Biosaline Agriculture (ICBA) and the UNL in 2016,[33] many respondents characterized this drought as the deepest in recent memory.

[33] The ICBA and the University of Nebraska's National Drought Mitigation Center (NDMC) under a USAID funded project (Regional Drought Management System for the Middle East and North Africa [MENA RDMS]) and in partnership with the Food and Agriculture Organization (FAO) regional office, undertook a survey of more than 35 stakeholders from government agencies, the private sector, civil society organizations and research institutes on droughts and their management in Morocco from June-August 2016.

Stakeholders also shared the perception that drought impacts in the country have been worsening over time due to the increasing environmental vulnerability linked to growing long-term water scarcity. This, in turn, was viewed as stemming from the combination of climate shifts, increased demand, and other anthropogenic causes. As a result, even relatively mild physical droughts are now seen as producing increased socio-economic impacts because of shifts in vulnerability.

Multiple interviewees likewise discussed the financial impacts of droughts and associated these events to declines in Moroccan GDP and economic health from year to year. The changes in 2016 were brought about by decreases in agricultural exports and increases in food imports, coupled with a roughly US$ 500 million management plan to safeguard cities and rural populations, agriculture, and food security. However, it is not clear that much of this amount was actually spent. Stakeholders also identified the economic knock-on effects of reduced hydropower production. In terms of agriculture, interviewees observed that multi-risk climate insurance from *Mutuelle Agricole Marocaine d'Assurance* (MAMDA), for which premiums are heavily subsidized by the state and which include drought coverage in rainfed areas (see the next chapter for more on this), had been highly beneficial in terms of stabilizing farmer income streams. However, they also mentioned that difficulties remain in terms of adequately identifying vulnerable zones that are eligible for insurance payouts.

Stakeholders largely agreed that drought impacts on rainfed cereals and livestock were, by far, the most important agricultural effects. Agriculture and livestock, dominated by rainfed crops (83 percent) and rangelands, are important sources of food for both rural and urban residents (Balaghi et al. 2008). While the crops in the north are diversified and cover a wide range of activities (orchards, annual crops, small grain cereals, and vegetables, those in the center (cereals integrated with subsistence livestock production of small ruminants and chickens) and south (oases and greenhouses) are less so.

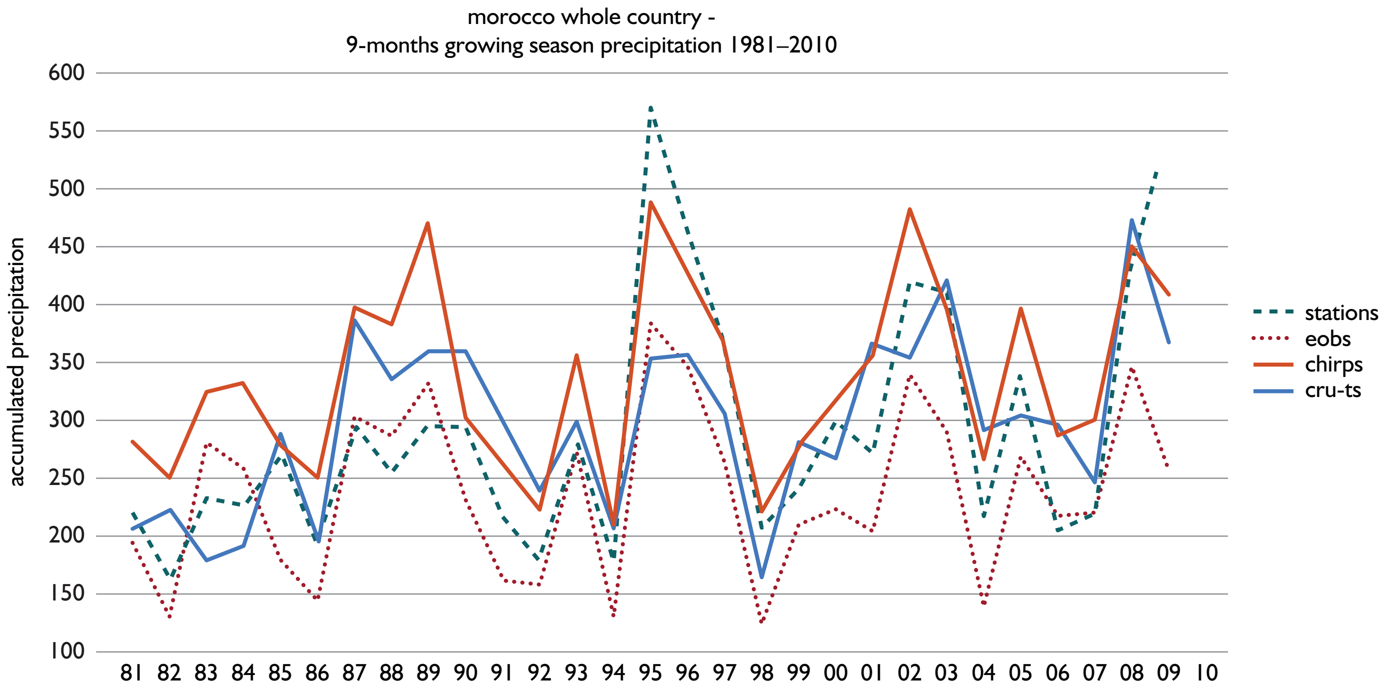
3.3 SECTORAL IMPACTS OF TEMPORAL AND SPATIAL VARIABILITY OF DROUGHTS IN MOROCCO

To better understand the spatial/temporal variability of droughts and their impacts for agricultural areas in Morocco, various gridded meteorological data sets were analyzed and linked to the crop data. With limits on the meteorological ground station data in terms of access and spatial/temporal coverage, available gridded global data sets were explored to provide more information on Moroccan droughts. The focus was on time-periods that were defined to reflect the importance of timing on drought impacts – autumn (September 1st to November 30th) and the 9-month growing season (September 1st to May 31st). This analysis excluded the south of the country, which is of little significance for agricultural production, and the summer as drought has significantly less effect on already mature crops at this time.

The Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) five kilometer daily data (Funk et al 2015), which first started to be collected in 1981, and the ENSEMBLES daily gridded observational dataset for precipitation, temperature and sea level pressure in Europe (E-OBS) and Climate Research Unit (CRU) were validated for the two seasonal periods against ground station data from 35 meteorological stations (see Figure 3.7 below).[34] The comparison showed that the four

[34] CHIRPS data generated at the University of California, Santa Barbara; E-OBS and CRU data generated at the University of East Anglia.

FIGURE 3.7 Comparison of Observed Precipitation in Morocco, 1981–2010



E-OBS RMSE = 31.2% CORRELATION = 0.76
CHIRPS RMSE = 26.2% CORRELATION = 0.82
CRU-TS RMSE = 27.2% CORRELATION = 0.69

Source: ICBA (n.d.).

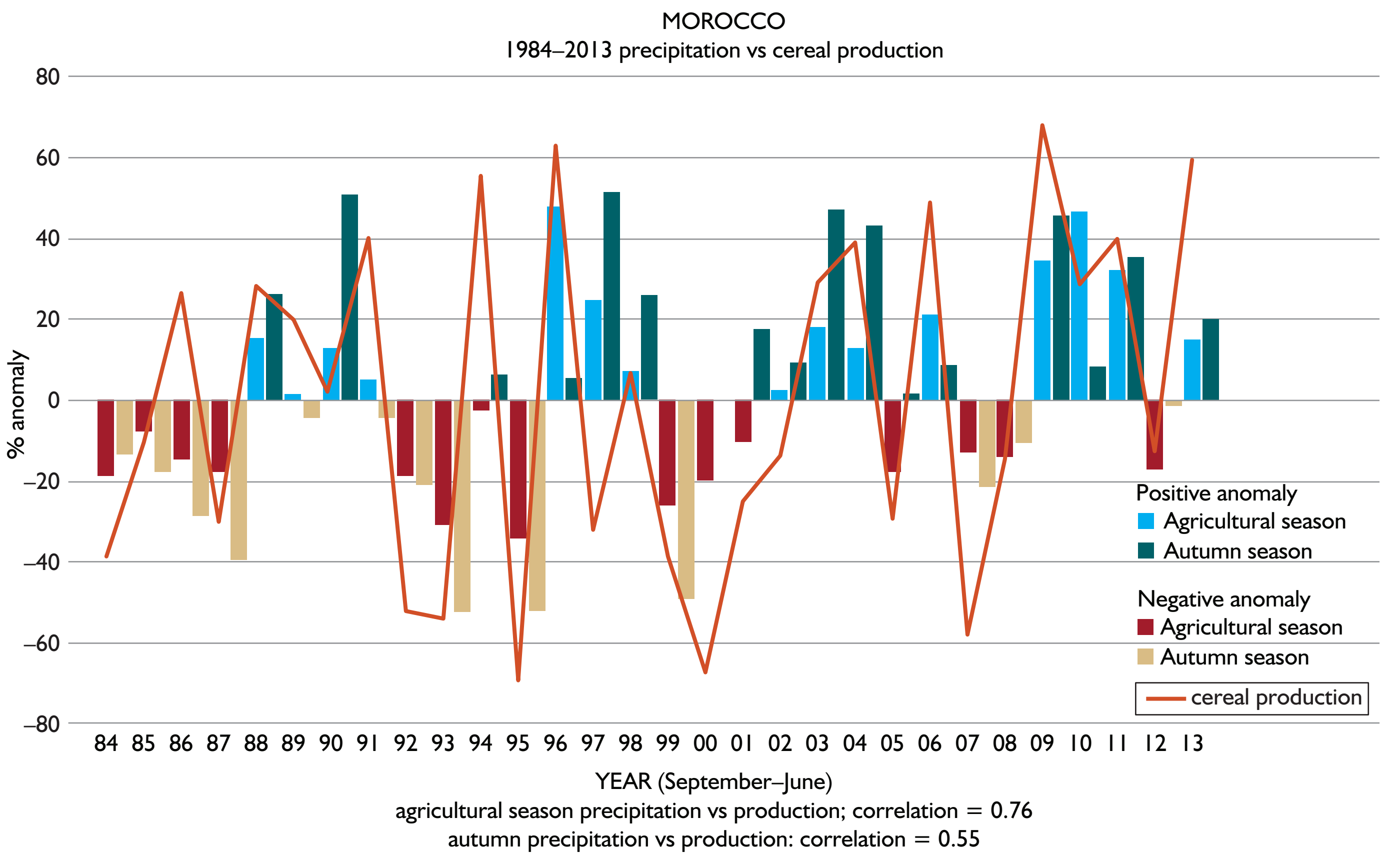
Note: Observed Precipitation over 35 Moroccan Meteorological Stations (black line) with the CHIRPS (red line), CRU-TS (blue line) and E-OBS (green line) data for the 9-months Agricultural Season (September to May), with RMSE and Correlation. CHIRPS = Climate Hazards Group InfraRed Precipitation with Station; CRU-TS = Climate Research Unit-Time Series; E-OBS = ENSEMBLES daily gridded observational dataset for precipitation, temperature and sea level pressure in Europe; RMSE = root mean square error.

data sets identified many of the drought events, but the CHIRPS data were statistically more closely aligned with the observed values for seasonal precipitation. This data set was then used as the basis for further analysis to define spatio-temporal relations linking dry years to the precipitation budget and patterns.

To identify the droughts, anomalies of precipitations were calculated in percentage terms so that periods of below/above normal values for the two defined parts of the growing season were determined. This permitted an analysis of the timing and extent of the precipitation anomalies to be linked to known crop yields to begin to understand the impacts on agriculture. The resulting values were then compared to government cereal production data for the same period that would indicate the occurrence of drought and the length of the events. The droughts identified from the CHIRPS anomaly data, many of them multi-year, were highly correlated with the events shown in the cereals yield data.

Figure 3.8 captures both the variability within a year – i.e., between autumn and the whole agricultural season—as well as between years. It shows that a wet or dry autumn does not always mean a drought for the year but production levels are often affected. In some years spring sowing during wetter conditions can often make up for any losses from an autumn drought. During the period analyzed there were thirteen favorable years for cereal production, characterized by positive precipitation anomalies during parts of the either the autumn or entire agricultural season. The wettest years for both autumn

FIGURE 3.8 Percentage Anomalies in Precipitation for the Autumn and Agricultural Seasons for the Areas with Cereal Production in Morocco, Compared with Cereal Production for the Same Areas, 1984–2013



Source: ICBA (n.d.).

and entire seasons are 1988, 1990–1, 1996, 1997, 1998, 2003 and 2004, 2009, 2010, 2011 and 2012, with the wettest occurring in the mid-1990's and the late 2000's when precipitation was more than 40 percent of average rainfall.

More unfavorable years are characterized by negative precipitation anomalies in the autumn and throughout the agricultural growing season from March to October. It is striking that there are more periods of multi-year negative anomalies, with 1984–1987, 1991–1994, 1999–2001, 2007–2008 all having extended dry periods. These are also periods of noticeable declines in cereal yields. Reviewing any changes in the frequency or severity of events, there is no noticeable increase in the number and intensity of droughts. This suggests that the general picture across the main agricultural areas is not presently one of increasing severity.

In more variable years with differences between autumn and whole season rains, unfavorable years of cereal production corresponded most to negative anomalies at the start of season precipitation, while in years with a more favorable positive anomaly start of season yields were not hit as hard. This analysis highlights not only the variability and frequency of droughts in Morocco, but that the timing of the period of dryness is important in determining the longer-term effects on yields. Given the dominance of rainfed cereal production in the humid parts of the country, the impacts of droughts during the timing of soil tillage—August/November—bring notable impact. Droughts occurring later in the year, following a wet, normal or even just less than normal autumn, have less effect on cereal production values. The data do not reveal an increasing number of negative anomalies, in other words more droughts, but they do show lower precipitation during wet years.

Due in part to periodic drought conditions, however, annual cereal production in Morocco tends to fluctuate widely, with average production on the order of 5.5 million tons and as high as 11.5 million and as low as 3.4 million, as is illustrated in Table 3.1 below. As observed above, Morocco's 1.5 million farms are mainly small with only 4 percent having more than 20 hectares and over 70 percent under 5 hectares. Thus, they are largely subsistence farming systems. Smallholders mostly have little diversification of crops, etc. and very low incomes. Therefore, they are highly vulnerable to market speculators and drought events. Agricultural exposure to various risks (drought, pest and diseases, and market price volatility) was estimated to be on the order of MAD 75 billion in 2008, and is projected to rise to as a high as MAD 180 billion by 2020.

In 2014–2015, cereal production reached bumper levels of 11.5 million tons because of plentiful precipitation. By the end of the 2015–2016 season, however, the rainfall deficit and its impacts were severe across much of the country. From figures published by the Ministry of Agriculture/United States Department of Agriculture Foreign Advisory Service (USDAFAS), crop production in 2016 was down to 1.9 million tons of common wheat, roughly 870,000 tons of durum wheat, and 620,000 tons of barley, together totaling less than one-third of the output of 2014–15. Durum wheat is the highest value crop among the cereals. During the 2015–16 season only 62 percent of planned sowing area was cultivated (3.2 million hectares instead of the 5 million originally planned) as the drought had already begun during the planting season.

Stakeholders interviewed for this assessment recognized that drought impacts for any given year depend greatly both on its seasonal onset and initial reservoir conditions. Fall and early winter droughts normally lead to significant reduction in cultivated areas in rainfed regions, whereas spring droughts tend to decrease cereal yields. The time-lag between drought onset and reservoir depletion means that irrigated areas experience drought differentially from rainfed areas. During the 2015–2016 drought, for example, the irrigation program in most *Périmètre Public Irrigué* (PPI, or public irrigation zones) was normal because, as indicated above, the reservoirs started at relatively high levels. Arboriculture, with the exception of olives, was likewise resilient during this event as most orchards were irrigated, frequently from groundwater, although this did put added pressure on these resources. Argan trees

TABLE 3.1 Morocco: Variations in Cereal Production by Crop, 2008–2016 (million tons)

Year/Crop	Durum Wheat	Common Wheat	Total Wheat	Barley	Total Production
2008/2009	2.1	4.3	6.4	3.8	10.2
2009/2010	1.6	3.2	4.8	2.5	7.3
2010/2011	1.8	4.1	5.9	2.3	8.2
2011/2012	1.1	2.7	3.8	1.2	5.0
2012/2013	1.9	5.1	7.0	2.7	9.7
2013/2014	1.4	3.7	5.1	1.7	6.8
2014/2015	2.4	5.6	8.0	3.5	11.5
2015/2016	0.9	1.9	2.7	0.6	3.4

Source: Adapted from Ministry of Agriculture, USDAFAS 2016.

are not irrigated and are more resilient than other tree crops. Thus, they are typically only severely affected by multi-year droughts.

During the most recent drought, conditions in Morocco's irrigated areas, which are vitally important for agricultural high-value crops—including those used in food processing—as well as for job creation were less affected by climate variability. This was because the dam and reservoir systems, which had been filled during the preceding "wet" year, were used to maintain production. Thus, the water in the reservoirs proved sufficient to support irrigation during the 2015–2016 season.[35]

The importance of irrigation for offsetting the impacts of drought in Morocco cannot be overemphasized. It is thus not surprising, however, that groundwater aquifers are severely impacted by droughts due to increased abstraction and decreased recharge. Stakeholders emphasized that in rural areas, shallow aquifers are the main form of drought resilience but that they are already severely stressed under normal conditions, particularly in the south and central parts of the country. The increasing utilization of fossil aquifers, especially during drought crises is a long-term concern in terms of both the quantity and quality of water supply, further aggravated by significant increases in saline intrusion in Agadir and, increasingly, in other coastal cities as well during these periods.

The development areas created under the PMV launched in 2008 were likewise important to maintain supplies of fruits and vegetables for export as well as for the production of certified seeds. During the drought, one of the priorities established by water managers for this increasingly scarce resource was to maintain water supply to the young fruit tree plantations in rainfed zones. Water availability and agro-ecological conditions must also be considered when identifying locations for planting orchards, whether for new or tree replacement. The impact of climate variability and of and the recent drought on the citrus and olive value chains is discussed in more detail in the next section.

Forage crops and rangelands, however, were also seriously impacted by the 2015–16 drought. Together with cereals, this sector contributes to some two-thirds of total agricultural production in Morocco. So the impacts were important. Forage prices started increasing by mid-December 2015, reaching high levels in January 2016 and negatively affecting the ability of farmers to feed their animals. This, together with the loss of pastures, led to a rapid decrease in the number of ruminants (Sadiki 2016).

Drought impacts on livestock also stem from low production in rangelands, reduced forage availability, and, in extreme cases, lack of drinking water. While just 18 percent of farmers gain their incomes solely from animal husbandry, livestock nonetheless constitutes a significant financial reserve for the majority of small farmers, particularly for those who have difficult access to agricultural credit. The drought of 1982–1985 caused the greatest impacts on livestock with losses of cattle and sheep herds reaching 25 percent and 40 percent of the total respective herd sizes. Recovery from these significant losses took almost 7 years. However, policy measures to ensure the availability of fodder during subsequent drought periods have tended to mitigate these effects.

Those interviewed also noted that pest damage is exacerbated during drought periods because of the increased vulnerability of crops and trees. The increased length of pest seasons, the increased number of insects, and the fact that some species that are usually benign have negative impacts during drought years all contribute to this situation. In 2016–17, pest problems were also amplified because of the return of species that have 10-year cycles coincided with deep drought.

[35] In addition, authorities predicted fruit tree yield to rise by 15 percent annually, including a 7 percent growth in citrus, which is a high-value export crop, and a 24 percent growth in olives (Economist Intelligence Unit 2016).

Stakeholders likewise stressed that the resilience of municipal water supplies to drought is very specific to locality. Generally, rural areas are the most vulnerable because of their frequent reliance on shallow groundwater aquifers and smaller reservoirs. Larger city vulnerabilities stem more from general infrastructure-related issues, a key example being Al-Hoceima's shortages in 2016. This largely resulted from long-term dam siltation, which has significantly reduced reservoir capacity for the coastal cities. Hydrological droughts, moreover, caused failure to sustain electrical power production in both 1984 and 1996.

Another kind of drought impact that particularly affects Morocco are forest fires, which increase in frequency, area burned, and intensity during such periods. Finally, droughts create major setbacks and disrupt government and private sector programs for reforestation, afforestation, and the conversion of rainfed cereals to arboriculture, i.e., programs that are being implemented in order to increase resilience to desertification and fix soils in vulnerable areas.

3.4 CLIMATE AND DROUGHT IMPACTS ON SELECTED KEY AGRICULTURAL VALUE CHAINS[36]

3.4.1 Overview

Morocco has made great progress in recent years to expand its citrus and olive production areas, initiate new plantings, and enable irrigation access to support commercialization of the citrus and olive sectors, as a result of the PMV. In opposition to these efforts, however, are the increasingly adverse effects of climate change, which create vulnerability and lack of predictability throughout the national and global supply chains. By taking steps now to address the key challenges facing Moroccan citrus and olive growers, and in particular by improving the cultivation and adaptation techniques of smallholders, who comprise the majority of agriculture producers, Morocco will be better positioned to ensure sector sustainability, meet targets for export and domestic consumption, and retain its admirable position in the global citrus and olive markets.

For olive production, the recent trend is characterized by an increase in the area of the olive trees and an increase in production with fewer fluctuations, as shown on Figure 3.9. This could be explained by the movement of olive production towards rainier areas, notably the north and the mountain areas. However, olive production remains vulnerable—not to the absence of rain, but to the hot winds of May and June that affect flowering.

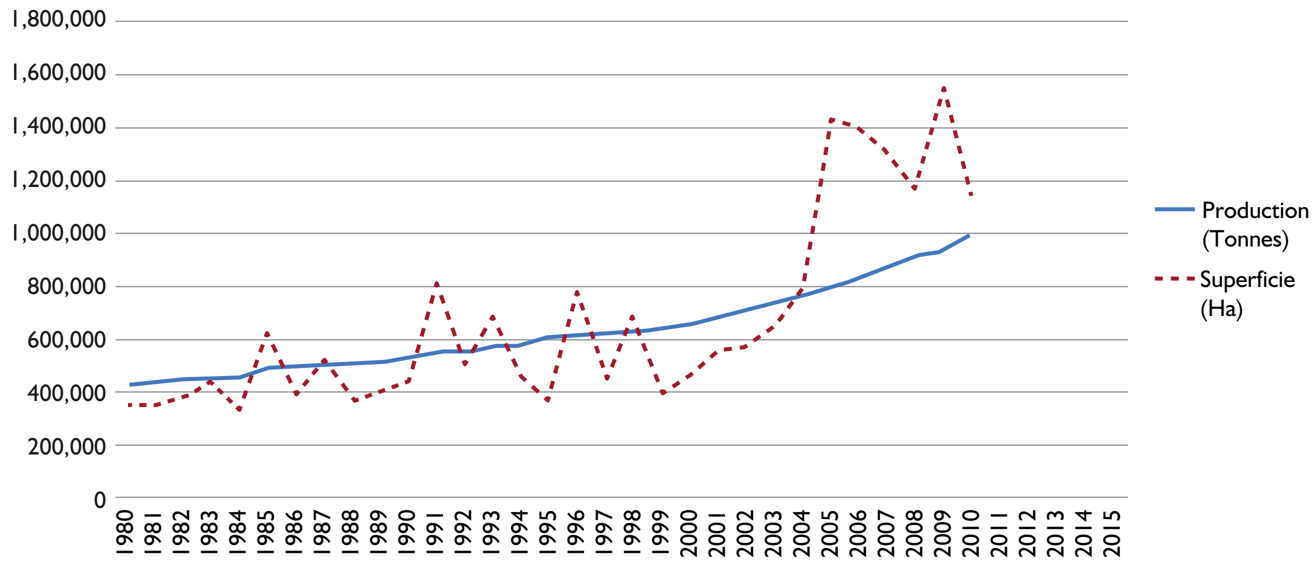
As for citrus, the increase in production in the context of climate change is explained by the extension of citrus acreage, which has gained more than 40,000 ha in 10 years (Figure 3.10). The extension of citrus-growing areas is generally accompanied by an increase in private irrigation (pumping from wells).

Similarly, regarding citrus, the amount of water available is down significantly. Rainfall is erratic in SM, a key citrus production region. This raises the question as to whether citrus production there is sustainable, given citrus' high water dependency for the production of quality fruit, or if consideration should be given to other more drought resistant crops.

As new and replacement citrus and olive trees are planted, care should be taken to plant them in geographic areas that can maximize the quantity and quality of fruit or olives produced. This is particularly important if growers are constrained in terms of access to affordable inputs and water availability.

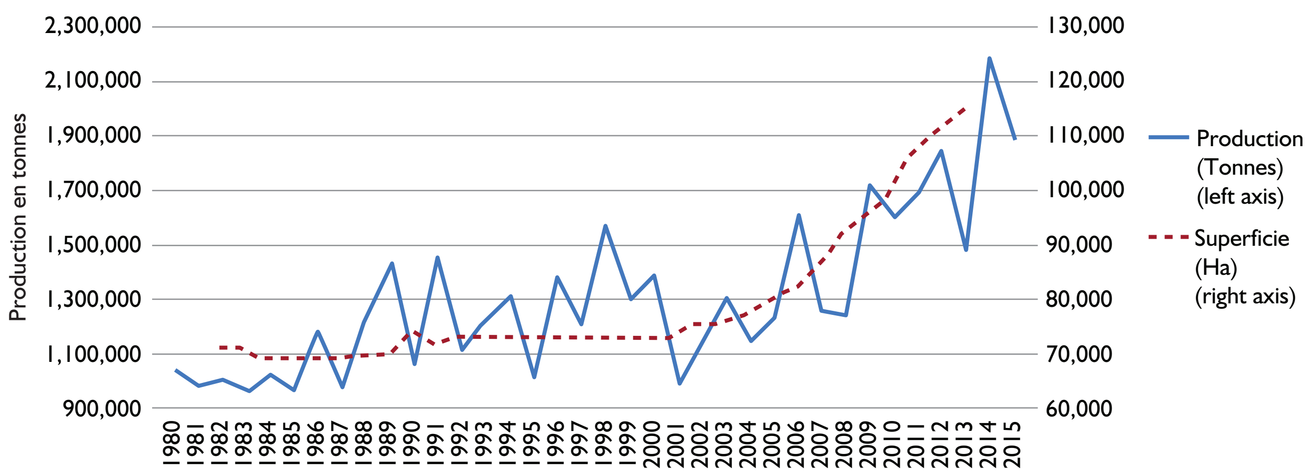
[36] This section is drawn from World Bank (2017).

FIGURE 3.9 Evolution of Olive Production



Source: World Bank data.
Note: Ha = hectares.

FIGURE 3.10 Evolution of Citrus Production



Source: World Bank data.
Note: Ha = hectares.

Use of certified trees adapted to specific regional growing conditions, as well as use of climate change resilient cultivars, can help maintain sector sustainability. While there are nurseries cultivating certified and non-certified trees in Souss-Massa and Marrakech-Safi (MS), no certified nurseries were identified in Béni Mellal-Khénifra (BMK).[37] Further, no nurseries were conducting long-term trials as to climate adaptive cultivars. Climate conditions in the areas surveyed for the present analysis at the time it was carried out are described in Annex 3.1. The more specific findings reported in the next two sections are the result of a rapid value chain assessment (RVCA) for these two important agricultural crops in Morocco. The methodology employed in this study is summarized in Box 3.2 below.

BOX 3.2 Methodology for the Rapid Value Chain Assessment for Citrus and Olives in Morocco

The research team conducted semi-structured and unstructured interviews with sector supply chain participants during May and June 2016, in the regions of Souss-Massa (SM), Béni Mellal-Khénifra (BMK) and Marrakech-Safi (MS). The primary objective of the interviews was to develop a deeper understanding of supply chain dynamics and market linkages, including perspectives on jobs, women, youth, and climate change adaptation in the value chains for the selected products of olive oil and oranges, which represent proxies for the olive and citrus sectors.

Separate surveys were prepared for growers and processors. Given limited resource availability, the rapid value chain assessment (RVCA) captured a small sample of growers and processors in each target region and profile, with participants and the resulting analytic data serving as a proxy for the socio-economic and market conditions among small-scale producers and processors in the target regions, particularly with respect to under-served populations, including women and youth.

With respect to growers, the RVCA captured data to provide insights into and contrast how citrus/olive farms perform differently, if at all, in different geographic locations under changing climatic conditions, and how women and producers in general are coping with these changes.

With respect to processors, RVCA captured farm-to-packhouse and farm-to-olive oil production and key issues and constraints along the value chains. Specific attention was paid to the role of women across the entire value chain and how the role of women can be increased in the respective value chain.

Citrus interviews targeted SM and BMK regions. At the time of the field mission, packhouse activity in both regions consisted of end-of-season conditioning and export of the orange variety Maroc Late. Local fruit prices rose in anticipation of Ramadan/seasonal demand for fresh-pressed juice. Independent and cooperative member growers, including cooperative members, were targeted for interview.

Olive interviews targeted BMK and MS regions. While olive oil trades throughout the year, the principal harvest and pressing season is October to January; as such, olive oil mill facilities generally were closed at the time of field mission, except for permanent staff conducting maintenance, storage and marketing operations. Independent and cooperative member growers were targeted for interview.

Source: World Bank 2017.

3.4.2 Climate Change Impacts on the Citrus Subsector

Citrus trees need irrigation to produce quality fruit. Orange trees in Marrakech, for instance, require 1,045 mm of water per year, which far exceeds the annual rainfall amount (El Hari et al. 2010). Water scarcity is therefore the most pressing impact of climate variability and change for the citrus sector. Some growers utilize government programs which partially reimburse investment in trees, irrigation, and other capital investment. However, the cost of electricity for operating a pump (often the highest or second highest cost after labor) or water charges (from irrigation canals or other public utility sources) can be prohibitive. For example, on average for farms surveyed in RVCA, electricity (48 percent) and

[37] For purposes of this analysis the SM and MS areas in the south were selected for citrus and olive production, respectively, and BMK in the north for both citrus and olive production (see Box 3.2).

water (30 percent) together comprise 78 percent of farm operating costs (excluding harvest) for a 10-hectare farm using electric-pump drip irrigation with water sourced from an irrigation canal.

For farms sourcing water from wells, as wells dry out, deeper but less productive ones are dug. This can cost 3–4 times more (e.g., electricity use increases from MAD 0.80/m^3 to MAD 2.40/m^3 or US$ 0.08/m^3 to US$ 0.25/m^3) in order to bring water to the surface. In addition, due to the large volumes of water required for each watering cycle, growers that use drip irrigation (whether canal- or well-sourced) must dig and maintain large retention ponds to store water prior to irrigation, thereby reducing the surface area available for planting.

Extreme shifts in temperature and rainfall timing and extreme weather events affect citrus production, timing of blossoming and ripening, and other quality and quantity metrics, sometimes significantly reducing regional yields in a given year or shifting timing of harvest. As a result of climate-induced problems, citrus processors suffer from unreliable quantity and quality of fruit. This, in turn, complicates their ability to meet commitments for export sales contracts.

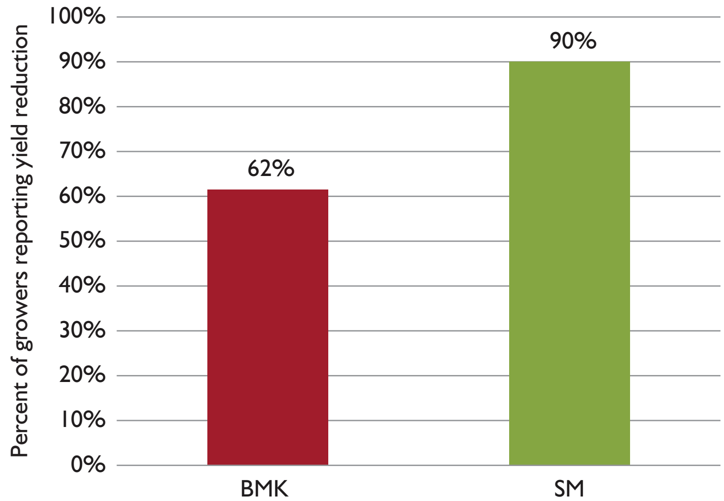
Much of Morocco's olive production is currently under rising threat due to water scarcity despite the crop's relatively low water needs, potentially jeopardizing sector sustainability and production for both local consumption and export of olive oil and table olives. Favorable agro-ecological conditions, including adequate water via rainfall and/or irrigation, exist for only 36 percent of the olive planted area (hectares) (regions in proximity of Al-Hoceima and Tangier). At least 47 percent of the olive area and 50 percent of olive production quantity is at climate risk. The Marrakech area, comprising 14 percent of planted area and 18 percent of production quantity, already suffers from insufficient rainfall. Areas in proximity of Beni Mellal, Meknes, Fes, and Oujda likewise have unfavorable agro-ecological conditions, i.e., mountainous terrain and/or insufficient water availability conducive to olive productivity.

Water scarcity is a key issue for Moroccan citrus production. Citrus trees require large amounts of water relative to other tree crops, as well as temperature and other growing conditions conducive to producing high quality marketable fruit. Historically, Moroccan citrus has developed in regions with ideal climatic conditions and adequate groundwater for irrigation. Public irrigation schemes have enhanced grower access to water, but do not provide sufficient water for most growers, given the broad needs of the agricultural sector and diminishing water supply to such programs. Furthermore, rising irrigation costs increasingly squeeze growers' net income

The following paragraphs and Annex 3.2 discuss the specific results of the RVCA on citrus with regard to the impact of climate variability and change on surveyed farmers. Because the climate change-related questions asked of respondents were framed in the context of the RVCA concerning the farmers' personal citrus farming experiences, however, the timeframe comprises their experience over the past few years, not the long term (scientific) definition of climate change. In this context, growers typically report effects of weather variability as being effects of climate change. It is thus important to reiterate that these results are farmers' perceptions rather than scientific measurements of longer-term climate change impact.

Climate Impacts on Yields. The majority of the citrus growers surveyed (80 percent overall, 62 percent of BMK and 90 percent of SM) reported irregular or declining yields in the past several years due to decreased rainfall (see Figures 3.11 and 3.12). Among growers reporting a decline, effects of yield rate declines averaged 41 percent in BMK (range 10 to 50 percent) and averaged 37 percent decline in SM (range 20 to 55 percent). Thus, even though all citrus growers surveyed irrigated their crops, this was insufficient to maintain the desired crop volume.

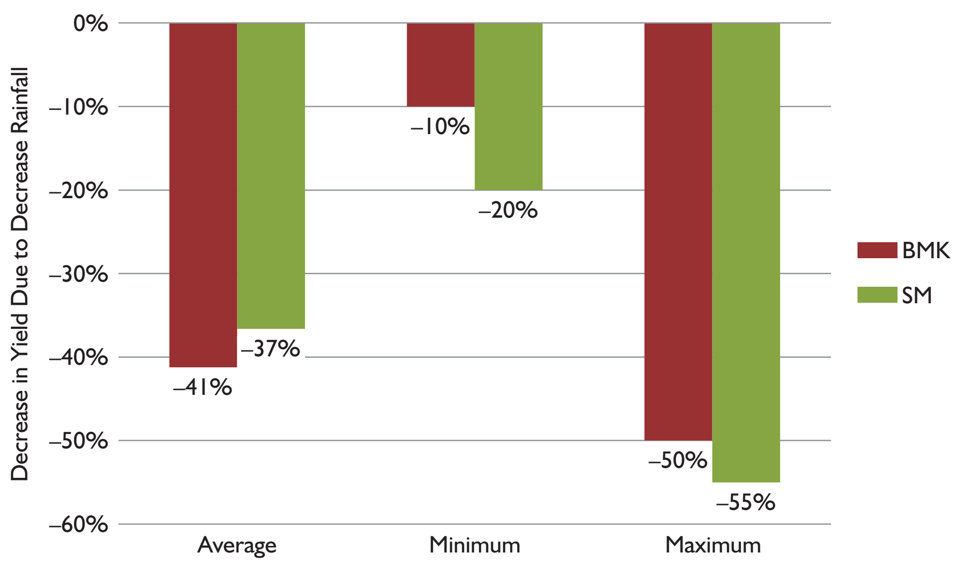
FIGURE 3.11 Citrus Growers Experiencing Yield Rate Decline due to Decreased Rainfall



Source: World Bank data.
Note: BMK = Béni Mellal-Khénifra; SM = Souss-Massa.

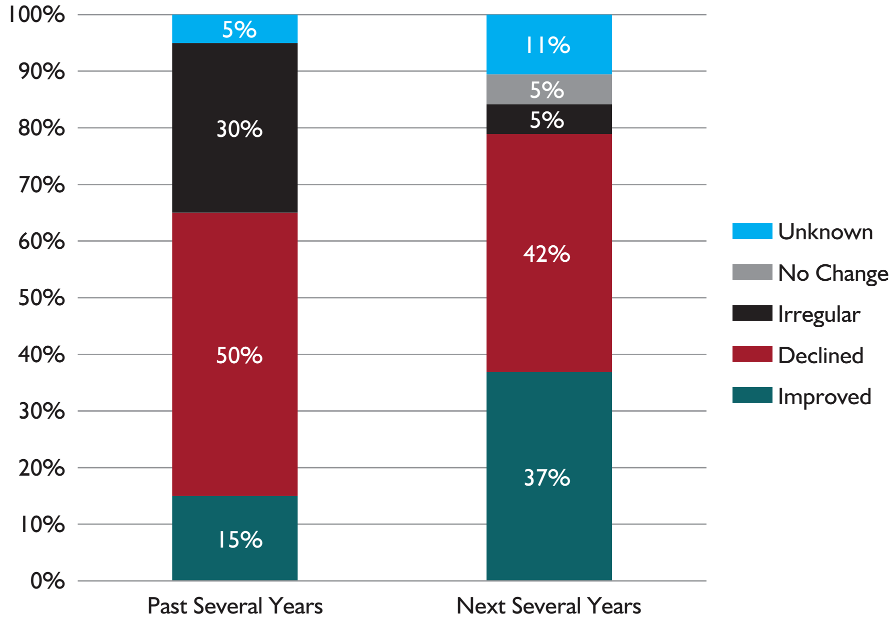
All farmers reporting declining or irregular yields attributed at least some portion of this loss to climate change, with 13% also attributing some of their low yield to disease/pests, for which climate change can be a factor. The type and prevalence of disease and pests affecting a given area can change over time, moreover, as habitats shift with weather and temperature patterns. Some growers (15 percent) reported that they were able to improve yields despite climate variability due to better farm management. When asked about future outlook, 47 percent of growers anticipate declining or irregular yield due to climate

FIGURE 3.12 Reported Citrus Yield Rate Decline due to Decreased Rainfall



Source: World Bank data.
Note: BMK = Béni Mellal-Khénifra; SM = Souss-Massa.

FIGURE 3.13 Recent and Future Yield Rate for Citrus Growers



Source: World Bank data.

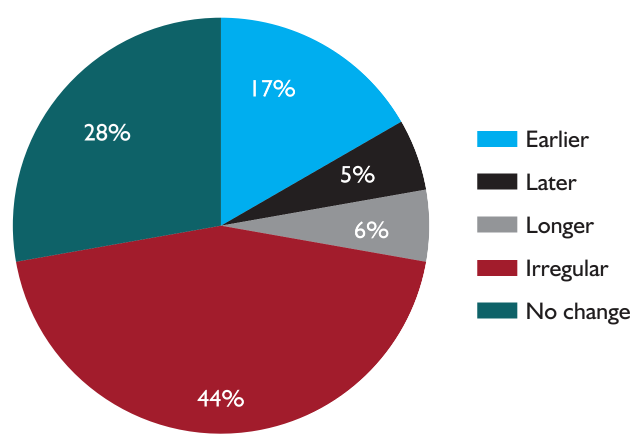
change, while 37 percent expect yield to improve, despite climate change because of better technical skills and farm care (67 percent) and/or new plantings (33 percent) (see Figure 3.13).

Climate Impact on Harvests. Extreme fluctuations in temperature, rainfall timing, and extreme weather events associated with climate variability and change affect the timing of blossoming and ripening, significantly altering the citrus harvest cycle and fruit color/quality. This shift in harvest timing, reported by 72 percent of growers surveyed (see Figure 3.14), also reduces export competitiveness, since packhouses require reliable timing of crops in order to meet export market contracts, instead of the irregular timing that was reported by 44 percent of the growers surveyed for the past several years.

Each variety, farm, and region responds differently to climate change, although lemons are somewhat immune to a shift in harvest timing due to their year-round production. Climate variability not only affects growers, but citrus processors also suffer from unreliable quantity and quality of fruit as a result. Other economic impacts of climate change on citrus production are summarized in Annex 3.2.

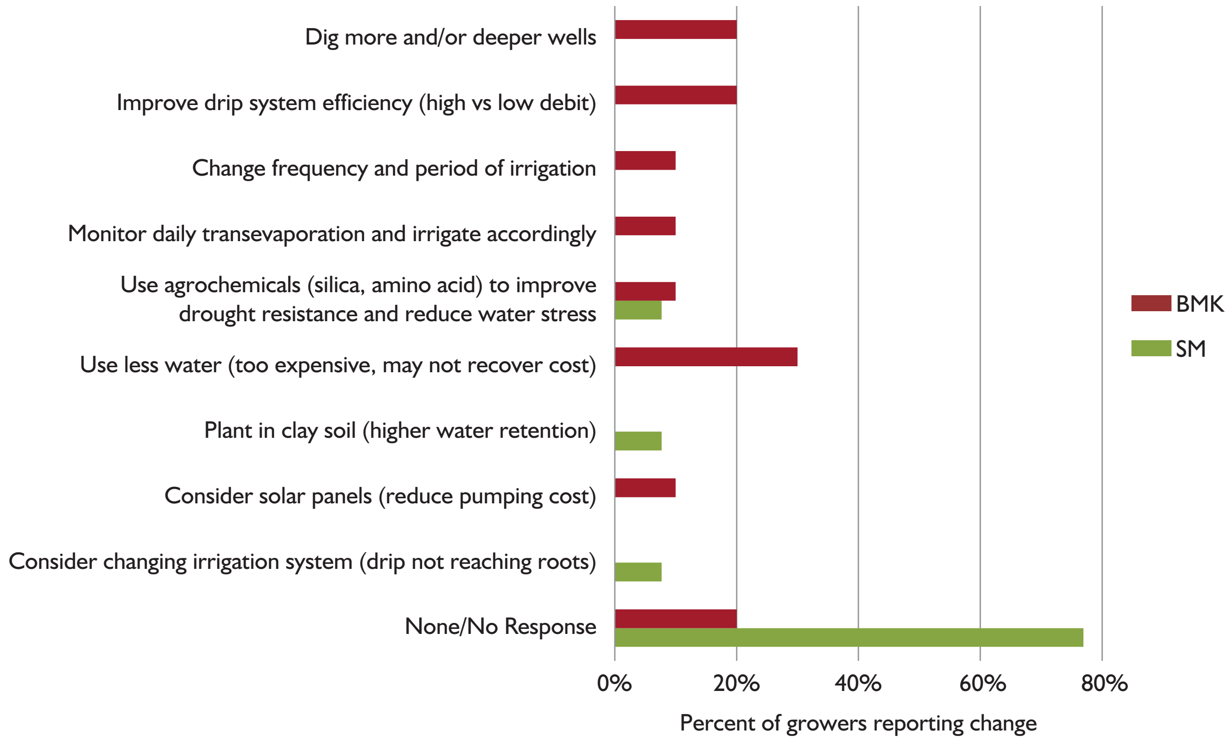
Adaptation to Climate Change. Faced with a changing climate and shifting growing conditions, the most common farmer response among surveyed growers is to "do nothing" (52 percent overall; 20 percent in SM and 77 percent in BMK – see Figure 3.15 below). However, 80 percent of SM growers and 23 percent of BMK have taken at least some adaptive measures. Surveyed citrus growers took basic approaches such as digging more and deeper wells, and innovative approaches

FIGURE 3.14 Change in Citrus Harvest Cycle in the Past Several Years



Source: World Bank data.

FIGURE 3.15 Climate Adaptive Changes to Water Management for Citrus Sector



Source: World Bank data.
Note: Multiple responses accepted. SM = Souss-Massa; BMK = Béni Mellal-Khénifra.

such as using agrochemicals to improve drought resistance. Unsurprisingly, the more developed region was more adaptive with 30 percent of SM growers reducing their water use, citing cost/benefit reasons for this decision (i.e., although yields will be reduced with a reduction in water, growers realize that with rising water costs, they may not recoup irrigation cost via fruit sales price).

Conclusion. Morocco is expected to produce more citrus fruit in the coming years due to the expansion of planted areas and increased yields by improving irrigation systems (USDAFAS 2016). Nevertheless, the Moroccan citrus sector remains vulnerable to drought and other effects of climate variability and change. Grower approaches to combat water scarcity are haphazard and they would benefit from better sector coordination and knowledge regarding climate change adaptation and general cultivation techniques. Such capacity development will benefit both growers and packhouses whose ability to fulfill export demand requires reliable quantities of high quality fruit. In addition, growers lack knowledge and skills to adapt to the effects of climate change. By taking steps now to address the challenges facing citrus growers, and in particular to mitigate the climate change vulnerability that affects both the quantity and quality of the fruit, Morocco will be better positioned to ensure sector sustainability, meet its export targets and domestic consumption needs, and retain its success in the global citrus market.

3.4.3 Climate Change Impacts on the Olive Subsector

Weather is increasingly variable with extreme conditions year-to-year and, as such, olive growers generally have been unable to adapt appropriately, as conditions and associated challenges are constantly changing. Several large and small growers described 2016 as "crazy," since, due to extreme temperature variation, trees exhibit both fruit formation and pre-fruit blossoms simultaneously. No grower was able to speculate on future results, since this phenomenon has never been seen before.

Although olives are much more drought tolerant than citrus, water scarcity can still be an issue, since reduced water (whether via rainfall or irrigation) results in less oil and lower oil quality. Table 3.2 indicates the amount of water (mm/year) used by an average oil olive grove (table olives require slightly more water for high quality fruit) and the effects on the grove of different amounts of water applied. For example, olive trees require at least 693 mm/year of water to maximize oil production. Olive oil yields are compromised in conditions where olive trees do not realize at least 396 mm/tree annually, and oil quality (in terms of oil chemical and sensory characteristics) is reduced in conditions of less than 297 mm/tree annually. Depending on the specific cultivar and agro-climactic conditions, the amount of water that constitutes "full use" (i.e., the total amount used in full evapotranspiration) by a mature olive grove may vary slightly from the average of 990 mm/year; in such a case, the water requirements for the various situations described may be calculated using the percentages in the final column in the table.

For smallholders, water scarcity adaptation consists largely of (seeking permission to be) digging another well when the existing one dries up, or forgoing irrigation altogether, even in the case of new trees provided under a Government of Morocco (GoM) and Millennium Challenge Corporation (MCC) scheme which funded the first two years of irrigation and maintenance and expected growers to continue tree maintenance after the maintenance contract ended. Even where water exists (through well or canal/irrigation schemes), the cost of pumping or water charges tend to be prohibitive to smallholders. Similar to citrus, olive growers with larger farms and using drip irrigation maintain large retention ponds to store water for each irrigation cycle, reducing surface area available for planting.

Intermediaries (buyers and sellers of olives and oil) and processors of oil (who also buy or grow olives) have adapted by diversifying olive procurement geographically, since climatic effects differ regionally. For example, one Haouz-based (MS) intermediary grower and traditional mill-owner now brokers olives from as far as Oujda (900 km away) versus from within MS as had previously been the case. Modern oil mills targeting quality, however, generally do not follow this path, as they procure olives through forward contracts after closely monitoring their cultivation, and only have resources to evaluate growers within the mill vicinity. The following paragraphs and Annex 3.3 summarize the results of the RVCA on olives with regard to the impact of climate variability and change on surveyed farmers with the same caveat in relation to climate change as stated above with respect to citrus.

Climate Impact on Yields. The majority of surveyed olive growers (50 percent overall, 64 percent of BMK and 36 percent of MS) reported irregular or declining yields over the past several years due to decreased rainfall (Figure 3.16).

Among the aforementioned growers reporting a decline, reported effects of yield rate decline averaged 41% in BMK

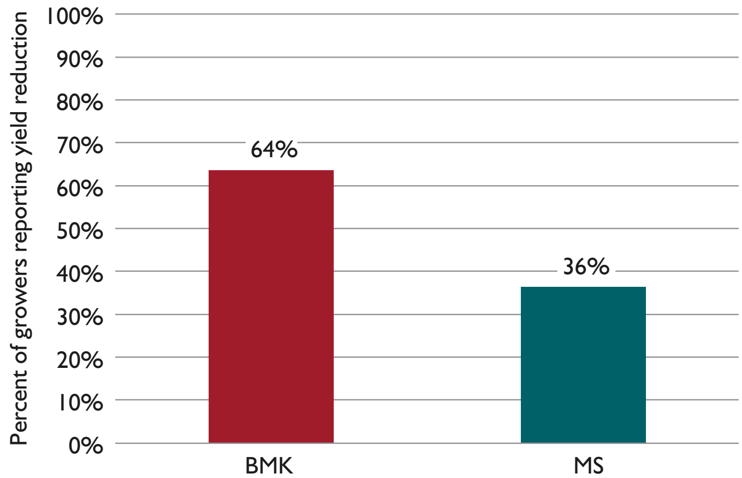
TABLE 3.2 Average Water Requirements for Oil Olives

Parameter	Water Requirement: Avg. mm/Year	Water Requirement: % of Full Water Use
Mature olives full water use	990	100%
New planting water use (10% canopy cover)*	198	20%
Max. oil yield/tree	693–749	70–75%
Max. oil quality	327–396	33–40%
Good oil quality, but oil yields begin to reduce	≤ 396	≤ 40%
Oil quality and yield reduced	≤ 297	≤ 30%

Source: Compiled by Global Development Solutions from: http://ucmanagedrought.ucdavis.ed/ Agriculture/Crop_Irrigation_Strategies/Olives/

Note: Full water use is reached once canopy cover exceeds 50% of the orchard surface. In young orchards with less than 50% canopy cover, crop water use will be reduced but not by the amount of the cover reduction. Increased reflection from the soil surface and advective heat from unshaded areas between rows increases water use by young trees. If canopy cover is less than 50%, water use is estimated to be twice what the canopy cover percentage would suggest. For example, 10% cover would mean multiplying full ETc by 0.2 (or 20%), 30% cover means multiplying full ETc by 0.6. ETc = .

FIGURE 3.16 Olive Growers Experiencing Yield Rate Decline due to Decreased Rainfall

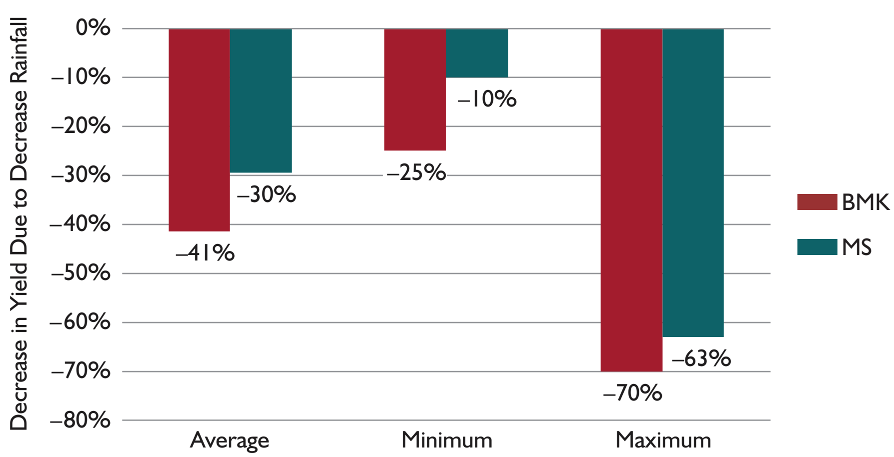


Source: World Bank data.
Note: BMK = Béni Mellal-Khénifra; MS = Marrakech-Safi.

(range 25 to 70 percent decline) and averaged a 30 percent decline in MS (range 10 to 63 percent) (see Figure 3.17 below). When asked to what cause(s) they attributed the yield loss and irregularity, 70 percent of surveyed farmers responded that climate change was the cause. The 43 percent who instead reported improved yield credited better farm management and new plantings to their success despite the challenges posed by climate change.

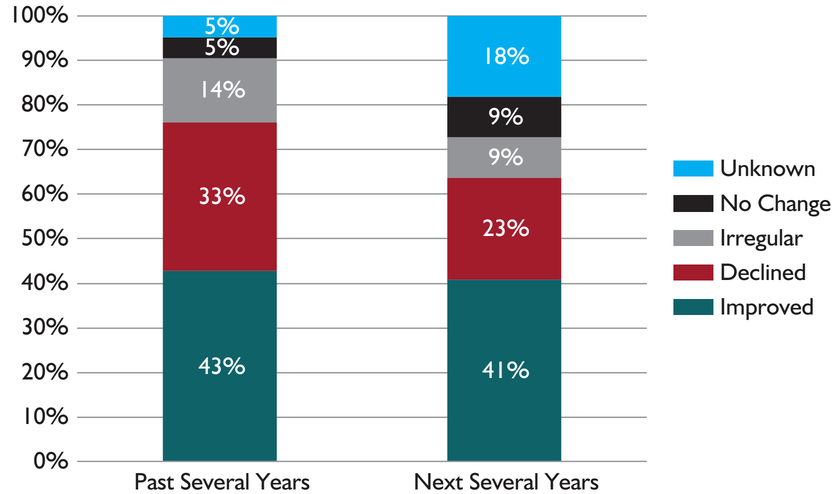
Regarding future outlook, 32 percent of growers anticipate declining or irregular yields due to climate change (60 percent), aging trees (13 percent) and poor tree husbandry (13 percent). More respondents were optimistic, with 41 percent stating they expect yields to improve (See Figure 3.18), despite climate change. These growers hope to improve tree care (50 percent) and acquire new plantings (50 percent).

FIGURE 3.17 Reported Olive Yield Rate Decline due to Decreased Rainfall



Source: World Bank data.
Note: BMK = Béni Mellal-Khénifra; MS = Marrakech-Safi.

FIGURE 3.18 Recent and Future Yield Rate for Olive Growers



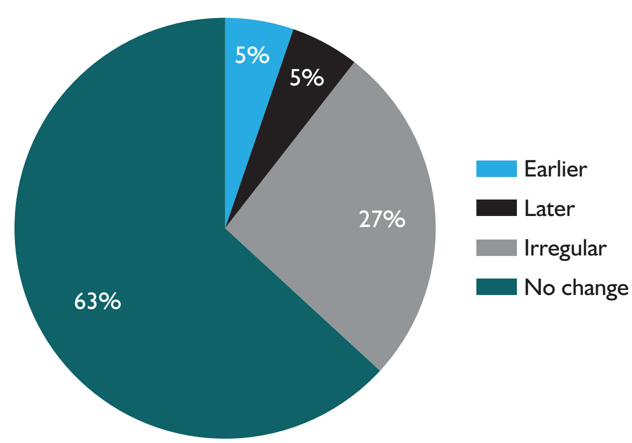
Source: World Bank Data.

The remaining 18 percent of growers could not predict future results given extreme climatic effects which are becoming more common.

Climate Impact on Harvests. The intended use of olives affects harvest timing. For example, table olives are generally harvested earlier than oil olives. Oil olives for modern mills are harvested earlier (e.g., November) than oil olives destined for traditional mills, and quantity-focused growers press later in season (e.g., December or January), since the early season olives have higher quality, albeit lower extraction rate, while the later season olives produce more oil per olive. However, rainfall timing and distribution throughout the season, as well as extreme temperature and weather events such as hail affect the timing of blossoming and ripening, often disrupt the ideal harvest schedule and potentially require multiple harvest cycles in a year. Among surveyed growers, 37 percent reported harvest timing shifts in recent years, and 27 percent noted irregular and unpredictable harvest timing from year-to-year (see Figure 3.19 below). In some cases, farmers encountered multiple stages of maturity and blossoming on the same tree, though the specific effect varies by variety, farm and region. Sixty-three percent of growers reported no change in harvest timing. However, the timing may be independent of the effects of climate change. Many villages may follow an ancestral calendar for harvest and pressing, with each family's "turn" at the traditional mill pre-assigned, disconnected with olive readiness.

Growers with only one variety of olive are at the highest risk for adverse effects of climate change. For example, an MS intensive grower of three olive varieties (Arbequina, Arbosana and Koroneiki) who experienced extreme temperatures throughout the season and hail during May 2016 expected to lose 70 percent of this year's crop of Arbequina, 100 percent of Arbosana

FIGURE 3.19 Change in Olive Harvest Cycle in Past Several Years



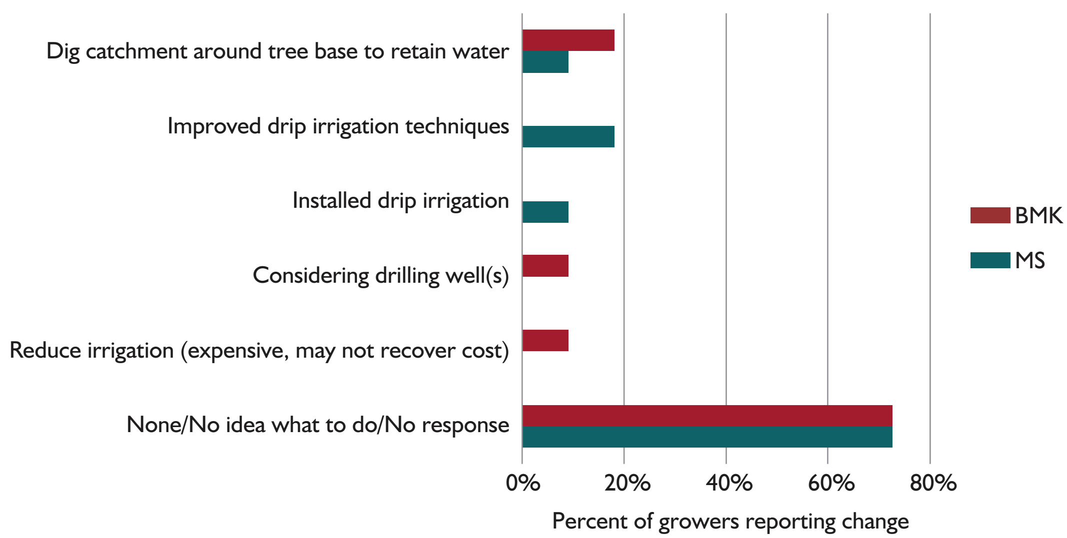
Source: World Bank data.

and 0 percent of Koroneiki. While 73 percent of growers surveyed in MS have two or more varieties, 73 percent in BMK grow only Maroc Picholine, putting the region at higher risk of crop loss and reducing the likelihood that national targets for olive and oil production for domestic consumption and export will be reached. BMK growers also had older orchards relative to MS growers, and are less likely to have updated and diversified tree stock to maintain performance and incorporate Menara and Haouzia varieties, which the *Institut National de la Recherche Agronomique* (INRA, National Institute for Agricultural Research) has found to be more resistant to drought and disease than is Maroc Picholine (International Olive Council, 2012). Monocropping also potentially reduces export competitiveness, because it is difficult to respond to changes in the market when different varieties are in demand. Other economic impacts of climate change on the olive producing sector, including exports, are briefly described in Annex 3.3.

Adaptation to Climate Change. Growers lack coping mechanisms and incentives to adapt, and the most common grower response (73 percent for both BMK and MS) to recognized climate change impacts is to "do nothing." The olive sector in Morocco is characterized by a traditionally low-maintenance approach to olive tree care, and concerned growers lack the skills to deal with unprecedented climate effects. Of those that do take adaptive measures, growers take both labor and capital-intensive approaches. Growers in MS and BMK reported digging a catchment at the tree base for water retention, and in MS some growers installed or improved drip irrigation (See Figure 3.20). BMK growers were more likely to reduce their irrigation levels due to cost, since low rates of commercialization result in limited funds available for irrigation and farm management.

Historically, olive trees in Morocco exhibited drought resistance and provided growers, particularly smallholders, with reliable minimum crop volume, and household food supply and income, even in adverse conditions. However, weather variability is compromising sector production. Both old and new plantings are at risk as trees prove increasingly susceptible to effects of extreme weather, with growers ill-equipped to cope with unprecedented conditions. Mills also are affected, as traditional mills find income reduced in lower yield conditions, and modern mills are further unable to predictably plan production

FIGURE 3.20 Climate Adaptive Changes to Water Management for Olive Sector



Source: World Bank data.

Note: Multiple responses accepted. BMK = Béni Mellal-Khénifra; MS = Marrakech-Safi.

cycles or source sufficient quantity and quality of raw material. Smallholder olive growers who focus on production for household/gift and informal markets will likely still have sufficient food and/or net income, particularly given the low investment in orchard care by traditional smallholder farms. However, smallholders seeking to integrate to the formal commercial sector (e.g., to sell olives for modern oil milling) will be challenged, since drought and other climatic effects may compromise their ability to provide a reliably high quality crop in sufficient volume to meet mill purchase requirements. Commercial (e.g., intensive) growers already find production and income to be constrained. The transformation of the olive oil sector toward a path of modern milling to produce high quality oil for local and export markets requires that growers large and small maximize yield rates. Smallholders, which comprise the majority of olive planters,[38] will need to improve their production, rather than rely on a *status quo* which is increasingly under threat due to climate change.

Conclusion. Morocco has made great strides in recent years to expand olive production area, initiate new plantings, and enable irrigation access to support commercialization of the olive sector. Nevertheless, the Moroccan olive sector remains vulnerable to drought and other effects of climate change. Growers large and small lack knowledge and skills to adapt to and mitigate the very real effects of climate change. By taking steps now to address the key challenges facing olive growers, and in particular improving the cultivation techniques and reducing climate change vulnerability of smallholders which comprise the majority of olive producers, Morocco will be better positioned to ensure sector sustainability, meet targets for export and domestic consumption, and retain its admirable position in the global olive sector.

3.4.4 Challenges and Recommendations for Climate Change Adaptation in the Citrus and Olive Subsectors

As concerns the key Moroccan agricultural value chains considered above, finally, four types of climate variability and change-related challenges were identified, and the associated specific recommendations for both citrus and olives are essentially the same. They are the following:

Challenge 1*:* Lack of coordination regarding climate change strategy and sector-specific intervention activities at the national and regional levels.

Recommendation: Support newly-formed task force between the Ministry of Agriculture and Maritime Fisheries (MAPM) and the Ministry of Energy, Mining, Water and the Environment to develop climate-smart policy/strategy with specific intervention activities at the sub-sector and regional levels where resource needs are different.

Challenge 2*:* The high and rising cost of irrigation and mixed outcome regarding irrigation results.

Recommendation: Develop regional pilot studies and demonstration farms using funding from innovation challenge fund scheme regarding affordable small-scale on-farm alternative energy sources for power/irrigation (e.g., solar, wind) and appropriate application of various irrigation methods to ensure growers that adopt drip irrigation maximize benefits of the technology; and conduct through

[38] The dominant olive farming system in Morocco is “traditional extensive” (i.e., limited inputs, with trees typically 50 years or older, tree density less than 100 trees/hectare, and much of production kept for own consumption), which comprised 73.7 percent of farms and 51.3 percent of planted area.

membership associations to assess the direct benefit to small-scale farmers and review electricity tariff rates to develop a more refined tiered tariff rate for different uses and industry including agriculture, to move Morocco toward a best practice electricity pricing scheme and potentially reduce farm irrigation cost.

Challenge 3*:* The lack of local institutional and grower knowledge regarding climate change adaptation techniques.

Recommendation: Foster a "learning exchange" for direct cross-learning between global and Moroccan climate change adaptive growers to share appropriate best practice adaptive water-smart techniques (e.g., recycled waste water, reclamation, harvesting, control of water resources, improved efficiency drip irrigation, desalination, agrochemicals for drought resistance); partner with international institutions (e.g., Greenhouse Gas Management Institute, World Resources Institute) to receive training-of-trainers and latest technologies and information regarding climate change adaptation; use innovation challenge fund scheme to help finance support activities; and provide training/education and regular stakeholder forums on climate change adaptation, organized and funded through regional member-based grower and stakeholder associations (innovation grant).

Challenge 4*:* Lack of cultivar diversity; orchard locations are incompatible with shifting regional agro-ecological conditions.

Recommendation: Through partnership arrangements with nurseries, growers and development partners, expand the use of certified trees appropriate to regional agro-climatic conditions; provide tree replacement and diversification program to encourage planting of multiple appropriate varieties on same farm to reduce grower climate change risk; establish a certified tree replacement credit system through the partnership to provide farmers with credit vouchers which they can redeem to receive discounts on agro-inputs, equipment and technical services; and for Government-sponsored tree programs, improve coordination with nurseries regarding procurement versus production cycles, procurement transparency and length of time horizon to enable more efficient supply/demand and sector profit.

CHAPTER **FOUR**

DROUGHT MANAGEMENT FOR THE AGRICULTURAL SECTOR IN MOROCCO

This chapter describes the evolution and nature of Morocco's present drought management system, giving particular attention to those elements that are intended to help mitigate drought impacts on the agricultural (including livestock) sector. It considers both how the Government is presently organized to address drought situations and briefly describes the instruments that are used to mitigate their impacts. This discussion is largely based on a review of existing literature and the field research carried out by the International Center for Biosaline Agriculture (ICBA) and the University of Nebraska–Lincoln (UNL) in 2016 referred to in the two preceding chapters. It also points out both areas of good practice and continuing challenges and gaps that remain to be filled. These form the basis for the policy options that are suggested in the final chapter of this report.

4.1 INTRODUCTION

As discussed in Chapter 2, drought events in Morocco are expected to become more frequent and intense in the future as the result of global climate change. This will have particularly harmful effects on the agricultural sector and have broader repercussions for the national economy as a whole. In response to this situation, the Government has gradually established an Integrated Drought Management System (IDMS) that, according to the World Meteorological Organization (WMO) and Global Water Partnership (GWP), is organized around three main elements:

- ***A monitoring and early warning system***: this entails development of national institutional and technical capacities particularly for climate modeling, remote sensing, and crop forecasting. In this context, a National Drought Observatory (NDO) was established in 2001 to improve forecasting, assess impacts, and develop strategies and tools for decision support and drought preparedness. However, this Observatory has been discontinued.
- ***Emergency operational plans to alleviate the impacts of drought***: the country reportedly has longstanding experience in the development and implementation of programs to alleviate the impacts of drought based on interventions aimed at: (i) securing safe drinking water for rural populations in particular; (ii) preserving livestock through feed distribution; (iii) implementing income and job-creating activities (mainly through the maintenance of rural roads and irrigation infrastructure); and (iv) conserving forests and other natural resources.

- ***A long-term strategy to reduce vulnerability***: this strategy is based on a risk management approach that seeks to reduce the vulnerability to drought of the national economy as a whole and of the agricultural and rural economy in particular. It involves a diverse and multi-dimensional array of policies and instruments that take drought risk into account together with droughts' geographical diversity and economic and social implications, and their expected continuing long-term recurrence (WMO and GWP 2014).

4.2 LESSONS FROM INTERNATIONAL EXPERIENCE WITH DROUGHT MANAGEMENT

As observed in Chapter 1 and reflected in part in Morocco's own experience, in recent decades many countries have shifted their approach to drought management. The traditional approach consisted largely, if not exclusively, of the taking of emergency relief measures once droughts have started and their adverse impacts were already being felt. The currently recommended one, in contrast, is a more proactive one entailing risk management approach that focuses on improved monitoring and early warning systems, together with a variety of preparedness measures, so as to better anticipate and mitigate the harmful economic, social, and environmental effects of this recurrent climate-related phenomenon. In this regard, a recent review of evolving experience in a number of developed and developing countries with respect to drought management (Redwood 2017) highlights a number of lessons that are worth considering when examining the Moroccan experience to date:

- Numerous countries have a long history of dealing with droughts and responding to drought impacts. However, in the past the bulk of these efforts have occurred in a largely *ad hoc* and reactive manner. More recently, a drought risk management approach has been taken in many countries in order to help address and reduce the likely increasing serious nature of future droughts.
- Because droughts are complex phenomena and their impacts evolve as social vulnerabilities change over time, improving drought risk management requires a long-term commitment. Short-term projects may meet with only limited success. But proactive risk management strategies may require years to develop and evolve in order to successfully reduce drought impacts.
- Long-term drought risk management can be difficult to advance when the pressure caused by a current severe drought heightens the focus on immediate crisis response. However, it is often a severe drought crisis that provides the best opportunity and impetus to implement longer-term drought risk management measures.
- Because drought risk management involves a long-term commitment, initial efforts may be comparatively simple with the expectation that they will become more sophisticated over time. A prime illustration of this the United States Drought Monitor (USDM), which was a much simpler process when it started in 1999 (see Box 4.1). There are similar expectations in relation to the newly established Drought Monitor for Northeast Brazil (see Figure 4.1 and Table 4.1) (De Nys, Engle, and Magalhães 2017).
- The iterative process that occurs between drought monitoring and improved drought risk management through preparedness planning at different spatial scales has been demonstrated in various countries. These include Brazil, Mexico, and Spain (see Box 4.2), as well as Morocco, which have focused on activities at the river basin level, together with Australia, India, and the

BOX 4.1 The Drought Monitor in the United States

A key monitoring instrument was developed as the result of a partnership between National Drought Mitigation Center (NDMC) at the University of Nebraska–Lincoln, the National Oceanic and Atmospheric Administration (NOAA), and the Department of Agriculture of the US Federal Government with the purpose of improving and disseminating drought-related information on a real time basis. This takes the form of the United States Drought Monitor (USDM) Map, which is updated weekly, thereby raising awareness about drought conditions and impacts throughout the country. This map is used both by federal and state governments to assess evolution of drought conditions and trigger drought response and mitigation programs. It also permits early warning, improved seasonal forecasts, and delivery of this information to decision makers at all levels and to other public and private stakeholders, including individual farmers and ranchers. In short, it is an essential decision support tool for both planning and response to droughts of varying spatial incidence, degrees of severity, and duration.

The USDM map can be readily accessed on line and, based on real time monitoring data, indicates those parts of the country in drought conditions of increasing intensity, ranging from "abnormally dry" to "exceptional drought" passing through "moderate," "severe," and "extreme" drought. It also indicates whether the existing drought is short-term (i.e., typically less than six months) or long-term (more than six months). The greatest impacts of the former are mainly on agriculture and grasslands, while those of the latter also influence both hydrology and the ecological situation in the affected areas. The map can be viewed on a regional and state-by-state, as well as nationwide, basis. A short text summary, which accompanies the map, describes changes in drought conditions that have occurred over the previous week. It also summarizes short-term temperature and rainfall forecast information on a regional basis.

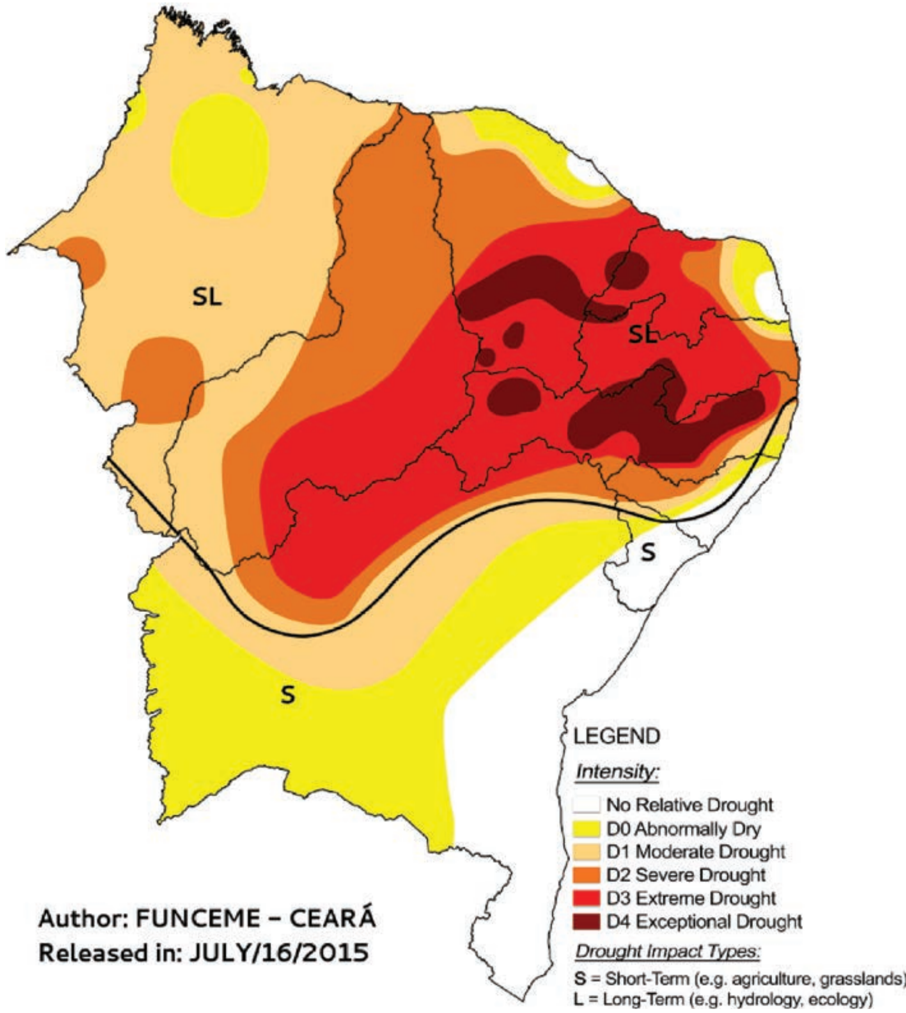
Source: Redwood 2017.

United States, where drought risk management efforts have occurred largely at the state level.[39] At the national level, moreover, Australia, has adopted a variety of measures to help address drought impacts on the agricultural sector (see Box 4.3).

- In robust systems better drought monitoring tends to lead to better planning over time as improved information enters the decision making process at both the national and subnational levels. This has been recognized by virtually all of the countries surveyed, both inside and outside the Middle East and North Africa region, although achievements to date have been mixed.
- In some countries, such as Mexico, development of a National Drought Policy provided the momentum to help break initial inertial attitudes within the national government with respect to the adoption of a more proactive approach to drought management, illustrating the importance of having strong "top-down" support for drought risk management.
- Active stakeholder engagement, transparency, and broad dissemination and other public awareness and educational measures concerning drought risk, together with associated management activities, help to ensure success of the latter.
- Continuous engagement on the part of drought-prone countries with international experience and exchange of information on drought risk management through conferences, workshops, and by other means has been beneficial. This has been the case both for the development of

[39] See, for example, ABARES (2012), and Turner et al. (2016); De Nys, Engle, and Magalhães (2017), and WMO and GWP (2014); Mount et al. (2015); Rathore (2014); Vargas (2008).

FIGURE 4.1 Drought Monitor for Northeast Brazil for July 16, 2015



Source: De Nys, Engle, and Maganhães, 2017.

more dynamic risk management approaches and for the infusion of updated knowledge and research findings into these approaches. Current technical cooperation activities in Middle East and North Africa, including that by ICBA and UNL to support a Regional Drought Management System (RDMS)[40] – which has also generated important inputs for the present study—are seeking to capitalize further on such exchanges at the regional level.

[40] Four Middle East and North Africa nations – Jordan, Lebanon, Morocco, and Tunisia – are the initial beneficiaries of three-year regional technical assistance project funded by the United States Agency for International Development (USAID) and the United Nations Food and Agriculture Organization (FAO), which is being implemented by ICBA and the NDMC at UNL. Its stated objective is to empower decision makers to plan for and manage the impacts of droughts on food and water security under current and future climate conditions (USAID, ICBA). This project has four major activities: (i) engaging stakeholders: needs and opportunities analysis; (ii) establishing and operationalizing a drought monitoring, early warning and information delivery system; (iii) conducting drought vulnerability and impact assessments and developing management plans; and (iv) operational support and training for drought monitoring and early warning system. Other partners in this exercise are the FAO's regional office for the Near East and North Africa and NOAA.

TABLE 4.1 Drought Categories and Associated Impacts that are Tracked Using the Northeast Brazil Drought Monitor

Category	Percentile	Description	Possible Impacts
D0	30th	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered
D1	20th	Moderate Drought	Some damage to crops, pastures: streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested
D2	10th	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed
D3	5th	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions
D4	2nd	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortage of water in reservoirs, streams, and wells creating water emergencies

Source: De Nys, Engle, and Magalhães 2017.

BOX 4.2 Drought Management at the River Basin Level in Spain and Mexico

Concrete examples of drought management in Spain can be taken from the experience of individual river basins. The Júcar River, which flows into the Mediterranean, and its Basin, for instance, is managed by the Júcar District Partnership, or Hydrographic Confederation (CHJ), which oversees an area of nearly 43,000 square kilometers including several adjacent basins. Development of the Júcar Basin Plan depended on the use of models and decision support systems (DSSs) for the past three decades. Special drought preparedness plans (SDPs) were also developed. These included definition of long-term (planning), medium-term (alert), and short-term (emergency and mitigation) measures, which are activated by the use of Standardized Operative Drought Monitoring Indicators (SODMI) for precipitation, reservoir storage, groundwater levels, and river flows obtained from an automatic data acquisition system. The SODMIs and resulting threshold curves for assessment of local drought conditions are calibrated by intensive use of DSSs for drought-risk estimation and the DSSs are also regularly used for real-time management at board meetings to assess drought risks over short- and medium-term time horizons, ranging from a few months to an entire hydrological year (extending from October to the following September), or even two hydrological years.

As a result of a severe multi-year drought, in January 2013 the Government of Mexico announced a National Program against Drought (PRONACOSE) to be coordinated by the National Water Commission (CONAGUA) with the assistance of the Mexican Institute of Water Technology (IMTA). PRONACOSE's basic objective is to develop tools for proactive and preventive integrated drought management (IDM) at the river basin level, following an approach generally similar to that previously adopted in Spain. Its specific objectives are to: (i) initiate a targeted training program on the basic concepts of drought and best practices to develop local capacity to ensure the sustainability of IDM in Mexico; (ii) raise awareness at the basin level and develop a host of preventive and mitigation measures against droughts; (iii) establish an interagency committee to coordinate and direct existing drought-related programs, guide and assist PRONACOSE, and fund actions proposed by stakeholders at the basin level; (iv) involve experts and researchers in responding to the identified needs of IDM; and, (v) develop a communication and outreach program, which emphasizes vulnerability, participation, prevention, and the evolution of drought. The program also contains an important evaluation mechanism with the aims of assessing the effectiveness of each of its implemented strategies and activities and providing continuous feedback and lessons learned in order to ensure its improvement over time and long-run sustainability.

Source: De Nys, Engle and Magalhães 2017.

BOX 4.3 Selected Drought Assistance Measures for the Agricultural Sector in Australia

Farm Management Deposits (FMDs): These are a financial risk management tool to help farmers smooth the uneven income streams in agriculture that result from market and climate variability, including droughts. This mechanism encourages farmers to set aside pre-tax income in good years for use in low-income years. They provide tax benefits if kept for at least 12 months. Eligible farmers in Exceptional Circumstances-declared areas may access their FMDs within 12 months, while retaining their tax benefits. The ceiling on deposits is US$ 400,000 and eligibility requirements determine if and when deposits can be withdrawn.

Tax Relief: The Australian Tax Office can help drought-affected people by: (i) allowing more time to pay tax obligations without incurring interest charges; and (ii) arranging for tax debts to be paid in installments without interest charges. In special circumstances, the Commissioner of Taxation may release individuals from normal income tax obligations on a case by case basis when it is demonstrated that payment would result in serious hardships. Other taxation-related measures and concessions available to drought-affected farmers include profit from the forced disposal or death of livestock and deductions for investments in water supply facilities and natural resource conservation.

Rural Financial Counseling: The national Rural Financial Counseling Service (RFCS) provides free and confidential financial counseling to farmers, fishermen, and agriculture-dependent small businesses. While not limited to drought-related assistance, the RFCS seeks to provide information and support to rural Australians for improved access to needed services.

Social and Emotional Counseling: People suffering from stress or personal difficulties as the result of a drought can contact a counselor who will provide free guidance and support through the Family Relationship Services Program or the Drought Assistance Hotline.

Whole-Farm Planning: The adoption of whole-farm or property management is a vehicle to promote improved risk management, productivity growth, and sustainable development. Through the use of tools such as land capability assessments, farm budgets, marketing plans, and decision support systems, farm plans allow producers to identify the element of risk to their operations, including droughts, and take steps to minimize their potential impacts.

Other Instruments: Education and training can also be provided for risk management and drought-related research includes whole-farm management systems that integrate climate prediction, technical, biological, and financial information, and other pertinent developments aimed at meeting the needs of farm families in times of drought and other forms of climate stress.

Source: ABARES 2011

- Achieving the transition to more proactive drought policy and management extends beyond better drought preparedness and response in the agricultural sector. It can also help countries and the affected regions within them to build greater resilience to the increasing climate stresses that are likely to occur in the decades ahead. Thus, droughts and the ways in which they are managed can also be viewed as "adaptation catalysts" for improving management of climate change more generally, particularly in arid and semi-arid parts of the world. Recent studies on confronting and managing droughts in the dryland areas of Northeast Brazil and Sub-Saharan Africa's clearly bring out this important connection (Cervigni and Morris 2016, De Nys, Engle, and Magalhães 2017).
- Successful drought risk management often requires longer-term structural, policy, and institutional interventions. This includes, for example, water-related infrastructure development and ongoing water resource management and agricultural technology improvements, including:

(i) using scarce water supplies more efficiently and productively; and (ii) short-term emergency assistance measures to protect the livelihoods and ensure the protection of drought-impacted families and communities, especially in the most vulnerable rural areas. This approach has recently been recommended for Northeast Brazil but is applicable to other drought-affected parts of the world as well.

- Effective drought management likewise requires both supply side (i.e., expansion of water availability for both human consumption and more sustainable agricultural and livestock production) and demand side measures, including water use restrictions and pricing, primarily aimed at conserving water and allocating it to priority uses during drought-related periods of increasing water shortage. This is being applied to help combat droughts in places as different as Australia (Box 4.3), California (Box 4.4), and Morocco (see below).
- Policy and institutional coordination, together with that of drought monitoring, mitigation, and response activities, among different levels of government and between the public and private sectors and civil society, particularly at the local level, are likewise essential. Again, many of the individual country experiences examined both in Middle East and North Africa and elsewhere illustrate the importance of improved communication, coordination, and collaboration among governmental agencies and with non-governmental ones, as well as of participatory decision-making processes more generally.

These lessons are particularly important for the agricultural sector, including livestock, and the populations that are dependent on it for their subsistence and livelihoods. As in many other countries around

BOX 4.4 Recent Drought Management Measures in California

California has the most variable rainfall in the United States with a few large storms making the difference between a wet and a dry year, and the recent multi-year drought significantly reduced the amount of water held in the state's reservoirs. This led to severe water shortages and a 50 percent reduction in hydropower generation in the state. In response, the Governor declared a statewide drought emergency and established an Interagency Drought Task Force in 2014. Both the state and Federal Governments have provided funding for drought relief, and the State Water Control Board (SWCB), which is responsible for administering water rights and quality standards, has approved water allocation plans that curtailed water diversions for many lower priority water users.

Some of these measures directly affect the state's agricultural sector, which requires a high volume of water for irrigation during the dry summer months. This amount is estimated to be four times more than that required by the state's populous cities, even during years of normal rainfall. Over the past few decades, farmers have reportedly adapted to the growing water scarcity by making significant investments in more efficient irrigation systems and shifting production to higher value crops per unit of water used. But these changes reportedly did not adequately increase resilience to drought, or sufficiently augment overall water supply. Thus, in 2014, new state legislation was enacted, including the Sustainable Groundwater Management Act, and a US$ 75 million new water bond was approved. In January 2016 additionally, the SWCB adopted a resolution authorizing the sale of an additional US$ 1.2 billion in revenue bonds for the Clean Water State Revolving Fund (CWSRF) to meet further financing needs for new water infrastructure projects.

Source: Redwood 2017.

the world, this sector is particularly vulnerable to droughts, and especially to those that last for more than one planting and harvest years. Some of these populations, moreover, live in remote, and, thus, harder to reach locations, which also makes it more difficult and costly to provide drought relief assistance. The evolution of the Moroccan Government's approach to drought management over the past four decades further illustrates the relevance of many of the lessons listed above.

4.3 EVOLUTION OF NATIONAL DROUGHT POLICY, PLANNING, AND INTERVENTIONS IN MOROCCO

One of the most severe droughts in Morocco occurred in the early 1980s. This led to great hardship within the country, including a significant loss of livestock, and proved to be a major catalyst for government activity to help mitigate the impacts of future such events. Among the actions taken as a result, the Government decided to manage water more actively and effectively. Because of this policy, 92 large dams and reservoirs were built during the following years, resulting in an increase in total water storage capacity of 14 billion cubic meters.

Subsequent drought declarations by the Government in 1992–95, 1998–2001, 2005, 2007 and 2015–16, highlight the growing involvement of the state in drought mitigation. The drought of 1994–95 was particularly severe leading to a 7.6 percent decrease in GDP. This drought also resulted in passage of the 1995 Water Law 43-19. This led in changes in the way water was administered in the country with river basin committees becoming the main focus for decision-making and a more integrated approach to water management. The 1998 drought reportedly caused human health issues and the pertinent ministry ordered a series of measures through Decree 1998-4336. Continuation of this drought in 1999 forced a change to irrigation water pricing by Decree 1999-4662. GDP for 1998–99 was reduced by an estimated 1.5–2.3 percent, and more than one million hectares of cropland were affected.

The significant applications made to international funding agencies in the late 1990s and early 2000s highlighted the increasing focus on mitigation activities, as well as on improved water management and irrigation capabilities. A grant from the Islamic Development Bank (IDB), for example, was administrated by Decree 2000-4870 for water facilities development. The aforementioned NDO was also established at this time by Decree 2001-4881, although, as noted above, it has since ceased to be operational. 2000, 2005 and 2007 were characterized by slower economic growth due to the impacts of drought on agriculture and the drought of 2009 forced another change in irrigation water pricing (Decree 2009-5709). These measures notwithstanding, the pernicious nature of recurrent droughts continue to impact Morocco in spite of the growing government and public awareness and the mitigation measures introduced. The naturally variable climatic conditions and the country's strong reliance on rainfed agricultural systems means that the rural population and sectors associated with farming continue to be vulnerable to recurring drought conditions.

During the 2015–2016 drought, in turn, in order to manage expected wheat shortages and to reduce the likelihood of rising wheat prices, the Moroccan Government lowered the import tariff on wheat from 75 percent to 30 percent in late 2015. This helped to keep domestic prices at around 2,588 MAD (US$263) per metric ton. However, this move was later somewhat reversed once the harvest results were known and rains came. The Government later increased the import tariff to 65 percent in order to safeguard and support local production capabilities and keep consumer prices unchanged (USDAFAS 2016). To fill the cereal gap, imports were secured from the United States and the EU.

During the 2015-2016 drought, multi-risk insurance subscriptions for cereals – an instrument that was first launched in 2011—increased to cover more than 1.1 million hectares. This was the largest area covered by this mechanism since its establishment. This means of offsetting drought impacts, about which more will be said below, is now actively utilized by the Government as one of several actions farmers can be encouraged to take. Other measures include increasing land cultivated using irrigation, although, as indicated above, once reservoir levels decline, this increases the pressure on already limited groundwater supplies.

4.4 ORGANIZATION AND INSTRUMENTS OF DROUGHT MANAGEMENT IN MOROCCO

Drought management planning and interventions presently occur at both the national and regional levels in Morocco. As in other countries, however, this is ultimately a political process because of its often significant institutional and financial ramifications. Each ministerial directorate has its own action plan that includes drought management components for implementation at the regional and local levels. There are also legal responsibilities at the water basin level with the respective *Agences de Bassins Hydrauliques* (ABH) having a legal remit to lead water management decision making within their districts during formally declared drought periods, as well as more generally.

The Green Morocco Plan (*Plan Maroc Vert*, or PMV), currently under implementation, also includes integrated sectoral strategies to deal with drought. Thus, overall, drought interventions are controlled by pre-developed legal guidelines and strategies that define the actions to be taken under specific conditions and whether they require official drought declarations. However, while the interventions agencies make are largely predetermined, how they will be undertaken, which agency will carry out each one, and, most importantly, how areas are declared drought-affected, which determines what actions will be taken, is not clearly written into law. More generally, drought management in Morocco takes place within the institutional context for agricultural and water resource management, which has also recently evolved, and will be briefly reviewed below.

4.4.1 Institutional Framework for Agricultural Development and Water Resources Management

The services within the Ministry of Agriculture and Marine Fisheries (MAPM) were restructured with the inception of PMV, which was adopted in 2008. The central directorates were consolidated, while regional structures were strengthened, and implementing agencies were created, including the Agricultural Development Agency (ADA), the National Food Safety Office (ONSSA), and the National Office of Agricultural Extension Services (ONCA). The irrigation water management framework, in turn, is defined by the Water Law and by the basin agencies responsible for the mobilization, allocation, and protection of water resources. Farmer representation and water use contracts are also part of this management framework.

Agricultural Development Agency. ADA was created to guide implementation of the government's agricultural development strategy. It is responsible for proposing action plans in support of agricultural subsectors with high value added in order to improve their productivity. Its main tasks are to find and mobilize land for the expansion of agricultural production and the development of high-value crops. It encourages the development of agricultural products through the introduction of new irrigation systems, farm equipment, better packaging, and improved marketing. It supports the promotion of agricultural investment and implementation of partnerships with investors. ADA is also responsible for proposing action plans to support agriculture solidarity through the promotion and implementation of economically viable projects to improve farmer incomes.

National Office of Agricultural Extension Services. Developed in 2010 to support the implementation of the PMV, the government's agricultural extension strategy aims at a progressive empowerment of and stronger accountability to farmers. In order to achieve this objective, the government regulates and stimulates the development of the private agricultural extension services while remaining guarantor of a local public service to farmers. Private actors are empowered to relay the action of the state. Implementation of the strategy relies on the redesign of the advisory and guidance activities. The first action taken in this regard was the creation of ONCA in 2013. This was a milestone in the renovation and restructuring of the network of local entities for Agricultural Advisory Services (capacity enhancements of public agricultural advisors and creation of a body of private agricultural consultants). ONCA's actions are based on new channels of transmission and knowledge management including farmer field schools, virtual network knowledge, call centers, and production and distribution of audio-visual materials.

Regional Offices for Agricultural Development. ORMVAs are public institutions with financial autonomy and legal personality. Their mission includes development of land consolidation works, the creation and operation of irrigation and drainage infrastructure, and management of agricultural water resources use in their geographic areas of jurisdiction. They also participate in the training of farmers. They are likewise responsible for operational management of drip irrigation activities in irrigation systems conversion projects under the general supervision and control of the Ministry of Agriculture and Maritime Fishing.

Chambers of Agriculture. A new role was also assigned to the existing Chambers of Agriculture. This involves: (i) participating in the governance of the system of agricultural extension services; (ii) promoting agricultural organization and raising awareness of farmers in forming groups; (iii) contributing to feeding into the knowledge management system by collecting best practices to farmers; and (iv) contributing to the development and implementation of agricultural development projects that meet the needs of farmers.

Water Management. The institutional framework for water management is defined by the Constitution[41] and by law (the Water Act No. 10-95), including for the pertinent national consultation frameworks (i.e., the Superior Council for Water and Climate and the National Council of the Environment),[42] other public institutions, including at the subnational level (i.e., water basin agencies and irrigation agencies—ORMVAs) and decentralized representative structures such as Water Users Associations (WUAs). Mobilization of this institutional framework depends mainly on agricultural policy. More specifically,

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[41] According to Article 31, "the state, public institutions and local authorities are working to mobilize all available resources to facilitate equal access of the citizens to the conditions allowing them to enjoy the right . . . [to] access to water and a healthy environment [and to] sustainable development."

[42] Instances of representation and consultation are numerous in Morocco. The houses of parliament, the Chamber of Deputies and the Chamber of Advisers combine both territorial and professional representativeness, controlling power and direction and power of proposal. Other bodies have advisory powers and help guide Water and Irrigation policy. These include: the Economic, Social, and Environmental Council, which is a constitutional institution, and those governed by specific laws, including the National Council of the Environment, the Higher Council for Water and Climate, and the Higher Council of Planning.

the Ministries of Agriculture and of Water activate evaluation functions and implementation of programs in accordance with the law and guidance from stakeholder representation and consultation mechanisms.

The Water Law. Law No. 10-95 governs both water withdrawals and discharges into rivers and underground. It establishes water as a public good (i.e., public ownership of water) and recognizes its economic value through creation of a fee system. It also identifies the watershed as a planning unit and it authorizes water management by basin agencies. The Law likewise promotes better agricultural water use by improving the conditions of its development and utilization for this purpose and establishes the principle of national and regional solidarity in order to reduce disparities in access to water and to ensure water security in urban and rural areas throughout the entire national territory. Finally, it determines key management tools including: (i) licensing mechanisms, administrative concessions, and the inspection and enforcement system for the various uses of water, together with sanctions for non-compliance; and (ii) regulation of polluting activities.

Water Basin Agencies. The watershed agencies (ABH), established under Law No. 10-95, have the status of public administrative institutions. They operate within clearly defined territories and are supervised by the government authority responsible for water. Their role is to carry out all local water resource-related measures at the basin level, including groundwater gauging and hydrological studies, hydrogeological, planning and water management both quantitatively and qualitatively. They must also take the necessary measures for the preservation or restoration of water quality, manage and control the use of mobilized water resources, and develop the necessary infrastructure investments for the prevention and fight against floods. They are likewise responsible for elaborating and ensuring implementation of integrated water resource development plans (PDAIREs) within their jurisdictions. They issue permits and concessions for use of public water resources in accordance with the PDAIRE. Each ABH plans, authorizes, and collects water extraction charges. Thus, water withdrawals for irrigation and other agricultural purposes at the basin level are authorized in the respective PDAIRE.

Water User Associations. Agricultural WUAs were created to organize participatory and integrated management of irrigation schemes and systems. These organizations operate in the areas of Great Hydraulic and Small and Medium Hydraulic perimeters (PMHs). They enter into agreements with the Administration concerning the planning of water resources, development and maintenance of the irrigation schemes. These agreements specify the size and limit the scope of the WUAs, their work plans and their financial plans for investment in and the maintenance, operation, and servicing of hydraulic structures under their control.

Groundwater Contracts and Adaptation to Climate Change. One basic principle adopted by the PMV is to encourage better adaptation to climate change through the promotion of greater agricultural productivity and other measures to increase farmers' incomes. However, in order to be effective and sustainable, the associated actions must avoid exposing farmers and the rural and urban populations living in areas of growing water stress more generally to more serious water scarcity problems. Fortunately, institutional solutions through groundwater contracts and water pricing based on scarcity now have a more consistent legal underpinning in Morocco. The challenge now is the activation of this legal framework.

Some water basin agencies appear to have moved towards the establishment of observation and control technologies and have progressed towards a real dialogue about the state of groundwater. Increasingly, farmers are aware that they must strengthen their knowledge and expertise to achieve a real adaptation. The restructuring of professional and representative bodies in relation agricultural development is expected to accelerate the development of more extensive stakeholder consultation, leading to greater cooperative behavior. The main persisting challenge in this regard is to break with isolated attempts to set up *ad hoc* climate change adaptation initiatives in favor of a planned and coordinated approach. There is also a need to better integrate national and subnational drought management activities with efforts in the agricultural sector to strengthen local resilience to climate change and to use scarce water resources more efficiently and cost-effectively. This observation also applies to drought management interventions in Morocco, which are further discussed in the balance of this chapter.

4.4.2 Drought Declarations

Official drought declarations and determination of the geographic areas eligible for particular drought relief interventions are made by a committee that includes the Ministries of Interior, Finance, Agriculture, and Water. While the ultimate decision-making criteria are not fixed, a mix of physical, social, and political factors are taken into account. In addition, little information is made public about how these decisions are actually made. There is nevertheless a strong emphasis on ground-level surveys of affected areas together with an assessment of regional history of drought impacts and vulnerability. In 2016, for example, the committee requested scientific evidence from the Royal Spatial Teledetection Center (the *Centre Royal de Télédétection Spatiale*, or CRTS), which was asked to provide its drought map, and observational data and forecasts from the Directorate of National Meteorology (DNM). However, it is not clear if and how this information was used in practice and the DNM/CRTS data are not publicly available.

Even though mitigation actions can be taken before a drought is formally declared, the Ministries involved must utilize their existing budgets for this purpose. Once the official declaration is made, a separate budget for drought mitigation interventions is established by the central government and additional mechanisms of cooperation and coordination are adopted. Marginal semi-desert and desert areas do not receive extensive agricultural support during droughts, however, due to their inherent vulnerability. In the case of an officially declared drought, government interventions are pre-developed but have changed in recent years to include climate risk insurance and the aforementioned coordinating role of the ABHs.

4.4.3 Drought Monitoring and Early Warning Systems

Given Morocco's vulnerability to water scarcity, particularly in the agricultural sector, as indicated in the preceding chapter drought events can have a significant impact both on crop production and domestic food security. National food security is highly dependent on cereal production, which is subject to substantial climate risk. Only 15 percent (1.4 million hectares) of Morocco's lands are irrigated. As observed in Chapter 1, agricultural activities consume more than 85 percent of the nation's water supply during years of normal precipitation but as low as 60–70 percent in drought years. The rest goes for domestic and industrial consumption. Thus, the ability to provide early warning forecasts of future drought conditions is an important tool for avoiding or minimizing the likely economic costs. This helps to avoid the possible misallocation of resources that could occur when farmers, herders, and other decision makers need to commit such resources before actual annual rainfall levels are known. To support early warning activities various forms of drought monitoring take place on several levels under the coordination of different institutions. Each of these institutions, however, has its own specific remit and dissemination of the information generated is largely limited to selected government officials and agencies responsible for water resource and agricultural management.

Drought monitoring through remote sensing. Since 2014 the CRTS has produced a national drought map on a monthly basis during the agricultural year using a composite drought index (CDI). The values are produced entirely from remotely sensed and modeled data at grid cells of 25x25 km resolution which is relatively coarse. The resulting map is provided to core partners and stakeholders from government agencies. These include the MAPM, Ministry of Interior, DRPE and the *Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification* (HCEFLCD, High Commission for Water, Forests and the Fight against Desertification). However, even though the map is provided to other partner and stakeholder agencies, they are not seen widely, if at all, by their technical staff

Seasonal forecasting and observational monitoring. The DNM produces both short-term and seasonal (3 months) forecasts using data from 206 automatic weather stations and 42 synoptic stations as well as climate modeling. Current seasonal forecasting includes information on the Standardized Precipitation Index (SPI),[43] the Palmer Drought Severity Index (PDSI),[44] and Deciles. Work is also undertaken to forecast the Standardized Precipitation-Evapotranspiration Index (SPEI),[45] an index that is currently produced for past periods only. This information is provided to stakeholders on a monthly basis though formal conventions. In addition, through special requests, entities may request past observed conditions in terms of SPI and land-surface temperature information. Lastly, DNM provides data on a number of meteorological characteristics on a daily basis to agricultural and water management stakeholders. This includes information such as incoming solar irradiance, actual evapotranspiration, temperature, and precipitation. In most cases, this information provision is automated.

Agricultural and hydrological monitoring. Observation and monitoring of evolving agricultural and hydrological drought conditions occurs under the auspices of the MAPM, DRPE, the basin authorities (ABHs), the *Institut National de la Recherche Agronomique* (INRA, National Institute for Agricultural Research) and, especially for rangelands and forest areas, the HCEFLCD. During the onset of drought periods, these monitoring activities provide directly usable information for the preparation of management interventions in the case of an official drought declaration, including for agricultural climate risk insurance payouts. Ongoing monitoring includes estimation of cultivated area using the Normalized Difference Vegetation Index (NDVI),[46] surveys in irrigation districts, and livestock monitoring by extension and veterinary services. Core agricultural commodity and input prices in both wholesale and commercial markets in nine major cities and smaller towns are also monitored.

Morocco's existing drought monitoring and early warning systems, in short, include both DNM's seasonal meteorological forecasting system and a system for crop monitoring and cereal yield prediction. At one point, in addition to the now closed NDO, this system also reportedly included the national component of a Maghreb-wide drought early warning system (SMAS), which also operated in Algeria and Tunisia. The first of these systems was established in 1994 to utilize both statistical and dynamic modeling approaches to provide seasonal rainfall predictions for the country based on two major projects known as El Moubarak and El Masifa. These studies resulted in adoption of a model that uses weather

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[43] This is a widely used index to characterize meteorological drought. It allows an analyst to determine the rarity of a drought at a given time scale (temporal resolution) of interest for any rainfall station with historical data.

[44] This index uses readily available temperature and precipitation data to measure relative dryness.

[45] As its name suggests, this index is designed to take both precipitation and evapotranspiration into account in determining the onset, duration, and magnitude of drought conditions.

[46] This index measures the "greenness" and vigor of vegetation over a seven day period as a way of identifying drought-induced stress.

anomalies over the tropical Pacific Ocean in October-December to forecast precipitation in Morocco during February-April of each year. Its outputs are disseminated to government authorities, including national agricultural and hydrological services. Morocco was also selected to lead seasonal forecasting for the Regional Climate Center of North Africa.

The second system monitors crop and agro-meteorological conditions for cereal production. This web-based system is known as CGMS-MAROC and was initiated by INRA in 2011. It is managed by an institutional consortium consisting of INRA, DNM, and the Directorate of Statistics of the MAPM. This is an essential part of Morocco's climate risk management efforts as it allows for the forecasting of expected grain yields two to three months prior to harvest. It, thus allows policymakers to become aware in advance of likely deviations from normal expected annual output of strategic cereal crops, which are critical for domestic food security.

The SMAS, in turn, was undertaken in the three participating countries in 2006–2009 as part of the LIFE-Pays-Tiers Program, financed by the European Union (EU) and was coordinated at the regional level by the Observatory of Sahara and Sahel (OSS) located in Tunis. In Morocco, it was implemented by DNM, CRTS, MAPM, and HCEFLCD. Each of these participating national institutions contributed drought indicators, which were then compiled into early warning bulletins that were produced on a monthly basis for November to April in 2008 and 2009 and made available on the CRTS website (El Khatri and El Hairach, n.d.).

Stakeholders interviewed in 2016 by ICBA and the University of Nebraska emphasized that individual drought monitoring efforts in Morocco are well coordinated and executed, as are management interventions, provided sufficient budgetary resources are allocated to cover them. However, it is still necessary to better integrate and streamline the sharing of the information produced so that all stakeholders can use it more productively as well as to better inform drought declaration and demarcation decisions. Interviewees also identified a number of persisting information-sharing barriers that adversely impact their work. These include:

- **Drought data sensitivity:** Drought data is considered highly sensitive from a political perspective, which exacerbates the other barriers described below. While information may be available in some cases through tiered access options, its overall dissemination is limited, which impedes the more general circulation of baseline climatic and agro-meteorological conditions.
- **Formality:** Government agencies typically share produced information only with their designated partners and through formal conventions. Without such previously agreed conventions, the information produced, if its provision is permitted, must be purchased at high cost, which again has the effect of restricting access.
- **Lack of information "percolation" within concerned agencies:** Beyond the general lack of information-sharing agreements, at times pertinent data does not reach technical staff even within agencies receiving the data. This prevents the incorporation of the information produced into new modeling and management systems.
- **Inter-agency information-sharing platforms:** Stakeholders emphasized the need for an integrated, inter-agency information-sharing platform with regularly updated data on meteorological, agricultural, and hydrological conditions. At present, the primary information platforms are functionally linked to specific modeling systems and have limited access points.

- **Uniform standards:** A wide variety of information sources are pertinent to drought monitoring and management, and stakeholders said that the present lack of uniform standards for data collection, reporting, and updating frequency are major obstacles to more effective planning. In some cases, moreover, paper records are still kept making information exchange cumbersome.

4.4.4 Short- and Long-term Drought Response Interventions

Starting in 1995, the Government of Morocco adopted preliminary guidelines for a more proactive approach to drought based on risk management principles. As a result, the National Program for Drought Mitigation adopted at that time possessed two "clear new orientations": (i) an operationally-oriented short-term reactive program with specific drought mitigation and relief actions; and (ii) a broad-based drought mitigation strategy, including long-term forecasting programs, water conservation measures, new agricultural techniques and new crop varieties or species, and a proposed drought insurance program. As part of the second of these two "orientations," strategies both for water resource management and the agricultural sector were reportedly adopted (Government of Morocco 2014). Thus, the current set of instruments and practices applied in Morocco to manage droughts and their effects, especially water shortages and their impacts on the agricultural (including livestock) sector and which have evolved over the past several decades, include both short- and longer term measures. They also include both supply and demand-side interventions.

The **short-term drought management interventions** that directly affect the agricultural and livestock sector in Morocco are of various types and include both supply and demand side measures. Their main focus is on water resource management and job creation, and they include specific financial and other interventions to assist famers in both rainfed and irrigated areas together with livestock owners in drought-affected zones. Those applied during the most recent (i.e., 2015–16) drought, for instance, are briefly described in the following paragraphs.

Crop interventions. In rainfed areas, the primary interventions depend on the seasonality of drought onset. If there is intense fall drought, government agencies provide subsidies, extension services, and preferential loans for farmers to plant spring crops, especially sunflower and corn, starting in January. In cases of winter and spring drought, climate risk insurance pay-outs are made to rainfed wheat and barley farmers in drought-zoned areas (i.e., areas that are officially declared to be drought-impacted). There are particular metrics for the drought insurance, whose geographic coverage may not necessarily be the same as the drought-zoned areas. Payouts are connected to drought declaration but other factors may also be involved.

In Public Irrigation Perimeters (PPIs) water allocation preferences change during droughts, whether declared or unofficial. The first priority is for arboriculture to ensure tree survival, then alfalfa and seed production systems, followed by industrial crops such as sugarcane and sugar beets. In addition, PPI authorities may augment groundwater pumping and departmental authorities may speed up the processing of license applications for well drilling outside of PPIs.

Livestock interventions. Interviewed stakeholders indicated that several livestock-related programs, the vast majority of which require an official drought declaration to be triggered, as among the primary focus of agricultural agencies during the occurrence of drought emergencies. This is primarily because existing insurance products for livestock in Morocco do not incorporate climate risks. Livestock safeguard programs include multiple elements in zoned areas, but the main concern is to ensure adequate access to water and fodder supplies.

First there is provision of subsidized feed through commercial feed-in subsidies or direct provision in rural areas. In 2016, for example, feed was subsidized at nearly 50 percent. Farmers are allowed to purchase set amounts of fodder at subsidized prices depending on the size of their herds as registered with local authorities. Stakeholders said, however, that this registration and feed allocation process can be a source of tension, as it often relies on self-provided evidence and tight supervision is required to prevent distortions and corruption. Second, government agencies provide water directly or drill wells for livestock and work to improve sanitary conditions. Third, vaccination programs are accelerated and extension agents increase the monitoring of animal diseases.

Financial interventions. As observed above, multi-risk climate insurance was first introduced in Morocco by the *Mutuelle Agricole Marocaine d'Assurance* (MAMDA) in 2011 to replace a national guarantee fund that covered approximately 65,000 hectares. While this instrument applies to multiple risks, droughts are considered one of the highest that the country faces along with excess water from occasional heavy rainfall and flooding, hail, frost, strong winds, and sand storms. This crop insurance scheme covers both cereals (i.e., durum wheat, bread wheat, barley and corn) and food legumes (fava beans, lentils, peas, chickpeas, and beans) with 677,000 ha reportedly having been covered during 2013–14. This insurance presently covers approximately 1.1 million hectares of rainfed lands. There are five levels of compensation under this arrangement depending on actual decreased yields, with subsidies to producers ranging from 55 to 90 percent of premium costs depending on the size of the farmer's holdings.

This agricultural insurance program was the object of a specific World Bank assessment in 2014, which concluded that a new public-private partnership (PPP) had strengthened this instrument by expanding the number of crops and risks covered and increasing its accessibility for farmers.[47] More comprehensive coverage was made available and eligibility of insurance was expanded to all areas of Morocco. In addition, declarations of losses at the commune level were made on a more objective and transparent basis as a requirement was introduced for sampled yields to fall below a reference yield of 60 percent of the average. However challenges remained, including data collection and management, national insurance capacity, and the increasing fiscal cost to the government. The main recommendations from this study are presented in Box 4.5.

A three-year pilot project was also launched in 2013-14 to test the feasibility of a parametric insurance mechanism utilizing climate indices and remote sensing data to complement or eventually substitute the multi-risk one. Aside from crop insurance, government financial interventions relate to credit systems. The large majority of agricultural credit is provided through state-owned Crédit Agricole Maroc (CAM, Moroccan Agricultural Bank), while "non-bankable" clients utilize its subsidiary, Tamweel. During drought periods these financial institutions may provide a special loan class for re-conversion from fall wheat and barley to spring crops and extend credit to existing loan-holders and delay repayment conditions.

Employment generation. Work creation programs are likewise a major component of short-term drought response. These programs focus both on replacing lost incomes and increasing long-term resilience. Their components include, among other elements, the creation or repair of water storage and irrigation and other physical infrastructure.

[47] World Bank2014.

BOX 4.5 Recommendations with Respect to Morocco's Agricultural Insurance Program

- ***Enhance data infrastructure.*** The establishment of a GIS database and management information system within Morocco's Agricultural Insurance Management Service (SGAA) is critical to allow SGAA to efficiently implement the agricultural insurance program. A data-sharing agreement with MAMDA could be explored since MAMDA has an established insurance database. Further investments in weather data infrastructure are also required.
- ***Provide capacity building on agricultural insurance to the Government of Morocco.*** Capacity building in actuarial skills and agriculture insurance would be needed in MAPM and the Ministry of Economy and Finance (MEF). SGAA could be the primary beneficiary of capacity building as it has been established to implement the agricultural insurance program.
- ***Define roles and responsibilities of key stakeholders.*** The roles and responsibilities between public sector institutions and with the private sector could be clarified to allow for improved continuation and expansion of the PPP.
- ***Conduct fiscal and welfare impact analysis of the PPP.*** A fiscal and welfare impact analysis could be conducted in the medium term to allow the Government to evaluate the costs and benefits of the public support to the agricultural insurance program.

Source: World Bank 2014.

Water management interventions. In accordance with Water Law No. 36-15, basin plans and sectoral strategies govern water management interventions. These follow 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 prioritizes municipal supply, irrigation, and then hydropower production. During drought periods, municipal water suppliers focus primarily on identifying and repairing leakages, introducing non-revenue water improvements, and strengthening demand management as well as on increased groundwater exploitation to cover remaining surface water supply and demand gaps.

Drought Management Actions in 2015–16. Government responses to the most recent drought began in January 2016 when indicators started revealing its effects, and a national program based on three components was deployed (Sadiki 2016). The Program for Mitigating the Effects of Rainfall Deficit was a one-time initiative, and the support measures it introduced were lifted as soon as rainfall conditions become favorable. Some of these measures had also been taken in the past, such as the distribution of barley and cattle feed to ensure the preservation of livestock, but others were new. Among these was support for the irrigation of 72,330 hectares of new plantations of fruit trees. The multi-hazard insurance for cereals discussed above, in turn, disbursed 1.02 billion dirhams. The program had three lines of action: (i) animal resource protection; (ii) plant resource protection; and (iii) maintain the equilibrium in rural areas.

Animal resource protection. The first component in this category targeted the large number of small ruminants and camels and made subsidized barley available in different regions of the country. Barley was made available to the beneficiaries in relay centers in each village in order to reach the maximum of beneficiaries. It was sold at a fixed subsidized price of MAD 2/kg. The program was launched in February 2016, covered 562 outlets, and by the end of November 2016 had led to the effective distribution of 7.2 million quintals benefiting about 710,000 beneficiaries. The second component made subsidized concentrated feed available to breeders of cattle that are identified through the National System of Identification and Animal Traceability (NTIS). This program set the selling price of these feed products at MAD 2.2/kg instead of MAD 3/kg. Sales totaled 360,000 quintals as of November 30, 2016.

In addition, a livestock watering operation was performed for an amount of MAD 155 million. These funds were used for acquisition of 2,508 plastic tanks, development and construction of 511 water points, and to support the operating costs of existing tankers. To protect the health of livestock, a vaccination program, which covered 15 million sheep and goats and 180,000 camels, and the protection of 200,000 beehives, were also implemented.

Protection of plant resources. To secure fruit tree plantations less than 4 years old under rainfed conditions within the scope of the PMV, maintenance irrigation was carried out for 126 projects in 9 regions. The affected area totaled 72,330 hectares with a budget of 116 million dirhams. The certified cereal seed multiplication program, for its part, benefited 60,000 hectares (versus 70,000 hectares planned), of which 25,000 hectares were irrigated. This area was divided between soft wheat (60 percent), durum wheat (29 percent) and barley (11 percent). Certified seed production has thus guaranteed a supply of 1.9 million quintals for the current agricultural season (2016–2017).

As far as irrigation schemes are concerned, a reinforced supervision of crops and farmers and the establishment of effective irrigation scheduling were undertaken, thereby securing the market supply of fruits, vegetables, and seeds, among other crops. Finally, a major program was implemented to boost spring crops during the 2015–2016 campaign. It covered 330,000 hectares of maize (54 percent), chick peas (24 percent), sunflowers (19 percent) and beans (4 percent). In addition to measures to ensure the availability of inputs and supervision by extension services, the CAM opened a special credit line for this purpose.

Maintaining the equilibrium in rural areas. All these activities reportedly benefited from an innovative governance framework that took the urgency of interventions and the need for effective mobilization of institutional actors into account. Thus, the national and regional organizational system in place for its management and coordination, as well as the effectiveness of the various measures enacted, helped to ensure rapid execution and a transparent program. This relied in part on a central command post and, in each region, development of detailed action plans for the various entities involved and continuous monitoring of each sales center via a computerized reporting system, supported by a regular audit of the transactions involved. The program launch was also accompanied by a communications campaign, information days, and direct outreach operations to farmers, for more than 400 agricultural advisers were mobilized.

Longer-term Drought Management Measures. In addition to short-term emergency relief and drought response measures briefly described above and aimed *inter alia* at securing safe drinking water for rural populations, feed distribution for endangered livestock, enhanced income generation and job creation activities, and forest and other natural resource conservation, the three pillars of Morocco's long-term drought management strategy (WMO and GWP 2014) consist of:

- **An integrated approach to water resources management** through mutually reinforcing policy and institutional reforms, as well as elaboration of a long-term investment program aimed at capturing most of the remaining rainfall runoff potential and developing accompanying hydropower infrastructure to reduce energy imports.

- **Improving access to water supply and sanitation and increasing wastewater treatment capacity** through optimized financing strategies and increased budget support for public infrastructure for rural water supply, sanitation and pollution control, service extension to poor peri-urban areas. In this context, for example, a National Sanitation Plan was established for 2006-2030 having a water pollution abatement objective of 60 percent.
- **Conserving water and improving efficiency, productivity, cost-effectiveness, and the sustainability of irrigated agriculture** through adoption of an integrated approach and expansion of investments for improvements in three areas: (i) the hydraulic efficiency of irrigation systems; (ii) strengthening the managerial capacities of irrigation agencies; and (iii) increasing productivity of water use. In this regard, a National Plan for Conservation of Irrigation Waters was developed with the aim of increasing the efficiency of on-farm irrigation water use, improve water cost recovery and asset management in public irrigation perimeters, and promote public-private partnerships for irrigation development and management.

More specifically, long-term supply-side measures presently employed in Morocco include maximization of rainwater storage through more than 140 national dams and associated reservoirs, use of marginal groundwater resources, aquifer recharge, improved efficiency of water distribution networks, water transfers, desalination, and wastewater reuse. Demand-side actions, in turn, include water metering, mandatory rationing, restrictions on municipal water use, tariffs and full cost recovery, voluntary water saving campaigns, promotion of public awareness to minimize drought damages, and increased regulation of irrigation and urban water supply use. For the agricultural sector specifically, long-term strategies to reduce drought-related risks include: (i) saving water by minimizing losses and improving water use efficiency in irrigation schemes; (ii) making better use of evaporated water through the development of pastures and agro-forestry (i.e., fruit tree) systems; and (iii) increased productivity in rainfed areas through the promotion of dry farming techniques, including improved water harvesting, storage, and use at both the farm and plot levels (El Khatri and El Hairach, n.d.).

4.5 PERSISTING CHALLENGES AND GAPS

Despite these measures and a stronger focus on risk management in recent years, gaps in the management of both drought and water scarcity still exist in Morocco. While a number of different Ministries and other government agencies are presently involved in these activities,[48] informed specialists argue that it would be "important to implement an independent organization or unit . . . [to] be responsible for coordination between the various departments and agencies." In addition, they affirm that "a standard and complementary drought management approach is needed" and that this should begin by "strengthening

[48] Government of Morocco (2014) presents a complete map of the complex web of government institutions involved in drought management in terms of decision making, coordination, and implementation at the national, regional, and local levels. While the Ministry of Agriculture and Fisheries is responsible for coordination of these activities together with an Inter-ministerial Technical Commission and both Provincial Technical Committees, and Specialized Committees at the local level, six other Ministries (Water and Environment, Forestry, Interior, Health, Energy, and Finance) are also involved in the decision making and implementation processes, as well as an Advisory Board, Provincial Technical Boards, and Local Drought Committees in the decision making phase and specific implementation agencies, the Provincial Technical Committees, and elected representatives and non-governmental organizations (NGOs) at the local level.

the sharing of information on droughts and the establishment of a global emergency warning system [while] mitigation plans . . . should be updated regularly." They go on to state that "insofar as drought protection is concerned, a concerted national strategy should be initiated by the drought management plans at the level of all river basins aimed at: (i) characterization of droughts: identification and proposal of monitoring indicators; (ii) implementation of structural measures: diversification of sources of water supply; (iii) development of contingency plans; and (iv) development of financial mechanisms such as the above mentioned agricultural insurance schemes and funds for natural disasters (El Khatri and El Hairach, n.d.).

Another set of local officials likewise identified some of the same constraints and further needs with regard to drought monitoring and management in Morocco. In their view, the main persisting problems are: (i) limited coordination of information coming from different ministerial departments; (ii) a lack of continuous drought indicators and defined thresholds; and (iii) unsustainability of the drought early warning system (perhaps in reference to the discontinuity of the former National Drought Observatory). Associated needs in their view are for improved cooperation among national institutions, earlier drought detection, and a better early warning system that entails improved data collection and dissemination of drought information at the national level. In terms of drought management more generally, the persisting constraints, according to these observers, are: (i) limited coordination between the above-cited sectoral strategies (e.g., for agriculture, water resources, etc.); (ii) poor implementation of the national legal framework in relation to water scarcity; and (iii) insufficient "capitalization" on sustainable drought monitoring, with the associated needs being for a cross-sectoral strategic coordination mechanism and improved implementation of water scarcity measures (Government of Morocco 2014).

Finally, those interviewed by ICBA and UNL in 2016 largely agreed with the specialists quoted above that the major challenges in drought management in Morocco stemmed from poor institutional coordination and ambiguity of drought declaration procedures during the early stages of crisis identification and management rather than specific technical challenges. They described an unclear system of institutional roles and regulations together with poor cooperation in determining what drought interventions should be taken and where. Drought management interventions are known and prepared, but deciding when, where, and how to implement them was seen as the principal difficulty. These difficulties are perceived as arising largely because of: (i) the absence of an overarching entity in charge of coordination and (ii) limited mechanisms for synchronization between individual agencies. These stakeholders also pointed out that the inter-ministerial committee that formally declares the existence of a drought meets only during its onset. Consequently, the resulting activities are largely reactive rather than proactive. Also as a result, institutional coordination and cooperation efforts begin in earnest only once a drought has started and its impacts are already intensifying.

Despite these shortcomings, a recent presentation by the Division of Sustainable Development of the United Nations Department of Economic and Social Affairs (UNDESA) and the Charlotte Research Institute at the University of North Carolina (UNC) argues that Morocco's achievements to date with regard to water scarcity and drought (WS&D) management are the most advanced in the Middle East and North Africa region. It likewise indicates that Morocco provides a "good example" of drought monitoring and assessment by having established the NDO (although, as stated earlier, this observatory has recently been discontinued) and demonstrated leadership in the Arab world by adopting the insurance mechanism for cereal production. However, this source also points to many of the same weaknesses and persisting challenges identified above and describes specific technical support to help the country address some of them.[49]

In summary, Morocco has taken important positive steps with respect to drought risk management over the past several decades, but there still appears to be room for improvement, as indicated both in the expert assessments cited above and the findings of the present study, which has focused specifically in the agricultural (and livestock) sector. As suggested above, moreover, ongoing technical assistance by ICBA, UNL, and FAO, as well as by other United Nations agencies will undoubtedly help to set the stage for further improvements in this regard. Ultimately, however, the effectiveness of the actions proposed will depend on how well they are implemented by the Moroccan Government and other national stakeholders. Other relevant considerations for this process going forward can be drawn from the principal conclusions and recommendations that emerge from the present survey of recent drought management experience in the agricultural/livestock sector in the country in the context of a rapidly changing climate, which are the subject of the final chapter of this report.

[49] This technical assistance project seeks to help build capacity for Morocco's future interventions in relation to WS&D preparedness and mitigation to be led by UNDESA and other UN partners, including FAO, WMO, United Nations Office for Disaster Risk Reduction (UNISDR), United Nations Environment Program (UNEP), United Nations Convention to Combat Desertification (UNCCD), and United Nations Development Program (UNDP). Its goals are twofold, to: (i) enhance Morocco's national preparedness for WS&D; and (ii) assist the country in further developing and implementing its drought mitigation strategies and plans. Its specific objectives are to: (i) raise awareness of up-to-date WS&D management tools, methodologies, and best management practices, and enhance national capacity; (ii) reinforce drought monitoring and early warning systems (i.e., characterization of droughts, identification and proposal of monitoring indicators); and (iii) improve the country's drought forecasting capacity (including development of associated contingency plans). These objectives would be pursued through high-level political fora and technical workshops, regional and international cooperation and partnerships, knowledge and best practice sharing, and technical and capacity building-related training support. However, neither the time frame for this assistance, nor its expected outputs and budget, were indicated in the UNDESA presentation.

CHAPTER
FIVE

POLICY OPTIONS

As indicated in the preceding chapter, the Government of Morocco is already taking a number of measures, including meteorological and agricultural monitoring and the use of multi-risk insurance for cereals, to address the rising frequency and severity of climate variability-related drought events. However, a review of recent international experience with respect to drought policy and management reveals that successful interventions in this field are increasingly based on a framework known as Integrated Drought Management Planning developed by multiple international stakeholders and led by the World Meteorological Office (WMO) and the Global Water Partnership (GWP). This risk management approach, which emphasizes drought preparedness, is predicated on the three pillars mentioned in Chapter 1: (i) drought monitoring and early warning; (ii) vulnerability and impact assessment; and, (iii) mitigation and response. Based on the findings of the present study, this report proposes a five-pronged approach to more climate-resilient drought management for Morocco, which covers each of these three pillars, as well for drought policy, planning, and risk management more generally.

5.1 NATIONAL DROUGHT POLICY

Morocco currently lacks a comprehensive national drought management policy or strategy even though many of the basic elements and potential instruments for its implementation are already in place. Others, however, are still lacking as is a well-defined institutional coordination mechanism. It would, thus, be useful for the Government to develop such a policy or strategy in consultation with key public and private sector stakeholders, including at the regional (e.g., river basin) and local levels in those sectors and geographic areas that have historically been most affected by recurring drought conditions. This process, which should be participatory in nature, could build off the country's own historical experience with drought management, but also be informed by the lessons of experience and demonstrated good practice, elsewhere in the region and internationally. The ten step process for formulation of a national drought management policy or strategy indicated in Box 1.2 could play a useful guidance role in this regard.

Development of a national drought management policy or strategy is thus strongly encouraged, particularly as concerns the linkages between drought risks in the context of increasing climate variability in the short-run, on the one hand, and the need to adapt to longer-term climate change, on the other. In order to more effectively address drought conditions in the years and decades ahead, these linkages need to be fully integrated into drought policy, as well as in both national and subnational strategies and management plans. Ongoing technical assistance and capacity building and regular information exchange with institutions and specialists facing similar challenges in other countries in the Middle East and North Africa region and elsewhere could prove to be very helpful in this regard.

5.2 GENERAL APPROACH TO DROUGHT RISK PLANNING AND MANAGEMENT

Morocco needs to more fully adopt a proactive risk management and adaptation approach rather than the reactive crisis response thinking that has generally dominated in the past. Good drought plans have been developed in the face of previous droughts, but their implementation has often proven difficult. More integrated drought monitoring coupled with practical drought mitigation planning and capacity development could help. These and other institutional capacity building and investment activities will likely take on even greater importance in the future. The main reason for this is the need for more effective mitigation planning and climate change adaptation strategies in view of the strong prospect of even more intense droughts and the increasingly serious associated rural water scarcity in the decades ahead, which are likely to affect even more sectors and communities.

Thus, future drought risk and water resource management must also go hand in hand, as well as planning for the agricultural sector more generally. Short-term benefits in terms of increased (authorized and unauthorized) ground water extraction for agricultural production and even livestock survival purposes during severe drought periods in Morocco must be viewed and assessed against possible long-term costs resulting from diminished water supplies and food security over the longer run. Due to this increasingly critical trade-off, a cross-sectoral as well as a long-term approach is also required.

5.3 DROUGHT MONITORING AND EARLY WARNING

Development of a series of scientifically sound climatological drought onset indicators that reflect the nature of conditions in Morocco could also be a priority. Once defined, these indicators could be the starting point for initiating coordination and cooperation efforts across the various agencies responsible for taking specific actions. To facilitate this, an integrated agricultural, hydrological, and meteorological data-sharing platform, which connects information from different relevant agencies and has automatic updates of specified datasets, could be established. In addition to improved drought monitoring, there is a need to better link technical and institutional efforts to provide a simple, but technically sound, early warning system with structured mechanisms to initiate broad drought management coordination prior to the occurrence of major drought-related impacts.

There is also a need to reach beyond the satellite images and model outputs to those experts throughout the country who are able to identify on the ground the signs of drought in their own areas. In short, there is a need to "ground truth" the information generated by automatic data generation devices and associated modeling activities by establishing a continual two-way information exchange and validation process regarding the outputs of these mechanisms and the observations of key local human informants (i.e., farmers, extension agents, and other stakeholders) in each of the affected areas. The development and implementation of expert networks to provide feedback and strengthen current drought monitoring efforts and information products could greatly help mapping accuracy as well as support ownership and trust in their reliability and capacity to improve drought management decision-making. More local-based links and mapping could also help coordinate the national planning and ABH (i.e., river basin commission) levels being promoted under the new water law.

Another key potential use of these generated data is as a basis for drought mitigation and climate change adaptation more generally for rural Morocco. By linking drought maps and related data to existing seasonal forecasts and hydrological modeling systems scenario planning and operation, optimization could be undertaken to support infrastructure development and other operations to mitigate drought impacts over both the short and the longer terms. This also suggests the need to more clearly link national and basin level efforts to anticipate and respond to recurrent droughts and those to adapt to the broader effects of climate change more generally in the agricultural and livestock sector in the country, including the need to better assist, through training and other means, those farmers who presently lack the knowledge and skills to do so effectively, as identified for the two specific high value chains specifically considered in this study.

5.4 VULNERABILITY AND IMPACT ASSESSMENTS

Another significant way to better anticipate—and thus to prepare to more effectively address—the impacts of future droughts is to carry out up-front vulnerability and impact assessments in the geographic areas most likely to be affected based on past experience. These assessments could be undertaken at varying spatial scales, including at the river basin level, and could help form the basis for the development of localized drought preparedness plans, as, for example, has recently been demonstrated with World Bank–supported technical assistance for historically drought-prone Northeast Brazil, for which a regional Drought Monitor, in the process establishing a very effective platform for institutional cooperation and coordination involving pertinent federal, state, and municipal government agencies and specialists, has also likewise been created and is now fully operational (see De Nys, Engle, and Magalhães [2017] for details).

More generally, the list of potential economic, social, and environmental effects of droughts listed in Chapter 1 could provide a useful starting point and analytical framework for identifying particular effects and vulnerabilities at both the national and subnational (i.e., province, district, and even community) levels. These assessments, together with an institutional capacity analysis and identification of financing mechanisms, could then form part of the inputs for the elaboration of drought preparedness plans at various (including river basin) levels, as can also be demonstrated by the recent experience in Brazil, where such plans were developed, on an indicative basis, for the basin and even municipal levels. In combination, these would be a key part of a more anticipatory and proactive approach to drought management.

5.5 DROUGHT MITIGATION AND RESPONSE

Strong institutional coordination mechanisms that clearly specify the role of each agency involved in drought management and adequate financial resources are also needed. Ideally, a single authority could be designated to lead drought management-related decision making and to coordinate implementation of the agreed resulting mitigation activities. Improved information-sharing and establishment of triggers to determine what types of actions need to be taken in what locations in accordance with the evolution of local drought conditions, including their extension over time and severity, could also be an essential part of this system. This drought governance arrangement, in short, could establish the roles of specific partner institutions early (i.e., once onset of a new drought is detected through the monitoring and early warning systems mentioned above). A national drought contingency fund could also be established. In addition, the budgetary resources required to enable the needed response actions to be implemented in a timely way need to be clearly identified and allocated in such a way as to obtain the most cost-effective results.

Greater timeliness and transparency (than perceived by interviewed stakeholders to have been the case in the past) in allocating the available funds for mitigation and any related new infrastructure investment to the pertinent participating agencies could help reduce the traditional (often essentially) political nature of drought response. It would also help to resolve one of the problems identified by some of the stakeholders that were interviews as part of this study (i.e., the perception that drought mitigation interventions in the past were not as beneficial as they could have been due to inadequate institutional coordination).

Finally, there is also a need to clearly recognize the link between the observed more frequent and severe droughts in Morocco and global climate variability and change. In terms of national climate change adaptation plans, for instance, Morocco's most recent submission to the United Nations Framework Convention of Climate Change (UNFCCC) in 2015 includes various measures for managing both floods and water scarcity. However, it does not specifically mention droughts even though some of the measures proposed for managing floods and addressing water scarcity could also serve as important drought mitigation measures. This is the case, for example, with respect to the construction of additional dams for flood prevention, the conversion of surface and sprinkler irrigation to drip irrigation, and the replacement of one million hectares of grain crops with fruit plantations. This also reinforces the need for Morocco to better integrate drought management and climate change adaptation policies and instruments.

ANNEX
2.1

CLIMATE CHANGE AND VARIABILITY IN THE MIDDLE EAST AND NORTH AFRICA

This Annex provides a brief update to information on climate, climate change and climate variability presented in the World Bank's Middle East and North Africa region climate change flagship report,[50] emphasizing the peculiarities relevant to Morocco and building on recent observational data and emerging scientific knowledge since the Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment Report was issued (AR5; IPCC 2013a).

The focus in the sections below is on the physical climate system that is addressed by IPCC's Working Group I. This report considers progress in the understanding of the human and natural 5.13 drivers of climate change, climate observations and attribution, and key climate feedback, in particular related to agricultural drought.

An update to the state of the global climate. **The IPCC's AR5 (IPCC, 2013a) concluded that**:

> *"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and oceans have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased."*

Since then, several years' worth of observations have been added to the data, which are discussed below and are considered in view of another significant climate phenomenon, which has been dominant recently, El Niño.

Global mean temperature change. In AR5 it was established that the global average surface air temperature increased by approximately 0.85°C during the period from 1880 to 2012. In addition to robust multi-decadal warming, global mean surface temperature exhibits substantial decadal and interannual variability (see Figure A2.1 below). As an example, the rate of warming from 1998–2012 was essentially consistent with no warming at all (uncertainty range assessed to be from –0.05 to 0.15°C per decade), beginning with a strong El Niño.

Since 2012, however, warming has picked up again, which is very probably also a temporary development, but has resulted in a new and warmer baseline than pre-2012. The global mean temperature

[50] See Christensen et al. 2012.

reached a new record high in 2016.[51] The magnitude of the global warming trend is expected to vary from year to year, despite being unambiguous over time. While a decade is a short period in terms of climate, the most recent decades are discussed below, both to provide an update on global temperature data and to elucidate the apparent reappearance of the continued warming trend.

Estimates of the global mean surface air temperature based on peer-reviewed methods are maintained by several research groups. These Centers use slightly different data sets and apply different averaging methods. In 1979, the European Centre for Medium-Range Weather Forecasts (ECMWF) started to provide a regular update of surface temperatures with complete global coverage based on an advanced data assimilation technique. This leads to modest differences in the specific monthly and annual values, as is also evident from Figure A2.1.1. All analyses nonetheless show that the rate of warming stalled around 2000, but picked up again in the most recent years, with 2016 being the warmest year on record to date. As already mentioned, for brief periods, the warming rates may vary considerably from the long term trend, although these variations tend to be short-lived. Therefore, the 10-year running mean is also shown. At this time scale many natural variations are averaged out.

The IPCC AR5's projections of 21st century temperature changes were based on simulations made by 42 global climate models (Flato et al. 2013), using the 20-year mean temperature for 1986–2005 as a baseline. For the 2006–2012, period the observed global mean temperature rise has been lower than the average simulated by these models (Figure A2.1.2). However, the observed change was still well within the variation among the model results.

The global mean temperature is not expected to rise steadily from one year to the next due to natural climate variability. Part of the natural variability is caused by variations in solar activity and by volcanic eruptions. For example, a temporary cooling was observed after the Mt. Pinatubo eruption in 1991, whereas low solar activity may also have affected the lack of warming (e.g., Lockwood 2010). Apart from the scientific relevance of discussing what caused the warming pause (hiatus) between around 1998 and 2012, the fact that warming has picked up again is the main concern of this report. Figure A2.1.2 summarizes the discussions from AR5 about how the hiatus, if it is to be dominating in the years ahead, would influence the IPCC-assessed near term likely global warming. However, it should be noted that decadal variability should always be considered when trying to attribute global temperature trends, and as a result of the most recent continued warming trend, the discussion about the potential extension of the hiatus has become obsolete.

Significant natural variability is also generated by internal fluctuations within the climate system, particularly in the oceans. The year 1998, with its exceptionally strong El Niño warming in the tropical Pacific for a long period, stood out as the one with the highest global mean temperature in one of the three observational analyses. In contrast, the relative coolness of 2008 coincided with a La Niña, which is the opposite of an El Niño. The strong El Niño in 2015–16 clearly altered the importance of what happened in 1998. Hence, a key element to be kept in mind is the fact that the hiatus commenced and was interrupted by two remarkably strong El Niño events.

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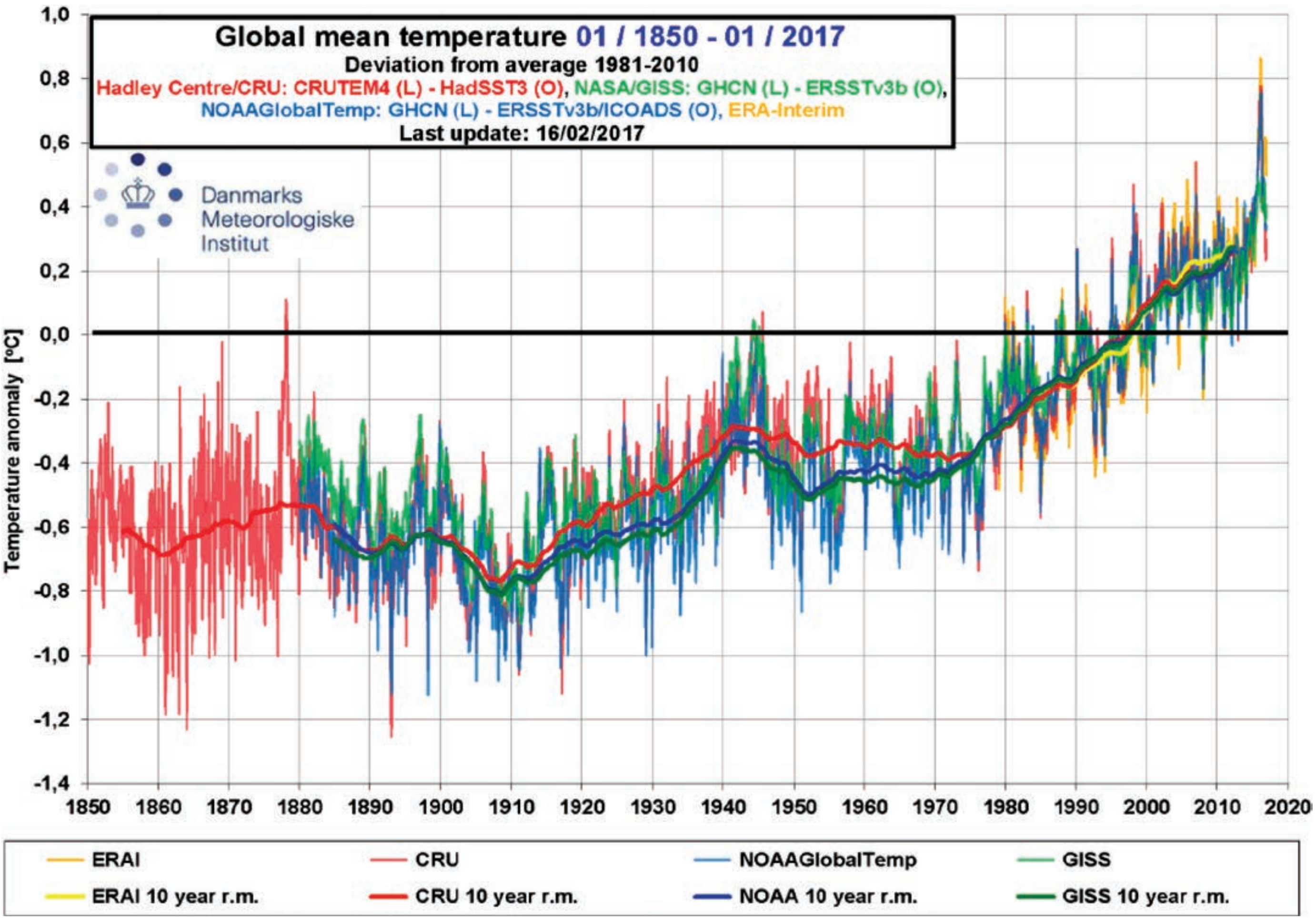
[51] According to the United States National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA), the global mean temperature in 2016 was 0.99°C (1.78°F) above the 20th century mean, making it the third year in a row to set a new record in global average temperatures. Not only was 2016 the warmest year on record, but eight of the twelve months from January through September, the only exception being June, were the hottest and those from October through December were the second hottest on record. In addition, researchers estimate that the strong El Niño in effect from most of 2015 and the first third of 2016 increased the average temperature anomaly by 0.12°C (0.2°F).

FIGURE A2.1.1 Average Monthly Mean Global Temperature Anomalies, 1850–2017



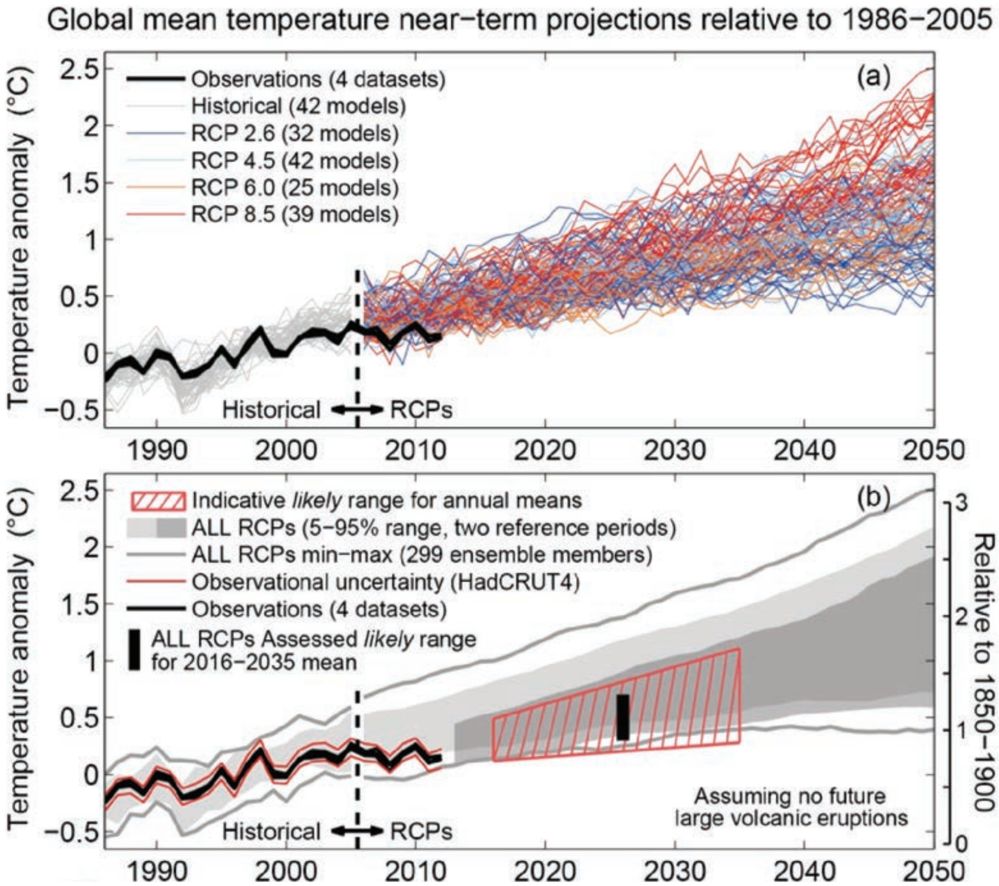
Source: DMI (2017; updated by Martin Stendel, DMI).

Note: Annual Mean Temperature Anomalies (thin lines) and 10-year Running Mean (heavy line) since 1850, according to the CRU and Hadley Centre, UKMO (red); since 1880 NASA/GISS (green) and NOAA (blue), since 1979 ECMWF (Yellow). CRU = Climate Research Unit; DMI = Danish Meteorological Institute; ECMWF = European Centre for Medium-Range Weather Forecasts; GISS = Goddard Institute for Space Studies; NASA = Noational Aeronautics and Space Administration; NOAA = National Oceanic and Atmospheric Administration; UKMO = United Kingdom Met Office

El Niño as regional driver of variability. El Niño is a natural climatic phenomenon that occurs every second to seventh year in the tropical Pacific. Because of the scale of this phenomenon, it affects weather over much of the globe. In Spanish, El Niño means "boy child" or "baby Jesus." It got its name because a weak, relatively warm ocean current is found along the Peruvian and Ecuadorean coasts in most years at Christmas time. The phenomenon has been recognized for centuries among local fishermen. But only in recent decades has its scale been known. Today El Niño designates a period of unusual warming of water along the South American west coast and in the central parts of the Pacific Ocean. This affects marine currents and atmospheric circulation over most of the central Pacific Ocean. The total phenomenon, linking atmosphere and ocean processes, is called El Niño Southern Oscillation (ENSO), where the Southern Oscillation refers to the atmospheric changes associated with El Niño.

ENSO particularly affects the weather in countries bordering the tropical Pacific. Among other effects these include heavy rainfall along the west coast of South America, while the Philippines, Indonesia, and

FIGURE A2.1.2 Representation of Global Mean Surface Air Temperature by Climate Models, 1986–2005



Source: IPCC, AR5 with updates by authors.

Note: (a) Projections of annual mean GMST 1986–2050 (relative to 1986–2005) under all RCPs from CMIP5 models (grey and colored lines), with four observational estimates: HadCRUT4, ERA-Interim, GISTEMP, and NOAA, for the period of 1986–2012 (black lines). (b) As (a) but showing the 5 to 95 percent range of annual mean CMIP5 projections for all RCPs using a reference period of 1986–2005 (light grey shade) and all RCPs using a reference period of 2006–2012, together with the observed anomaly for (2006–2012) minus (1986–2005) of 0.16°C (dark grey shade). The maximum and minimum values from CMIP5 using all ensemble members and the 1986–2005 reference period are shown by the grey lines. Black lines show annual mean observational estimates. The red-shaded region shows the indicative likely range for annual mean GMST during the 2016–2035 period. The temperature scale relative to 1850-1900 mean climate on the right-hand side assumes a warming of GMST prior to 1986–2005 of 0.61°C estimated from HadCRUT4. Also shown by blue and red triangles are the observed annual mean temperatures for 2013-2016 based on the same data providers. The size of the symbols represents a measure of uncertainty in estimating the annual mean temperature. CMIP5 = Coupled Model Intercomparison Project Phase 5; ECMWF = European Centre for Medium-Range Weather Forecasts; ERA-Interim = ECMWF Interim European Reanalysis of global atmosphere and surface conditions; GHG = greenhouse gas; GISTEMP = Goddard Institute for Space Studies Surface Temperature Analysis; GMST = global mean surface temperature; HadCRUT4 = Hadley Centre/Climatic Research Unit gridded surface temperature dataset 4; NOAA = National Oceanic and Atmospheric Association; RCPs = Representative Concentration Pathways of GHG emissions.

Australia experience drier periods during an El Niño. Following an El Niño the sea in the eastern Pacific cools again. Often, but not always, the water temperature drops more than what is climate normal. This is the reverse state of El Niño and is called La Niña, which means “the girl”. To define an El Niño or La Niña state the Oceanic Niño Index (ONI) has been developed. ONI is a temperature anomaly range for the central Pacific between 5 degrees south to 5 degrees north and 120 to 170 degrees west. This area is also called the Niño 3.4 region.

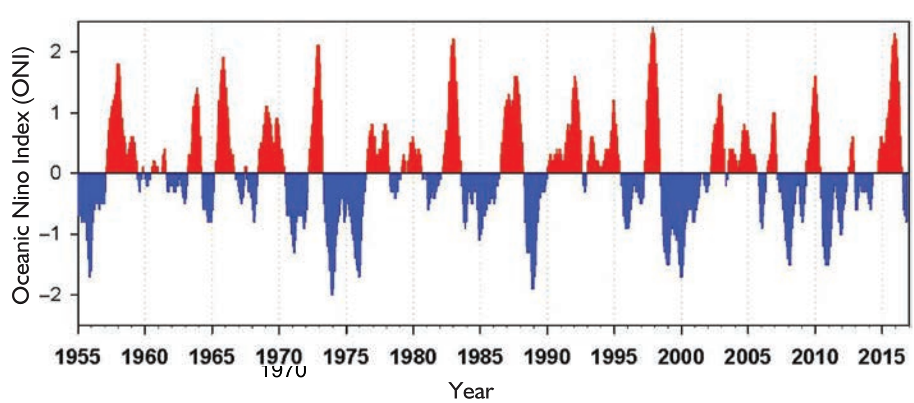
An El Niño is defined by an ONI greater than + 0.5°C, that is, a 3-month mean temperature that is at least 0.5°C above the 30-year mean. Similarly, a La Niña defined by an ONI lower than –0.5°C. Values between plus-minus 0.5°C are considered normal. A moderate El Niño has an ONI above 1°C and a powerful El Niño one greater than 1.5°C. The same applies to La Niña, only with negative values for ONI. Figure A2.1.3 illustrates the development in ONI since the 1950s.

ENSO is sometimes considered to influence climatic conditions more remotely than in the vicinity of the Central Pacific. Droughts and flooding worldwide are often perceived as being linked with a particular phase of ENSO. This is particularly the case for the stronger of such events. Formally, however, it is quite difficult to attribute any remote influence. In reality, a number of climate phenomena interfere with each other and, in a changing climate, the relations between these may vary at all times. Accordingly, this is a longstanding research topic in the scientific climate community (e.g., as formulated in the World Climate Research Programme core project, Climate and Ocean: Variability, Predictability and Change [CLIVAR's] mission to understand the dynamics, interaction, and predictability of the coupled ocean-atmosphere system).

This complexity notwithstanding, simple correlation measures depict the most important regional influences of ENSO. Based on a long time series of observed variations correlated with the phases of ENSO, it is possible to identify whether and where there is a remote ENSO influence. Figures A2.1.4a–d and A2.1.5a–d do exactly this. Figure A2.1.4 displays the geographical correlation of temperature anomalies with the ONI index described above. When the correlation is positive (shown in red), temperatures tend to be warmer than normal during an El Niño event and cooler during La Niña. Negative correlations (in blue) mean that the temperature signal is reversed.

From these maps, it is evident that the Middle East and North Africa region is only marginally influenced by ENSO in general. This is also confirmed by other studies (e.g., Liu et al. 2014). Possible exceptions to this rule are a weak to moderate positive correlation between temperature and the phase of ENSO in Northwest Africa from December to May and a weak positive correlation in Northern Africa from June to August. For precipitation there is a weak (possibly even moderate) anti-correlation with the phase of ENSO in North and Northwest Africa from December to May and a weak positive correlation in

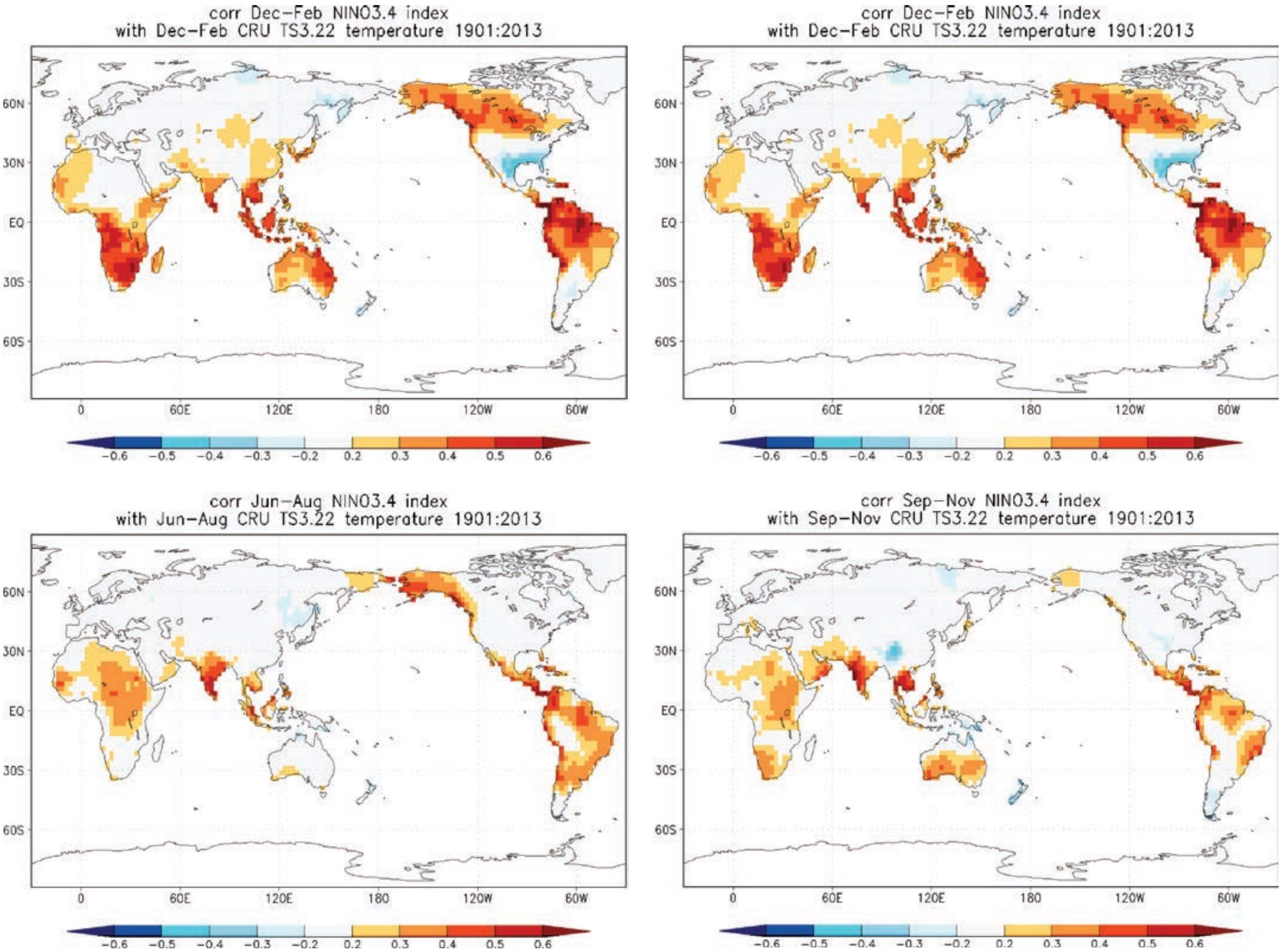
FIGURE A2.1.3 Values of the Oceanic Niño Index, 1955 to the Present



Source: NOAA: https://www.nwfsc.noaa.gov/research/divisions/fe/ estuarine/oeip/cb-mei.cfm.

Note: Red bars indicate warm conditions in the equatorial Pacific, blue bars indicate cool conditions in equatorial waters. Large and prolonged El Niño events are indicated by large, positive values of the index: note the > +2 value associated with the 1972, 1983, 1998, and recent strong event in 2015–2016. Recent cool anomalies (La Niña events) were during 1999–2002, 2007–2009 and 2010–2012.

FIGURE A2.1.4 Temperature Correlation Maps



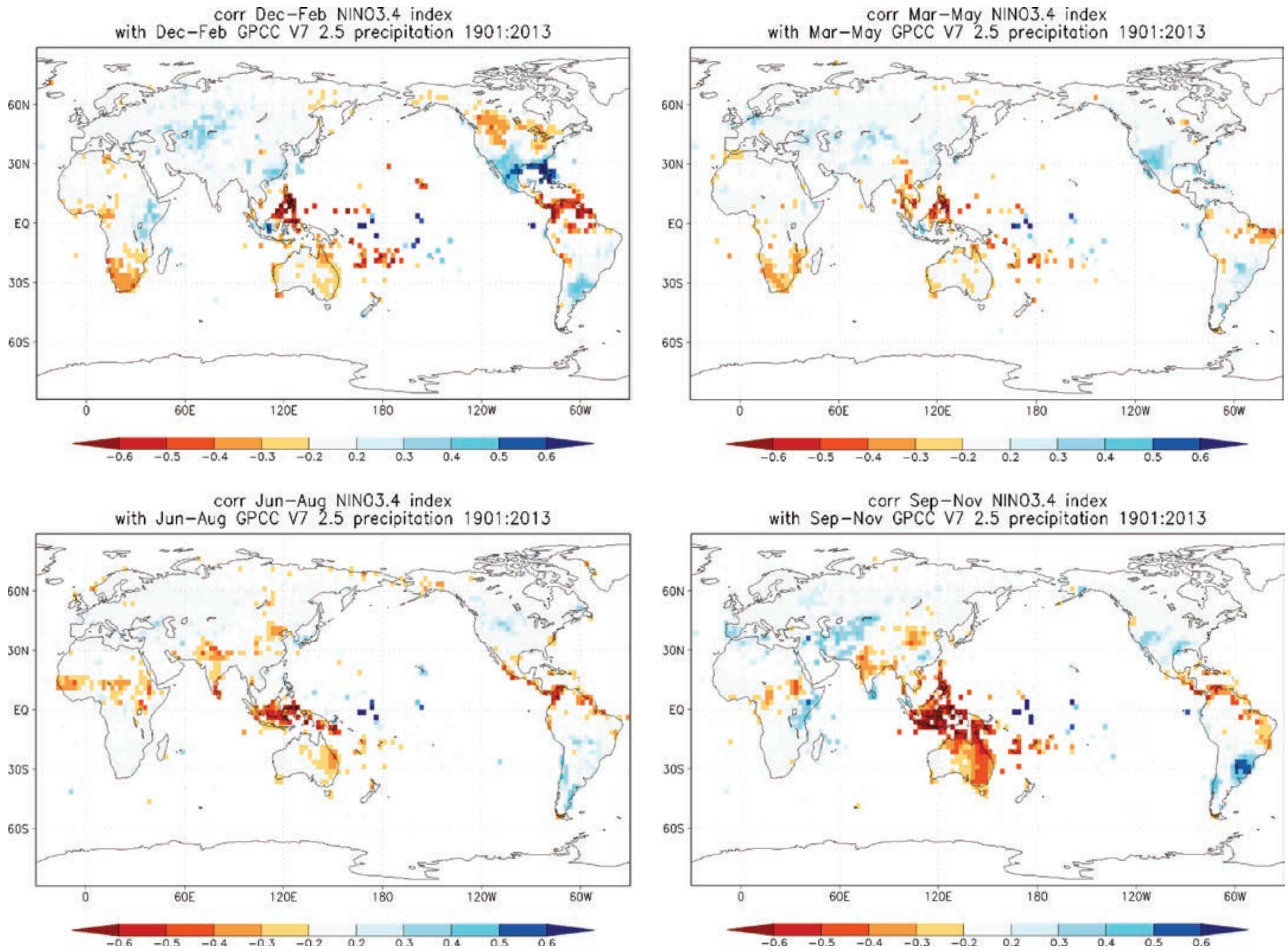
Source: KNMI Climate Explorer, https://climexp.knmi.nl/effects.cgi?id=someone@somewhere#temperature.

Note: Red colors denote locations that on average are warmer during El Niño and cooler during La Niña. Blue colors are colder during El Niño and/or warmer during La Niña. Some North America effects are non-linear: the effect of La Niña is not the opposite of the effect of El Niño.

North Africa and possibly in parts of the Middle East limited to the months of September to November. But in all cases, it is incorrect to solely attribute temperature or precipitation anomalies in these regions to the particular phase of ENSO. Only a weak signal appears to be identified at the specific country level, e.g., for Morocco, Tunisia, and Lebanon. Instead, Christensen et al. (2013) concluded that the most dominant climate phenomena influencing the entire Mediterranean region is the phase of North Atlantic Oscillation (NAO), particularly during the northern hemispheric winter. Christensen et al. (2012) summarizes this more specifically for the Middle East and North Africa region.

It is formally possible to assess the predictability of drought conditioned by teleconnection resulting from ENSO. Many research centers around the world are working on seasonal to decadal scale prediction systems. This involves large computational efforts with data assimilation elements from all parts of the climate system (atmosphere, ocean, cryosphere, land surfaces). These efforts have produced very

FIGURE A2.1.5 Precipitation Correlation Maps



Source: KNMI Climate Explorer, https://climexp.knmi.nl/effects.cgi?id=someone@somewhere#precipitation.
Note: Blue colors indicate that during El Niño there was, on average, more rain than normal, red colors indicate drought during El Niño. La Niña has the opposite effect in almost all locations. As a measure of the strength of the relationship we used the correlation coefficient with the Niño 3.4 index. The square of this number gives the fraction of the variance that is explained by this aspect of El Niño.

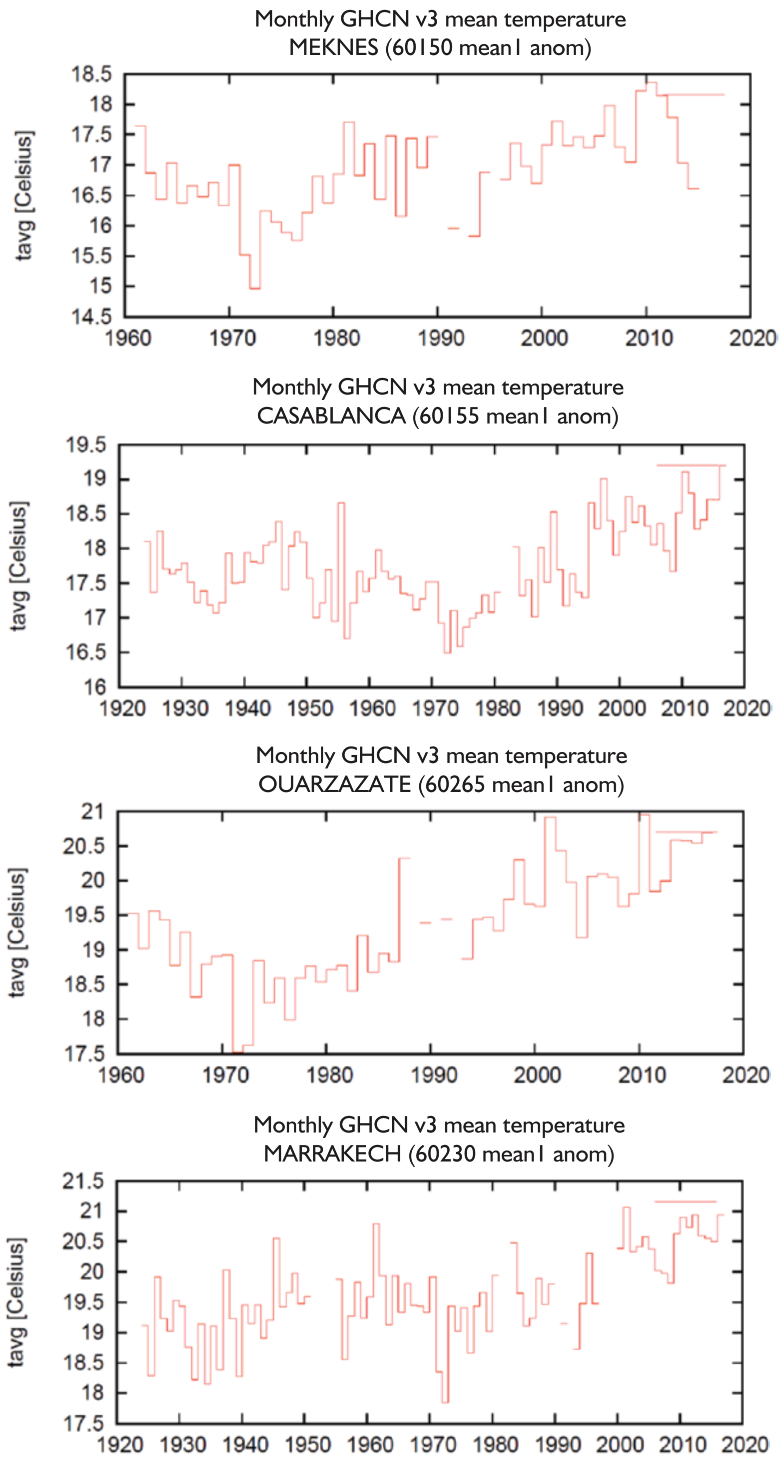
large data bases with synthetic climate records for a time span representing many centuries and even millennia. Using models, it is therefore possible to establish a statistically sound and, hence robust, basis for identifying correlations such as those depicted in Figures 2.4 and 2.5. In these maps, however, the correlations are not screened for robustness. For example, at each grid cell, the length and quality of the observational records are not depicted. In other words, it is not obvious if, at the grid point level, the correlation will remain the same if additional data from missing years are added. A second limitation is due to purely statistical reasons. Even if the correlation for say dry/wet conditions under La Niña/El Niño is moderately high (e.g., 0.5), the probability for the occurrence of the local dry/wet event is only 25 percent (0.5×0.5). Thus, 75 percent of the apparent structures may be entirely the result of chance and, hence, represent a false signal.

These formal limitations can be addressed using models. Here the modeled fields of temperature and precipitation can be analyzed against the modeled occurrence of ENSO. In case a statistically significant correlation is identified - typically correlation factors above 0.3 (below –0.3) are considered – potential predictive ability is identified. This is potential, because it is only realized in a model and still has to be demonstrated for the real world in order to be valid. For small correlations, real world attribution is even harder to obtain due to the lack of long time series and, hence, observed events. Thus, potential predictive ability is often considered as important as real predictive ability.

ANNEX
2.2

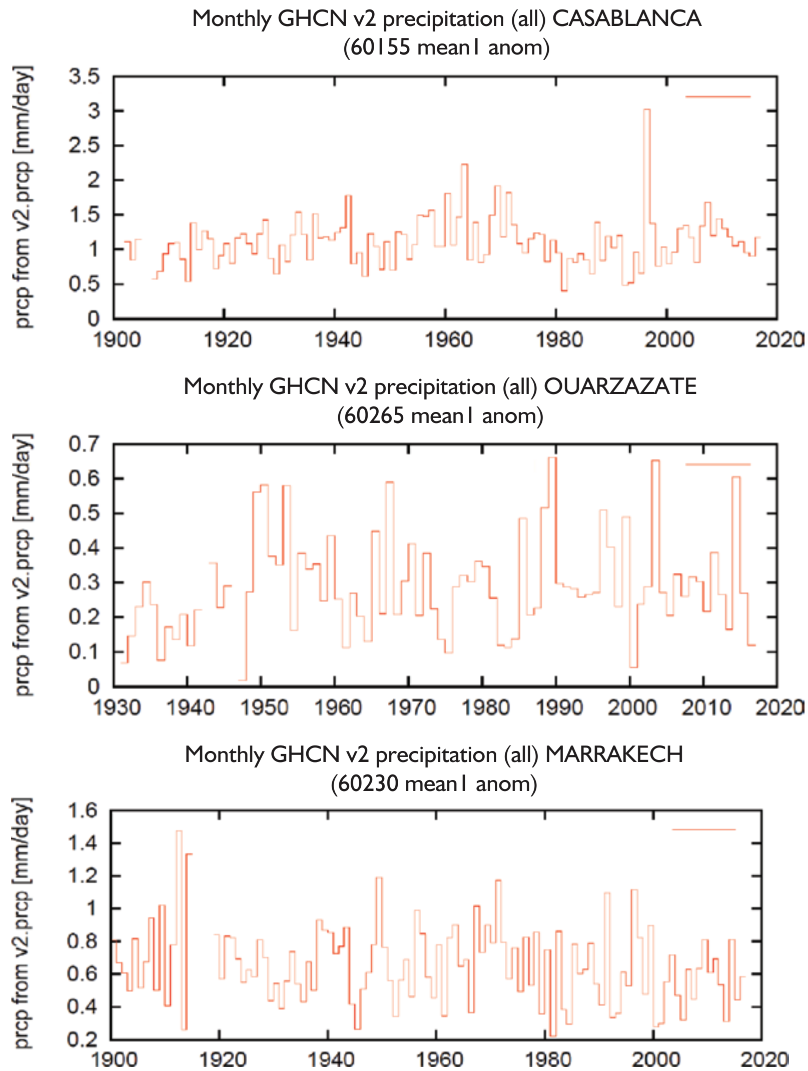
ANNUAL MEAN TEMPERATURE AND PRECIPITATION TRENDS FOR FOUR METEOROLOGICAL STATIONS IN MOROCCO

FIGURE A2.2.1 Annual Mean Temperature Series for Meknes, Casablanca, Ouarzazate, and Marrakech



Source: KNMI Climate Explorer, https://climexp.knmi.nl/selectstation.cgi?id=someone@somewhere.
Note: The series are incomplete but up to date (includes 2016 except Meknes, which includes 2014).

FIGURE A2.2 2 Annual Mean Precipitation Series for Casablanca, Ouarzazate, and Marrakech



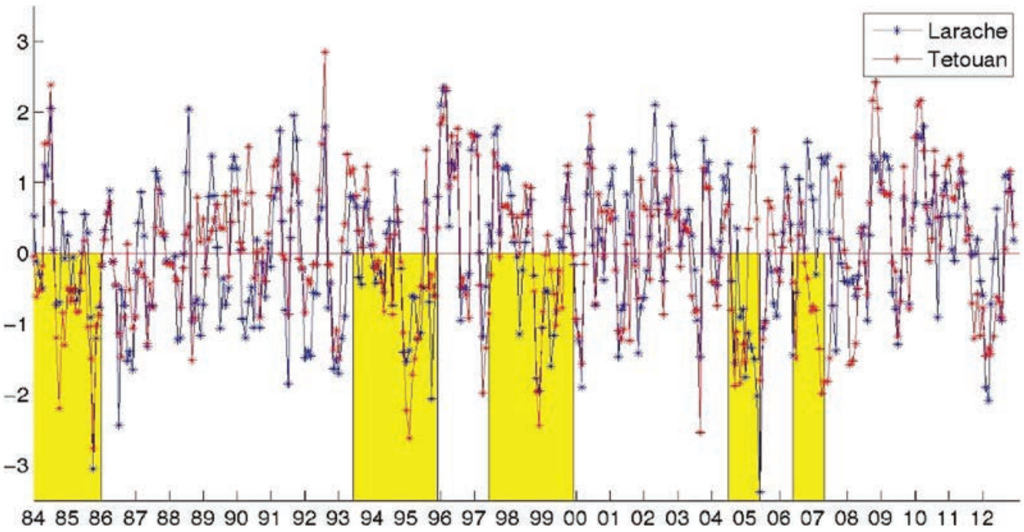
Source: KNMI Climate Explorer, https://climexp.knmi.nl/selectstation.cgi?id=someone@somewhere.
Note: The series are nearly complete and terminate in 2016.

ANNEX 2.3

DROUGHT VERSUS STANDARDIZED PRECIPITATION INDEX IN VARIOUS REGIONS IN MOROCCO

FIGURE A2.3.1 Standard Precipitation Index Values at Two Sub-humid Moroccan Stations: Larache and Tetouan

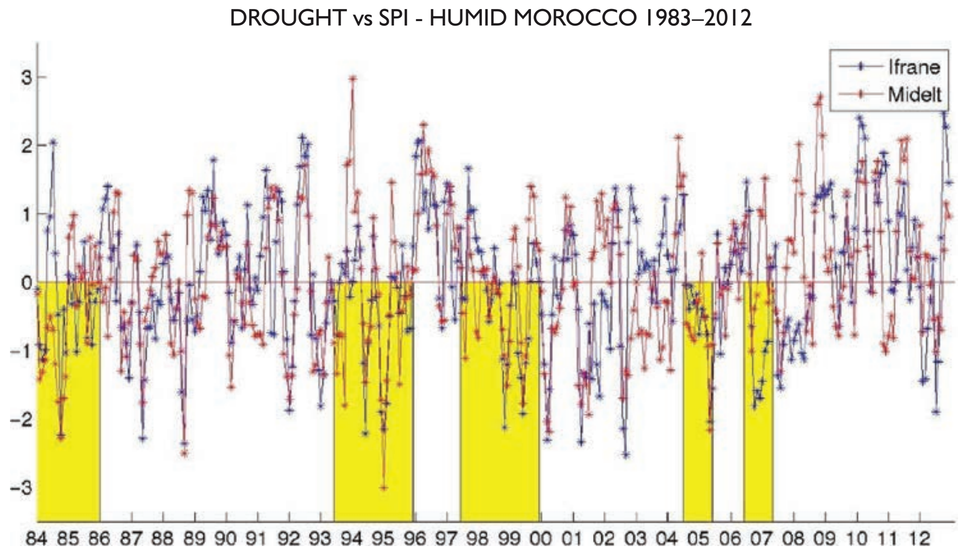
DROUGHT vs SPI - SUB-HUMID MOROCCO 1983–2012



Source: ICBA, n.d.

Note: Agricultural drought years according to the Moroccan Government are indicated in yellow. SPI = Standard Precipitation Index.

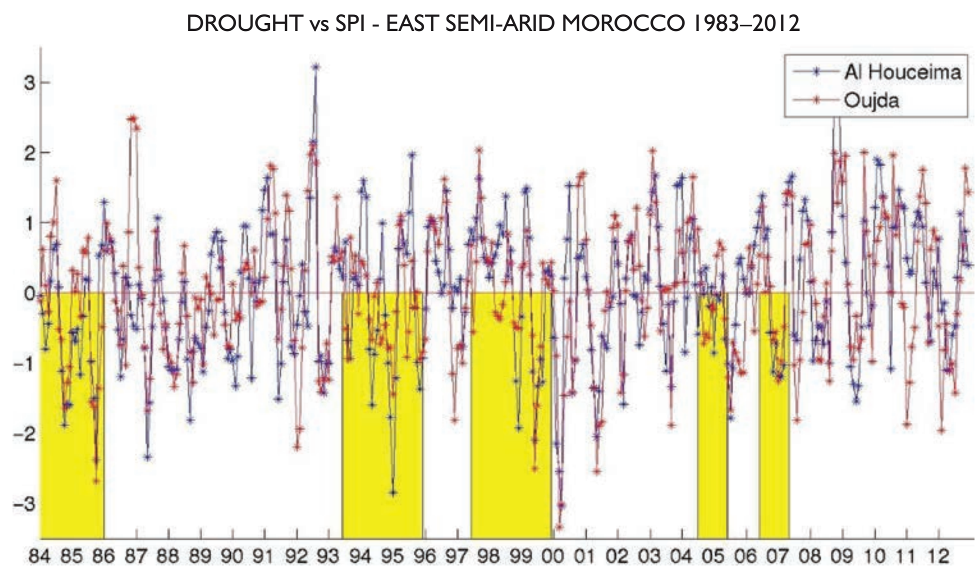
FIGURE A2.3.2 Standard Precipitation Index Values at Two Humid Moroccan Meteorological Stations: Ifrane and Midelt



Source: ICBA, n.d.

Note: Agricultural drought years according to the Moroccan Government are indicated in yellow. SPI = Standard Precipitation Index.

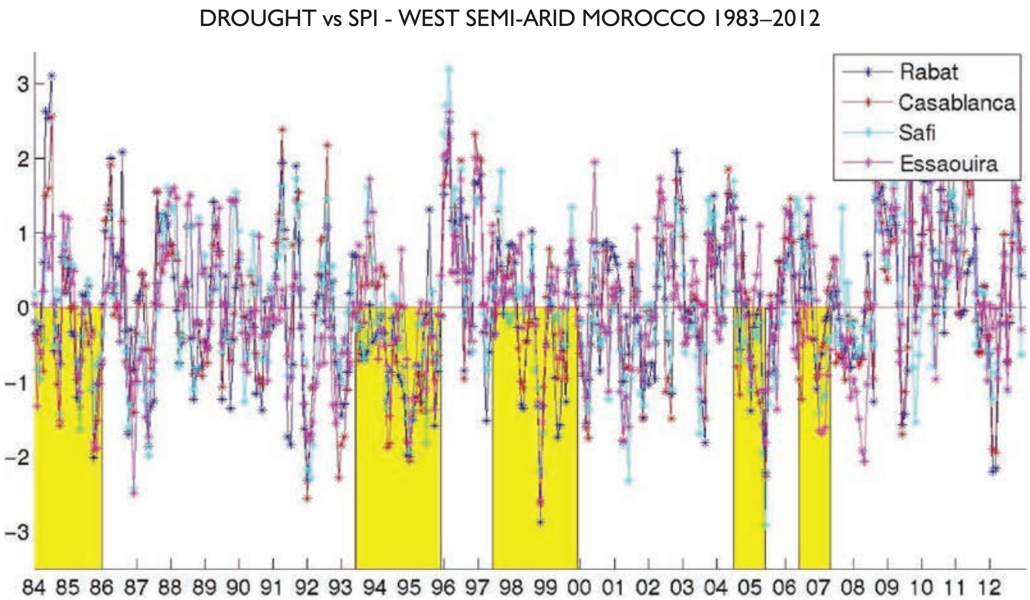
FIGURE A2.3.3 Standard Precipitation Index Values at Two East Semi-arid Areas Moroccan Meteorological Stations: Al Houceima and Oujda



Source: ICBA, n.d.

Note: Agricultural drought years according to the Moroccan Government are indicated in yellow. SPI = Standard Precipitation Index.

FIGURE A2.3.4 Standard Precipitation Index Values at Four West Semi-arid Moroccan Meteorological Stations: Rabat, Casablanca, Safi, and Essaouira



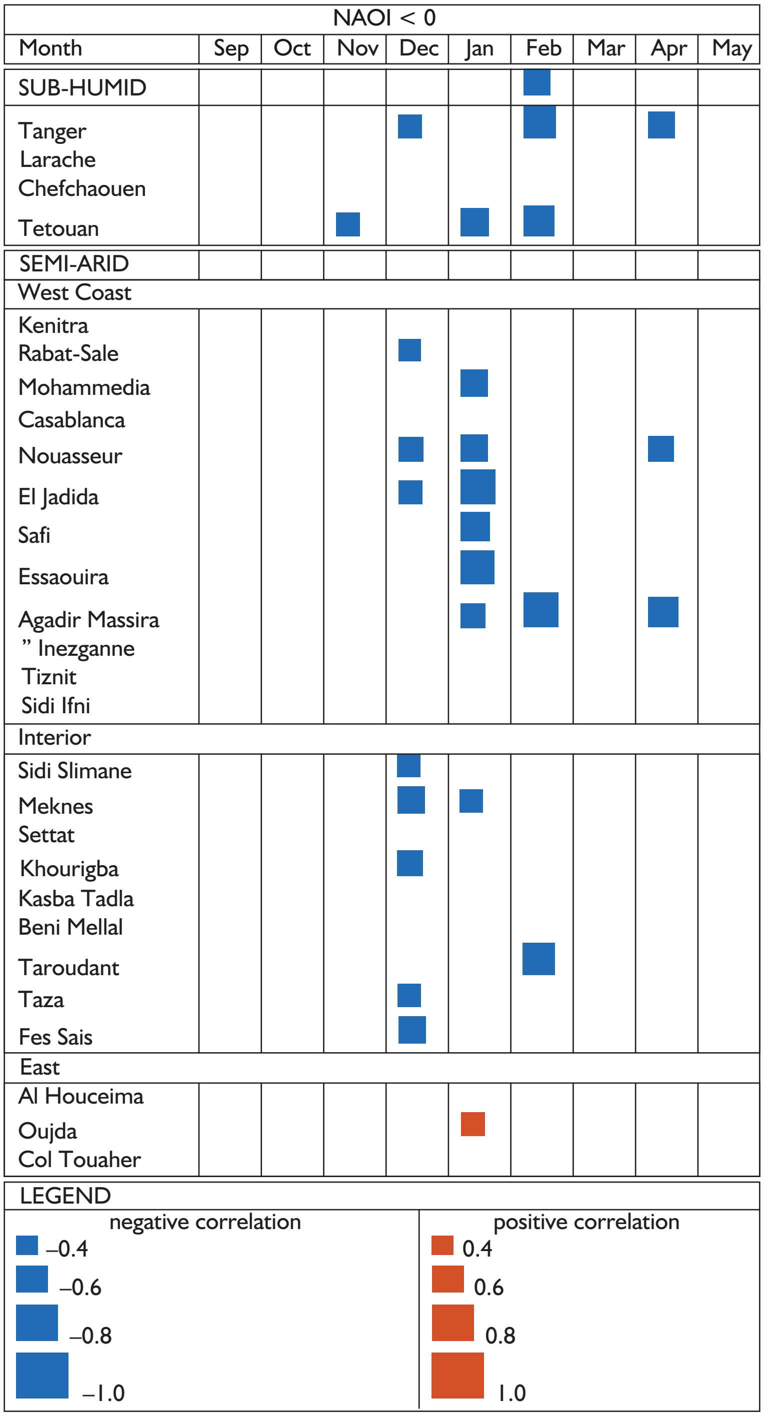
Source: ICBA, n.d.

Note: Agricultural drought years according to the Moroccan Government are indicated in yellow. SPI = Standard Precipitation Index.

ANNEX
2.4

CORRELATIONS WITHIN EACH CLIMATE ZONE FOR NORTH ATLANTIC OSCILLATION AND STANDARD PRECIPITATION INDEX/MEDITERRANEAN OSCILLATION INDEX IN MOROCCO

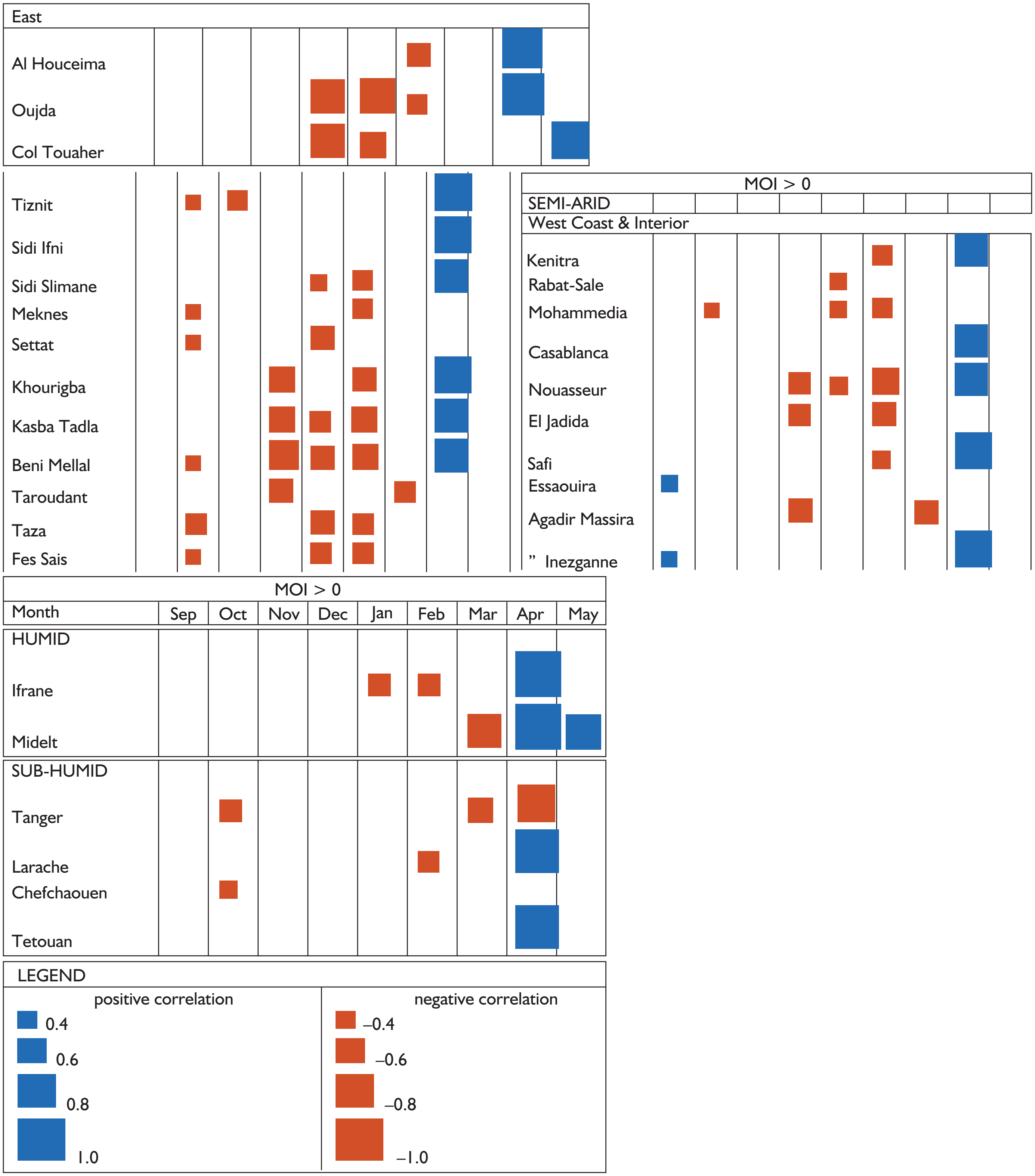
FIGURE A2.4.1 Correlations for Stations Within Each Climate Zone for North Atlantic Oscillation in Negative Phase Highlights the Strong Connections



Source: ICBA, n.d.

Note: Positive correlation (i.e., increased positive precipitation anomaly) is indicated in blue, negative correlation in red. The size of the squares indicates the correlation value and ranges from 0.4 to 0.99. NAOI = North Atlantic Oscillation Index.

FIGURE A2.4.2 Correlation Standard Precipitation Index/Mediterranean Oscillation Index With at Least 80 Percent of Confidence Interval for Sub-humid and Semi-arid Stations



Source: ICBA, n.d.

Note: Positive correlation (i.e., increased positive precipitation anomaly) is indicated in blue, negative correlation in red. The size of the squares indicates the correlation value and ranges from 0.4 to 0.99. MOI = Mediterranean Oscillation Index.

ANNEX
2.5

CLIMATE-RELATED EVENTS IN MOROCCO AND NEIGHBORING COUNTRIES, 2007–2015

- **2007** was characterized by several extreme weather events including heavy rainfall, heat waves, cold spells, and strong winds. Several records were broken and the annual mean temperature continued to rise. Northwest Africa experienced windy conditions across the region during February and March, with wind speeds exceeding 31 meters per second in some areas (full storm/hurricane). In April, many stations in Morocco, Algeria, and Tunisia reported rainfall exceeding 100 mm. A total of 73.6 mm of rainfall fell on 21 April in Nador in northern Morocco. These extreme rainfall events caused damage to property and infrastructure and claimed numerous lives, mainly because of the resulting springtime flooding in Algeria. Several heat wave events occurred in the summer of 2007, contributing to forest fires in the Rif Mountains of northern Morocco in July. During autumn, northwest Africa experienced a succession of weather systems. Region wide the mean rainfall exceeded 100 percent of the normal for the season, and daily rainfall records for November were broken. For example, 94 mm of rain fell at Tetouan City in the extreme north of Morocco on 24 November, breaking the previous daily record of 90 mm on 19 November 1969.
- **2008**. In northwest Africa, the annual mean temperature was 1°C to 2°C above normal in many regions. Winter was exceptionally cold with temperatures generally 0.5°C to 3°C below normal and daily minimum temperature records broken at many locations. In contrast, spring was more than 2°C above the long-term average over most parts of Morocco. During the summer, exceptional heat waves occurred across the region, with above-average maximum temperatures in several locations. Tangier experienced summer temperatures 3.3°C above normal. In northwest Africa, spring and summer 2008 were characterized by low rainfall totals, with March experiencing a deficit of more than 90 percent. However, autumn and winter 2007–08 were characterized by significant rainfall, especially across the northern regions. For October, many weather stations in Morocco and Algeria reported 24-hour rainfall totals exceeding 200 mm. In Morocco, October and November brought rainfall that was more than 300 percent of the monthly means.
- Several high daytime temperature records were set over the region in 2008. New records were set for Kenitra with a temperature of 49.8°C on 1 July, Tangier Aero with 37°C on 27 June, and 24.4°C on 3 April for Tangier Port. A number of low nighttime records were also broken. For example, Tangier Port recorded 9.7°C on 13 April, and Al Hoceima and Taourirt had

a minimum temperature of 7.6°C and 6.8°C, respectively, in October. Heavy precipitation occurred in October, with 24-hour rainfall records set in Larache and Chefchaouen at 108 mm and 117 mm, respectively, on 31 October, while 200 mm was observed at Tangier Port on 23 October.

- **2009.** In northwest Africa, the annual mean temperature was mainly above normal in 2009, with the anomalies between +0.4°C and +2.5°C. Winter and autumn were exceptionally cold over the region with monthly mean minimum temperatures 0.1°C to 3°C below normal. January anomalies of −2.0°C and −2.2°C were found in Algeria and Morocco, respectively. During the summer, exceptional heat waves occurred. The monthly mean temperatures exceeded the normal; for example, the anomaly was +2.4°C in Tetouan in July. On 21 July, the daily maximum temperature reached between 47°C and 50°C in Saharien City, Maskara in Algeria, Agadir, Tiznit, and Tan-Tan in Morocco. Precipitation records during December 2009 represented 31 percent of the annual total. Many weather stations in Morocco and Algeria reported rainfall exceeding 150 mm in less than 24 hours. Heavy storms that occurred from 20 to 25 December produced heavy rains causing floods. Rainfall amounts up to 200 mm in 48 hours were recorded, especially in the extreme north of Morocco. For example, Chefchaouen City recorded 835 mm in December for which the monthly values more typically are 265 mm (calculated from 1994 to 2000).
- **2009** was characterized by heavy rainfall events, especially during winter, that affected Algeria, Tunisia, and Morocco. These events caused important infrastructure damage and human life loss in many cities and villages when many daily rainfall records for September and December were broken. Record wind speeds also occurred; for example, 140 kph in Khouribga City in May and 115 kph in Tangier in December. Several forest fires occurred in July and August, especially when the daily temperature exceeded 50°C for some locations in Algeria and 49°C in Morocco.
- **2010** was an exceptionally warm year in northern Africa. Annual temperature was 1.0°C to 3.0°C above **normal** in most regions (based on 1971–2000 base period). The warmth was influenced by extreme temperatures, which were reported mainly during the summer. The annual mean temperature anomaly was between +0.1°C and +2.5°C in Morocco. Winter was relatively warm, with monthly minimum temperature anomalies exceeding +3.5°C in the northern Atlantic region. During summer, exceptional heat waves were frequent and strong monthly anomalies were recorded, for example, +3.5°C in August in the northern Atlantic city of Larache. During July and August, the daily maximum temperature reached 46°C in some parts of Algeria and 45°C in many parts of Morocco. The daily temperature was more than 5°C above normal on 29 August for most of Morocco. Some locations set their record-high daily temperatures in 2010: 42°C in Ouarzazate (24 July); 45.8°C in Rabat (26 August); and 45.4°C in Taza (27 August).
- Very wet conditions were recorded during 2010 in North Africa; winter and autumn were characterized by episodes of intense rainfall and floods. Heavy rainfall exceeded the monthly average by more than 500 percent for most locations over the region. Storms occurring from 27 to 30 November caused heavy rains exceeding 150 mm in six hours in the Moroccan cities of Chefchaouen (175 mm) and Casablanca (172.8 mm), resulting in floods in many parts of the northwest region. From September to December, the rainfall amount was more than

2.5 times higher than average at many locations (e.g., 804 mm in Chefchaouen, 761 mm in Ifrane, 508 mm in Larache, 438 mm in Casablanca, and 422 mm in Rabat). October and November were marked by significant heavy rainfall, leading to several floods in Morocco, Algeria, and Tunisia. These events caused major infrastructure damage and deaths. Many 24-hour rainfall records were broken during the year. According to the High Commission of Waters and Forests of Morocco, almost 500 hectares were destroyed by several forest fires in the extreme north during July and August; the Chefchaouen region was the most affected, especially during the heat wave when daily temperature exceeded 47°C.

- **2011**. Generally, both maximum and minimum temperatures were higher than average over the region. 2011 was the warmest in the last ten years. The annual maximum temperature averaged between 0.5°C and 3.5°C above normal with the largest anomaly observed in Taza, in the north-central sector of Morocco, south of the Rif Mountain. The annual maximum temperature anomaly was strongly influenced by extreme warm temperatures during the summer season. Overall, the annual precipitation was above average, especially during autumn when rainfall amounts reached 171 percent of normal in Rabat. Several locations recorded rainfall amounts approaching 100 mm in a 24-hour period during this time, resulting in flooding. The winter season was quite active with the development of storms that produced heavy rains approaching 80 mm in Chefchaouen, in a 24-hour period, and over 50 mm also in a 24-hour period in Tangier. October and November were marked by a succession of significant heavy rainfall events that led to several floods in Morocco, Algeria, and Tunisia. These events caused important infrastructure damage and loss of human life, especially in Algeria.
- **2012** was generally characterized by a succession of cold waves during the winter season accompanied by freezing temperature and snow, with snow depths reaching 75 centimeters at Jbel Morik in the Middle Atlas Mountains and up to 1.5 meters in northern Algeria at about 1,000 meters altitude, setting new temperature and precipitation records. This was in sharp contrast to 2011, which was considered the warmest in the past decade. During the winter, temperature was largely below the long-term mean, especially in February in Algeria and Morocco. February was characterized by the strengthening of the Azores anticyclone and a deep penetration of cold air from central Europe and the western Mediterranean basin into the region. The monthly average minimum temperature anomalies over Morocco ranged between about −0.2°C in Larache and −5.2°C in Chefchaouen. The lowest minimum temperature over Morocco was about −12°C on 9 February in Ifrane. These climatic conditions resulted in an unusually heavy snowfall, the most in the past 40 years, in low altitude areas (about 600 meters above sea level).
- July and August were warmer than normal with exceptional heat waves that began during the last 10-day period of July and continued through the second 10-day period of August with a record breaking maximum temperature of 49.6°C for the year in Marrakech. Overall in August, the monthly average maximum temperature was 6.5°C and 6.2°C above normal in Guelmim and Marrakech, respectively. Several extremely heavy rainfall events occurred in October. During this month, Khouribga received 433 percent of normal rainfall. The station of Ifrane recorded 142 mm on 30 October 2012, the highest 24-hour rainfall total in Morocco for the year. The freezing temperatures were accompanied by record-breaking snow storms. In contrast, intense heat waves occurred during the summer season. The heat associated

with predominant easterly winds favored the outbreak of several bush fires burning over 10,000 hectares in Morocco and Algeria.

- **2013.** Over Morocco, the annual mean temperature was near normal, with some exceptions. The seasonal average maximum temperature was 4.5°C above normal in Taroudant. The nation's highest temperature for the year, 48.6°C, was recorded on 8 August in Smara, in southern Morocco. Rainfall was generally below average across the region especially during January and February, except along the northern coastline from Morocco to Tunisia, where totals reached between 100 mm and 250 mm, indicating anomalies 20 mm to 50 mm above average for the two months. Rainfall deficits reached 50 mm to 100 mm below average along the west coast of Morocco. Extremely heavy rains also fell during the spring season. In Chefchaouen, the seasonal rainfall totals approached 160 percent of normal with a new 24-hour record of about 85 mm on 12 March.
- **2014.** The annual temperature was above normal across the region. In Morocco, the annual mean temperature and maximum temperature were 0.7°C and 0.8°C above normal, respectively. June was the warmest month of the year, with a record high temperature of 46°C reached at Smara and 45°C at Oujda (highest since 1919). Heat waves persisted across the region into fall, especially during October, when the monthly average maximum temperature was 7.7°C above normal at several stations in Morocco. In Tangier the temperature reached 36°C on 22 October, 14.8°C above normal and the highest since 1930. Overall, the region experienced an annual rainfall deficit, associated with anomalous anticyclonic circulation that persisted over the region, especially during the first half of the year. However, the region was also characterized by a strong geographical variation in precipitation ranging from 52 percent of normal at Nador to 239 percent of normal in El Jadida.
- Generally dry conditions persisted in northern Africa during summer, except at the end of August when convection contributed to heavy rainfall in some areas of Algeria. The monthly average for August is only 11.3 mm. On 20 to 21 September, 66 mm of rain was reported at Ouarzazate, while on 27 September, 93 mm of precipitation fell in just two hours in Fnideq on the Moroccan Mediterranean coast. Successive extreme rain events, associated with a deep trough with surface pressure as low as 985 hectopascals, were reported in November and December in southern Morocco and Algeria. Exceptionally heavy rainfall caused floods over the region, particularly in southern and central Morocco (Guelmim, Agadir, Ouarzazate, and Marrakech), in November, killing nearly 40 people, according to reports from the U.N. Office for the Coordination of Humanitarian Affairs. Several stations reported record 24-hour precipitation in November. This includes record rainfall on 28 November: 101 mm of rainfall at Tiznit and 117 mm at Agadir, equivalent to almost half the annual average at this location.
- **2015.** The annual temperature was the warmest since 1960 over Morocco. However, temperatures during January and February were markedly below average in association with a cold air surge from the Black Sea to the Maghreb. Temperatures during spring, summer, and autumn were all above normal in Morocco and Algeria. The average mean monthly temperature in Morocco was 3°C above normal in May. Winter precipitation over Morocco was highly variable. The average deficit in Morocco was about 89 percent of normal in January and 71 percent of normal in February. Lack of rainfall was associated with dominant atmospheric high pressure conditions on the Moroccan Atlantic coast and in Western Europe.

- Monthly precipitation in spring was generally below normal in Morocco. However, above-normal rainfall ranging between 145 percent and 230 percent of normal was observed in March across central Morocco. New 24-hour **rainfall** records ranging between 20 and 55 mm were observed during 23 to 25 May at various places in Morocco. Convective precipitation brought extreme weather conditions in summer, especially during July and August, leading to excess rainfall, with an average amount of around 158 percent of normal over Morocco. Total precipitation received during August was well above normal (e.g., 45 mm at Marrakech compared to the normal of 2.7 mm; 23.2 mm at Sidi Ifni compared to the normal of 2.1 mm). Unlike the recent autumns of 2013 and 2014, which were marked by a series of above-normal rainy conditions, autumn precipitation in 2015 was generally below normal over most of Morocco. Monthly rainfall ranged from 7 percent of normal at Casablanca to about 86 percent of normal at Midelt. May, July, and August were marked by several heat waves, resulting in high maximum temperatures. These heat waves were associated with continental dry air intrusions from the intense heat source in the Sahara. The heat waves, associated with an east wind, caused several forest fires, which devastated hundreds of hectares of forest, especially in northern Morocco.

ANNEX
2.6

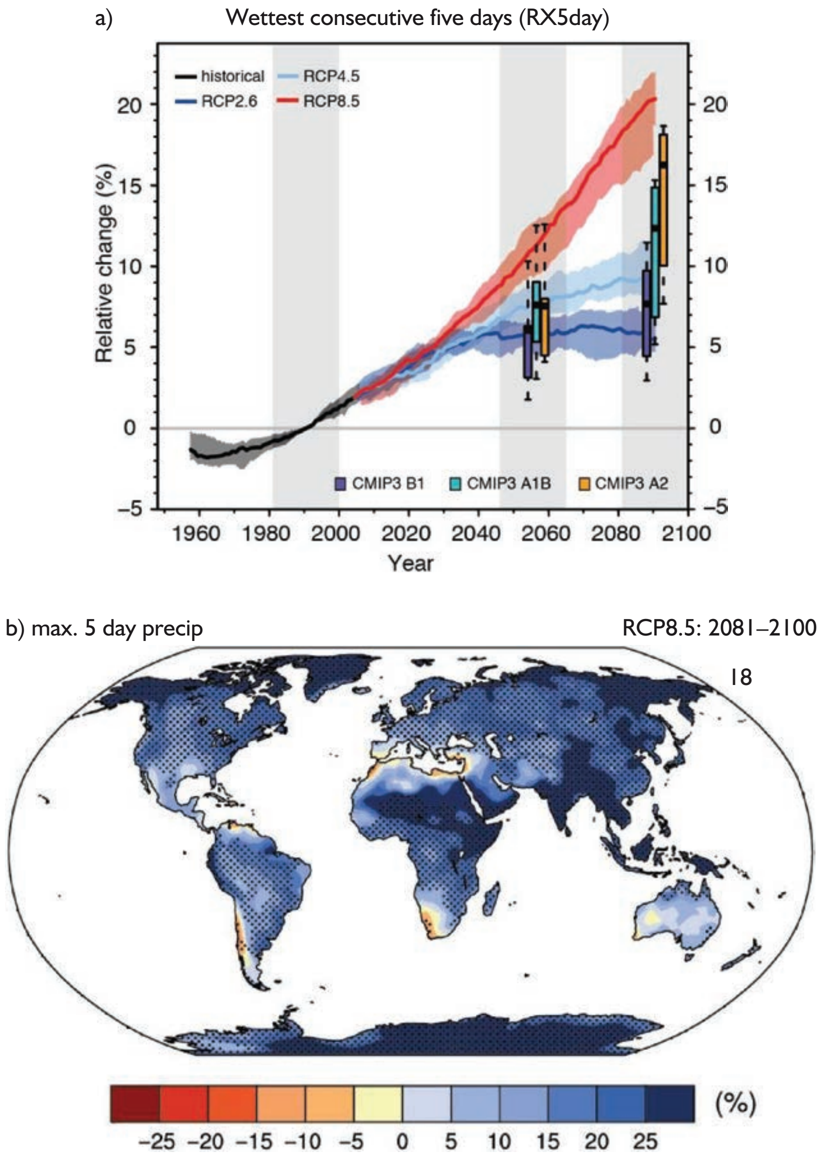
PROJECTED GLOBAL CHANGES IN TEMPERATURE, FROST DAYS AND TROPICAL NIGHTS

Based on a multi-model analysis Figure A2.6.1 exhibits simulated increases in five-day rainfall intensity between now and the end of the 21st century (upper panel). The lower panel shows a snapshot of the pattern of change towards the end of the century (2081–2100 versus 1986–2005). For northwest Africa and Morocco in particular, the statistical signal is weak but indicates an increasing risk of both increased rainfall intensity and more frequent droughts or dry spells in general.

The Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment Report (AR5) concluded that "*it is virtually certain that there will be more hot and fewer cold extremes as global temperature increases*" (Collins et al. 2013). FigureA2.6.2 shows multi-model mean changes in the absolute temperature indices of the coldest and hottest days of the year and the threshold-based indices of frost days and tropical nights from the Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble. A robust increase in warm temperature extremes and decrease in cold temperature extremes is found at the end of the 21st century, with the magnitude of the changes rising with increased anthropogenic forcing. The coldest night of the year undergoes larger increases than the hottest day in the globally averaged time series (Figure A2.6.2 and d). This tendency is consistent with older (CMIP3) model results also shown, which use different models and the IPCC Special Report on Emissions Scenarios (SRES). Similarly, increases in the frequency of warm nights are greater than increases in the frequency of warm days. Regionally, the largest increases in the coldest night of the year are projected under the RCP8.5 scenario (Figure A2.6.26a).

The subtropics and mid-latitudes exhibit the greatest projected changes in the hottest day of the year, whereas changes in tropical nights and the frequency of warm days and warm nights are greatest in the tropics. The number of frost days decline in all regions while significant increases in tropical nights are seen across the Mediterranean region and hence appear to be applicable to the conditions of Morocco. Furthermore, assessed from global figures, Collins et al. (2013) states that it is also very likely that heat waves—defined as spells of days with temperature above a threshold determined from historical climatology—will occur with a higher frequency and duration, mainly as a direct consequence of the increase in seasonal mean temperatures. Changes in the absolute value of temperature extremes are also likely and expected to regionally exceed global temperature increases, with substantial changes in hot extremes projected even for moderate (e.g. <2.5°C above present day) average warming levels.

FIGURE A2.6.1 Projected Percent Changes (relative to the 1981–2000 Reference Period in common with CMIP3) from the CMIP5 Models in Five-Day Extreme Rainfall, the Annual Maximum Five-Day Precipitation Accumulation



Source: Collins et al. 2013.

Note: (a) Global average percent change over land regions for the RCP2.6, RCP4.5 and RCP8.5 scenarios. Shading in the time series represents the interquartile ensemble spread (25th and 75th quantiles). The box-and-whisker plots show the interquartile ensemble spread (box) and outliers (whiskers) for 11 CMIP3 model simulations of the SRES scenarios A2 (orange), A1B (cyan) and B1 (purple) globally averaged over the respective future time periods (2046–2065 and 2081–2100) as anomalies from the 1981–2000 reference period. (b) Percent change over the 2081–2100 period in the RCP8.5 scenario. CMIP3 = Coupled Model Intercomparison Project Phase 3; IPCC = Intergovernmental Panel on Climate Change; RCP = Representative Concentration Pathway of greenhouse gas emissions; SRES = IPCC Special Report on Emissions Scenarios.

FIGURE A2.6.2 CMIP5 Multi-model Mean Geographical Changes under RCP8.5 and Twenty-Year Smoothed Time Series for RCP2.6, RCP4.5 and RCP8.5

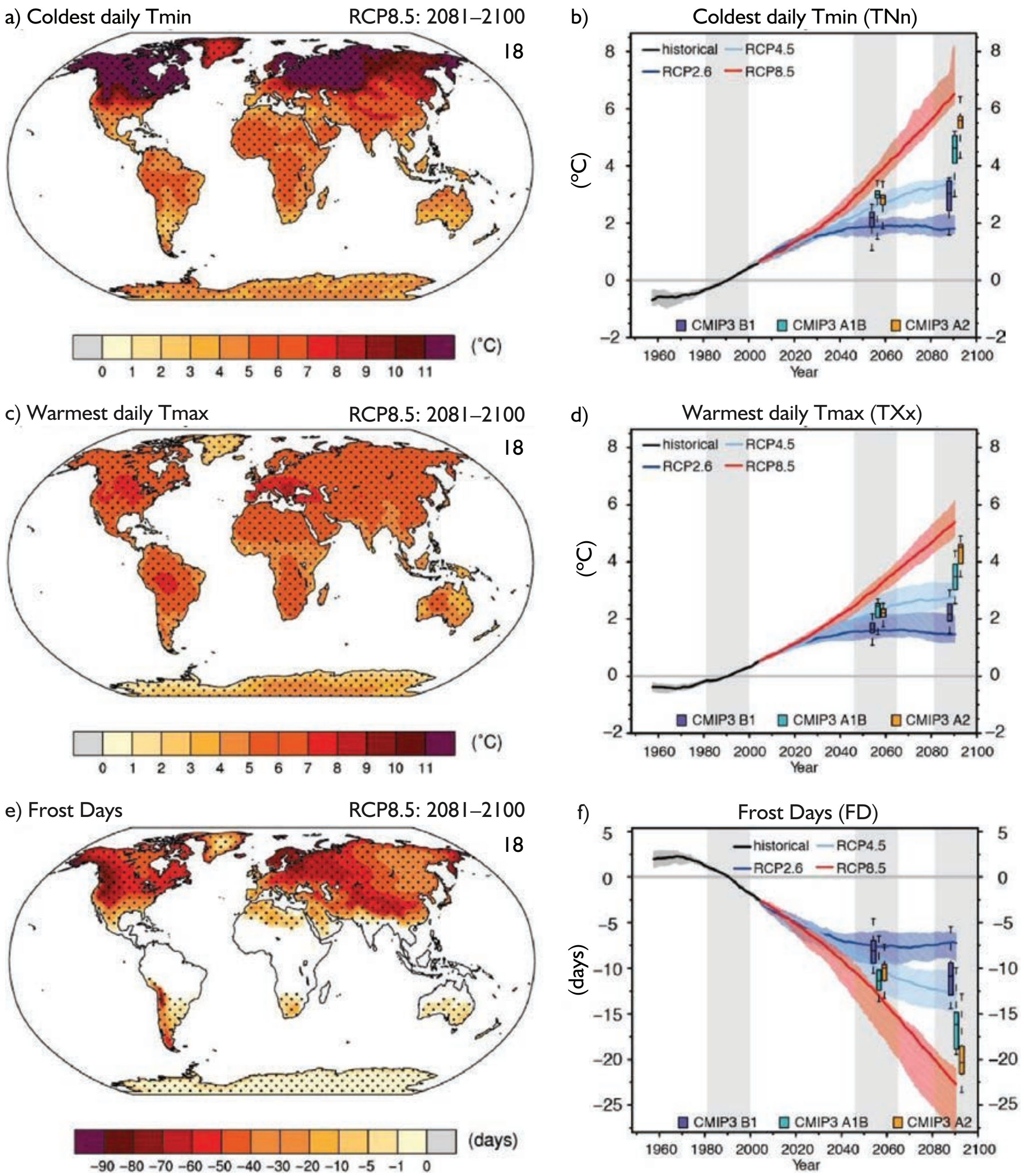


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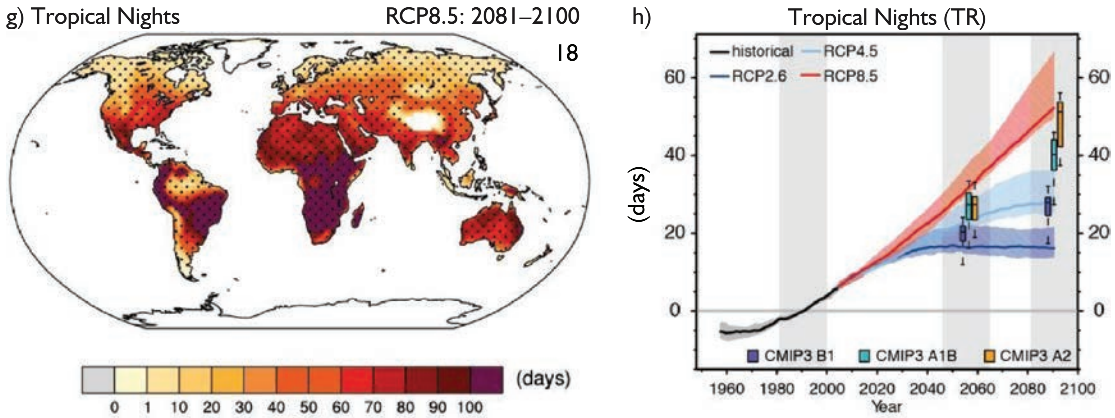
FIGURE A2.6.2 *(Continued)*



Source: Collins et al. 2013.

Note: This is relative to a 1981–2000 reference period in common with CMIP3. (a, b) annual minimum of daily minimum temperature, (c, d) annual maximum of daily maximum temperature, (e, f) frost days (number of days below 0°C), and (g, h) tropical nights (number of days above 20°C). White areas over land indicate regions where the index is not valid. Shading in the time series represents the interquartile ensemble spread (25th and 75th quantiles). The box-and-whisker plots show the interquartile ensemble spread (box) and outliers (whiskers) for 11 CMIP3 model simulations of the SRES scenarios A2 (orange), A1B (cyan), and B1 (purple) globally averaged over the respective future time periods (2046–2065 and 2081–2100) as anomalies from the 1981–2000 reference period. CMIP3 = Coupled Model Intercomparison Project Phase 3; RCP = Representative Concentration Pathway of greenhouse gas emissions.

ANNEX
3.1

REGIONAL CLIMATE CONDITIONS IN CITRUS AND OLIVE PRODUCING AREAS SURVEYED FOR THIS ANALYSIS

A3.1.1 SOUSS-MASSA

The weather conditions in Souss-Massa (SM) for agricultural year 2015–16 are characterized by a rainfall deficit despite recent rains, elevated daytime temperatures and a substantial drop in nighttime temperatures, which has resulted in a tendency for undersized fruits in certain varieties of citrus (Moroccan Citrus Producers Association 2016).

Temperature extremes have fluctuated over the past decade, as shown in Figure A3.1.1.

Rainfall has fluctuated widely in the past several years, most recently falling into drought conditions, as shown in Figure A3.1.2. Rainfall levels continue to drop in 2016, continuing a trend of drought from 2014–15. In addition to fluctuating annual rainfall levels, variability in the timing and distribution of rainfall is evident. By February 2015, a cumulative 150–450 mm of rain had fallen at various stations in the region; by the same time in 2016, only 70–130 mm had fallen (Moroccan Citrus Producers Association 2016).

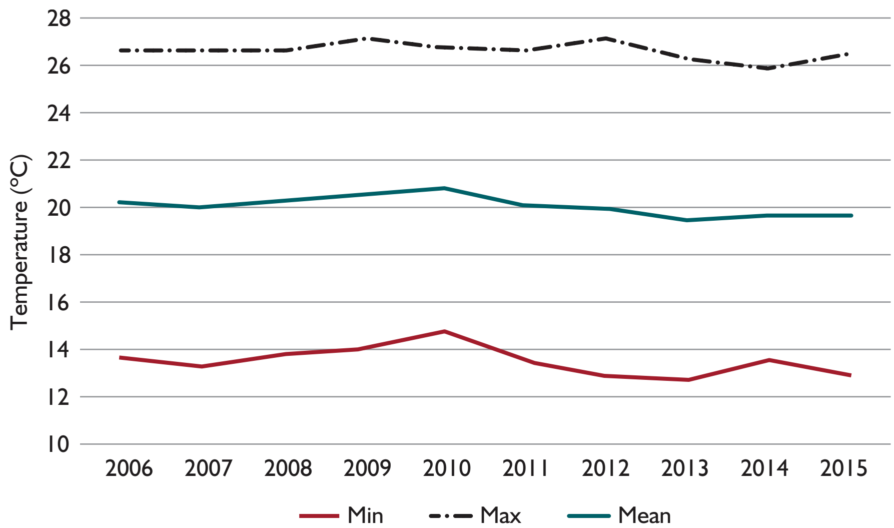
Water Resources and Irrigation. The Souss-Massa basin is characterized by limited and irregular surface water resources collected at dams and groundwater resources consisting of an alluvial aquifer. An imbalance between the limited water supply and increasing water demand has led in recent years to a water shortage.

Table A3.1.1 provides a concrete example of increasing surface water scarcity due to inefficient irrigation practices which require unsustainable amounts of water, and low recharge rates of surface water sources (an issue that will be exacerbated by climate change impacts should there be a decrease in precipitation averages as heralded by the current drought) (Toumi et al. 2016). For all dams supplying water to the region, reserve levels have decreased significantly since the previous year.

The surface water deficit resulting from low recharge rates is made up for by pumping an average of 260 million cubic meters (Mm3) per year from the aquifer, which has resulted in water level declines ranging from 0.5–2.5 m (average 1 m) every year for the past four decades.[52]

[52] Elame and Doukkali (2011); Keithand Ouattar (2003);Toumi, et al. (2016); http://digitalcommons.usu.edu/eri/268.

FIGURE A3.1.1 Annual High and Low Temperatures in Souss-Massa

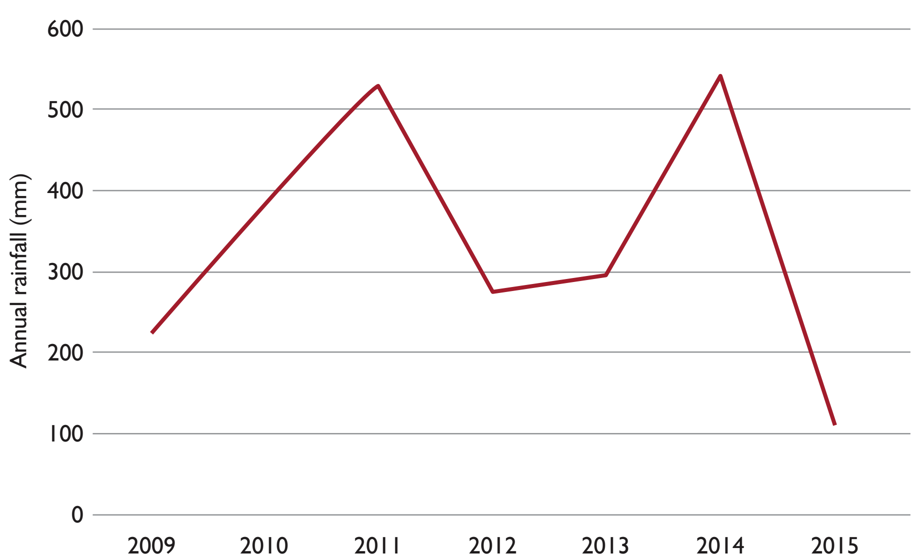


Source: http://en.tutiempo.net/climate/ws-602520.html.

A3.1.2 BÉNI MELLAL-KHÉNIFRA

Béni Mellal-Khénifra (BMK) has a warm and temperate continental climate with very hot summers and cold rainy winters. The climate is categorized as dry-summer subtropical (Csa) by the Köppen-Geiger climate classification system. The weather conditions in BMK for agricultural year 2015–16 are characterized by a rainfall deficit despite recent rains, elevated daytime temperatures, and a substantial drop in nighttime temperatures, which resulted in undersized fruits in certain varieties of citrus (Moroccan Citrus Producers Association 2016).

FIGURE A3.1.2 Annual Rainfall in Souss-Massa



Source: http://en.tutiempo.net/climate/ws-602520.html.

TABLE A3.1.1 Water Availability in Souss-Massa Region from Large Dams as of February 2016

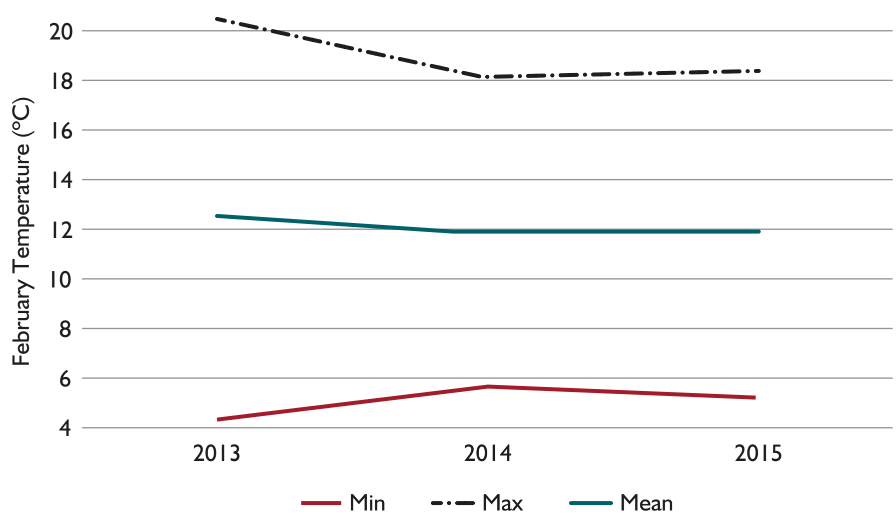
Dam	2015 Reserve (Mm3)	2015 Recharge Rate (%)	2016 Reserve (Mm3)	2016 Recharge Rate (%)	Change in Reserve Levels from 2015–2016 (%)
Idrissi 1er	885.0	78.4%	636.0	56.3%	–28%
Allal Fassi	57.3	89.9%	49.6	77.4%	–13%
El Wahda	2,173.3	58.5%	1,631.5	44.0%	–25%
El Kansra	195.8	88.7%	101.3	45.9%	–48%
Abdelmoumen	126.4	62.9%	73.1	36.4%	–42%
Aoulouz	88.4	92.2%	53.4	55.8%	–40%
Y.B. Tachfine	262.7	87.0%	164.9	54.6%	–37%
Mohamed V	175.5	75.0%	67.8	28.0%	–61%

Source: Moroccan Citrus Producers Association 2016.

Mean **temperatures** have decreased annually in the past three agricultural years, as shown in Figure A1.3 below. Although this decrease may appear to be very slight in the figure, it has been quite significant to sensitive crops such as citrus; while 2013–14 was a good year for growing conditions, 2014–15 and 2015–16 have had poor conditions resulting in yield losses.

In addition to yield losses due to decreasing temperatures, crop yields took a hit in May of 2016 and 2015, when an unseasonably early chergui (a hot, dry seasonal wind which blows off the Sahara) caused a significant drop of small young fruits, though the effects of the chergui were mitigated in orchards that were adequately irrigated during this period (losses were dependent on the amount of irrigation).[53]

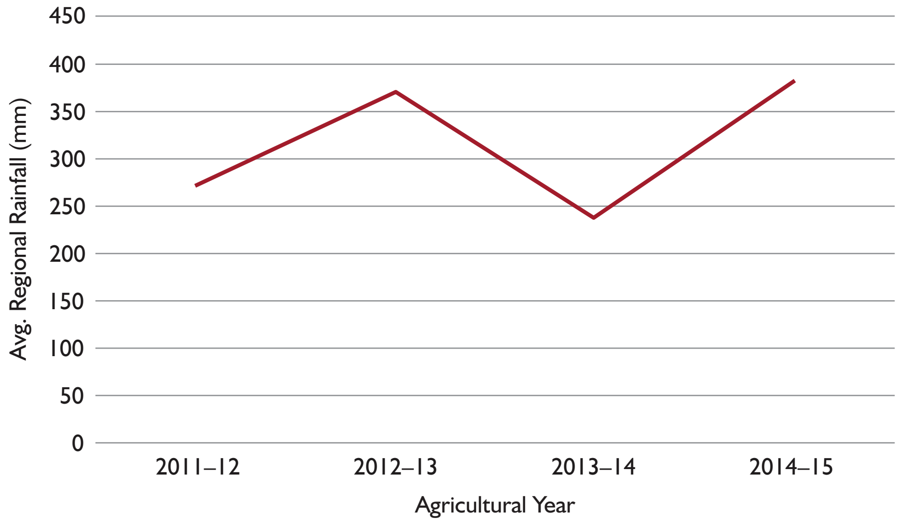
FIGURE A3.1.3 February High and Low Temperatures in Béni Mellal-Khénifra



Sources: DRATA 2014, 2015, 2016.

[53] DRATA (2015, 2016).

FIGURE A3.1.4 Annual Rainfall in Béni Mellal-Khénifra

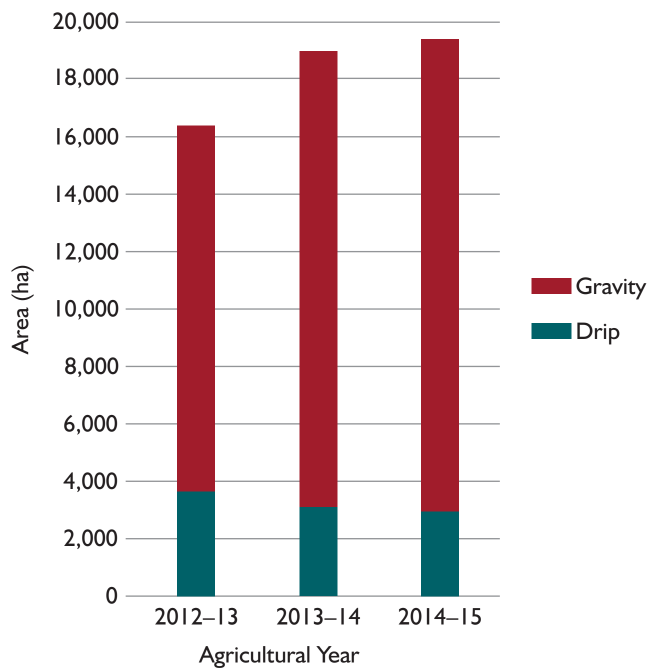


Rainfall has fluctuated over the past four agricultural years, as shown in Figure A3.1.4. While the increased rain in the 2014–15 season was better for crops than the unusually low rainfall of the previous year, overall growing conditions were poor in 2014–15 (due primarily to temperature and humidity) (DRATA 2015, 2016).

Water Resources and Irrigation. Figure A3.1.5 illustrates the change in irrigated area under various systems from agricultural year 2012–13 to 2014/15. Total irrigated area has increased over time, with drip irrigation gaining popularity over gravity systems.[54] The figures are across all crops and not specific to citrus or olives.

Surface water collected in regional dams and wells tapping groundwater, the primary irrigation sources in the region, have experienced a significant decrease in reserve levels since the previous year resulting from inefficient irrigation practices which require unsustainable amounts of water, and low recharge rates of surface water sources (DRATA 2014, 2015, 2016; Toumi et al. 2016).

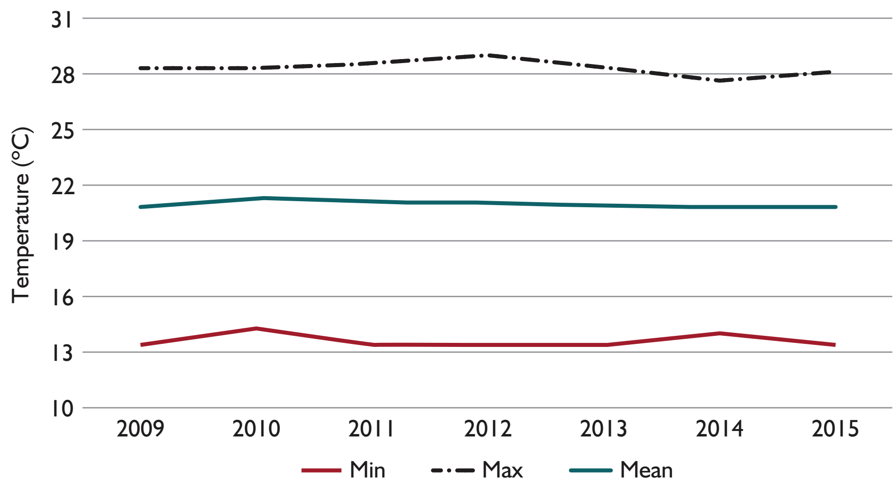
FIGURE A3.1.5 Irrigation Systems Utilized in Béni Mellal-Khénifra



Sources: DRATA 2014, 2015, 2016.
Note: ha = hectares.

[54] Although gravity systems are a type of drip irrigation, by local definition "drip" refers to an irrigation system with a mechanical pump that delivers water to the base of plants, while "gravity" refers to a subsurface drip system that relies on gravity, rather than a pump, to deliver water from an elevated reservoir (basin) to the root zone of plants.

FIGURE A3.1.6 Annual High and Low Temperatures in Marrakech-Safi.



A3.1.3 MARRAKECH-SAFI

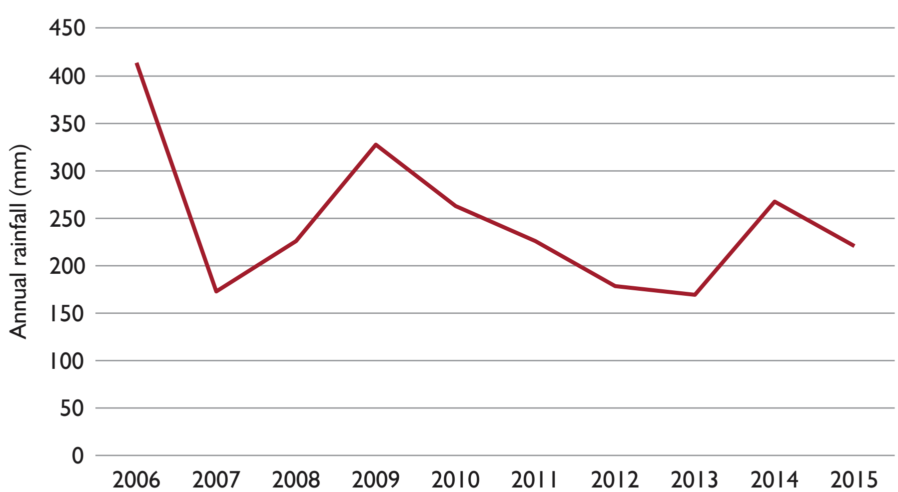
Marrakech-Safi has a semi-arid climate, and an average of 340 days of sun per year. Historically, in October and November the *Herrûrco*, a humid seasonal wind, brings rain and thunderstorms. The Atlas Mountains have snow from November to May.

Temperature extremes have fluctuated slightly over the past decade, as shown in Figure A3.1.6 below.

Rainfall is rare (fewer than 25 days per year) in the semi-arid climate of MS. Annual rainfall amounts have fluctuated widely over the past decade as shown in Figure A3.1.7.

Water Resources and Irrigation. Table A3.1.2 provides a concrete example of increasing surface water scarcity due to inefficient irrigation practices which require unsustainable amounts of water, and low recharge rates of surface water sources (Toumi et. al.). Note that for all but two of the dams supplying water to the Marrakech-Safi region, reserve levels have decreased since the previous year.

FIGURE A3.1.7 Annual Rainfall in Marrakech-Safi



Source: http://en.tutiempo.net/climate/ws-602520.html.

TABLE A3.1.2 Water Availability in Marrakech-Safi Region from Large Dams as of June 2016

Dam	Normal Capacity (Mm3)	2015 Reserve (Mm3)	2015 Recharge Rate (%)	2016 Reserve (Mm3)	2016 Recharge Rate (%)	Change in Reserve Levels from 2015–16 (%)	Normal Year Irrigation Availability for the Region (Mm3)[1]
Moulay Youssef	148.7	147	98.8%	88.2	59.3%	–40%	260
Lalla Takerkoust	53.3	49.5	92.8%	43	80.7%	–13%	82
Yahoub El Mansour	70.3	96.4	98.7%	65.4	93.0%	–6%	n/a
Hassan 1er	242.1	240.3	99.3%	164	67.8%	–32%	310
Abou Abass Sebti	24.8	24.1	97.0%	24.3	97.7%	1%	20
Sidi Mhammed Ben Slimane Jazouli	15.4	12.3	80.0%	13.6	88.0%	11%	12
Beni El Ouidane	1,233	1,200	98.0%	808	65.0%	–33%	235[2]

Source: Ministère Délégué Chargé de l'Eau, Situation journalière des principaux grands barrages.

ANNEX
3.2

ECONOMIC IMPACTS OF CLIMATE CHANGE ON CITRUS SUBSECTOR PRODUCTION AND EXPORTS

Impact on Jobs. Reduced crop volumes have resulted in reduced sector employment, especially in jobs associated with harvest and packhouses. Based on rapid value chain assessment (RVCA) results, every 10 percent loss of yield rate implies 12,899 fewer direct jobs nationally.

This impact notwithstanding, there are also potential opportunities for job creation in the face of climate change. Jobs in research, technology, and technical assistance, for example, will be crucial to adaptation, food security, and export competitiveness. Required jobs and skills include those in the areas of:

- Climate-resistant cultivars
- Production, sale, and application of agrochemicals to reduce impact of drought on trees
- Disease/pest management
- Grower technicians
- Extension services
- Packhouse quality control
- Local testing labs for soil/leaf and brix
- Affordable green energy for pumping
- Water desalination

Impact on costs. All citrus growers surveyed irrigated their crops. Drip irrigation is widely adopted in Souss-Massa (SM), while gravity systems are more prevalent for Béni Malal-Khénifra (BMK) farms, particularly for smaller farms (<10 hectares) and those with older trees with deep roots (see Figure A3.2.1 below). Some citrus growers using drip irrigation reported frustration with the results, as the water did not seem to be reaching deep into the soil to benefit tree roots, even for orchards planted with drip from the beginning where their trees theoretically were "trained" to seek the surface water. Growers expressed interest in changing irrigation systems but did not know where to turn for information or technical guidance. Several such growers were considering removing the drip and returning to gravity or other systems. Given that tree water benefit is a function not only of the irrigation system but of many other factors, including water quantity and frequency, temperature, and evapotranspiration rate, further research and technical support is required to identify how to maximize the benefits of drip irrigation for citrus production and determine and guide producers regarding the appropriate irrigation system by farm type, tree age and type, agro-zone, and other factors.

Irrigation cost has increased threefold in recent years, with individual costs (MAD/hectare) varying by grower, and power and water source. Water on metered systems (e.g., canals) is on quota restrictions due to drought, so multiple sources of water are required to ensure adequate irrigation volume (see Impact on **Exports**. In marketing year (MY) 2015–16, Morocco produced 918,000 metric tons (MT) of oranges and 1,055,000 MT of tangerines/mandarins, of which 79 percent and 64 percent, respectively, were consumed locally, with the balance exported (see Figure A3.2.3).

As noted previously (see Figure 3.4 in the main text), individual citrus growers reported declining yield rates of 10 percent to 55 percent due the effects of climate change-induced drought. Should the effects become more widespread at a national level, Morocco's ability to export citrus fruit would be adversely affected. Applying various yield rate decline scenarios to the MY2015–16 production levels, and assuming that local demand remains constant, under a 10 percent yield rate decline, Morocco would export 142,300 MT (28 percent) less fresh citrus fruit (both oranges and tangerines/mandarins). If yield rates declined 30 percent for oranges and 40 percent for tangerines/mandarins, there would be insufficient production to satisfy domestic demand, and Morocco would need to import citrus fruit (see Table A3.2.2 and Figure A3.2.3 below).

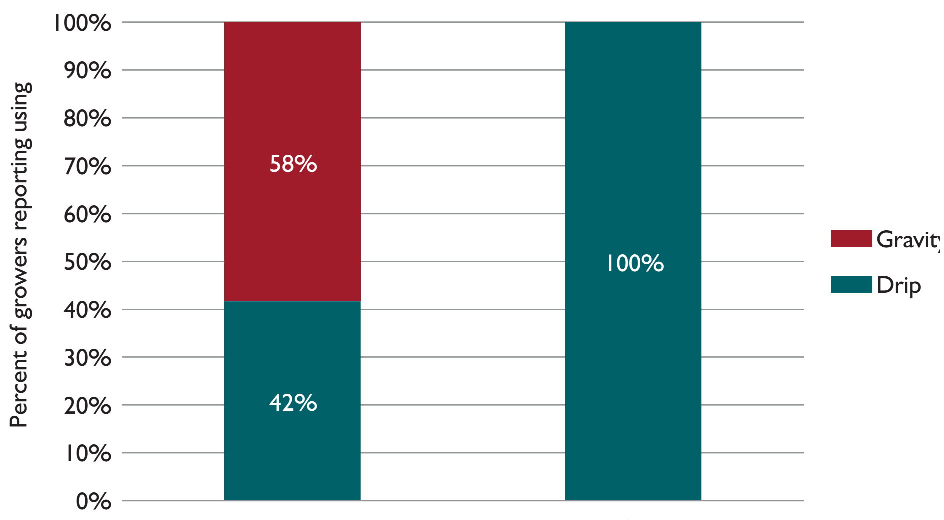
Figure A3.2.2), such as both wells and canals in BMK and both wells and dams in SM. Well water incurs pumping costs to retrieve water, and pumping costs increase when deeper wells are utilized.

TABLE A3.2.1 Estimated Employment Impact along Citrus Value Chain from Climate Change

National Job Loss for Every 10% Decline in Citrus Yield Rate		
Average yield rate	24	MT/ha
Decline in yield rate	10%	
Reduction in production yield rate	2.4	MT/ha
National planted area	117,985	ha
Reduction in national production quantity	283,164	MT
Job loss (permanent and FTE)	**8,460**	**On farm**
	4,439	**At packhouse**
	12,899	**Total**

Source: World Bank data.
Note: FTE = full-time equivalent; ha = hectares; MT = metric tons; MT/ha = metric tons per hectare.

FIGURE A3.2.1 Irrigation Method of Citrus Growers



Source: World Bank data.
Note: BMK = Béni Malal-Khénifra; SM = Souss-Massa.

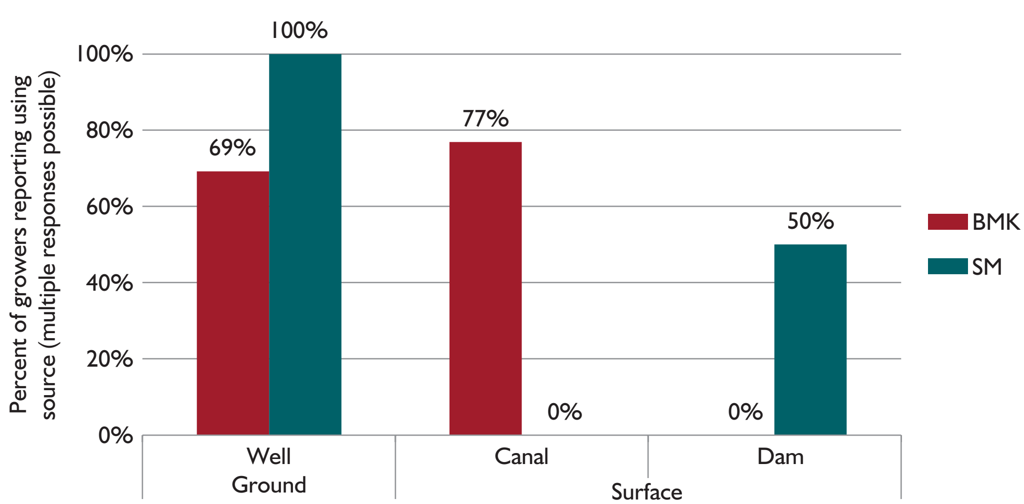
TABLE A3.2.2 Prospective Fresh Citrus Exports under Climate Change Scenarios (1,000 MT)

Indicator	Fruit	MY 2015/16	Yield Rate Decline			
			10%	20%	30%	40%
Production	Orange	918.0	826.2	734.4	642.6	550.8
	Tangerine/mandarin	1,055.0	949.5	844.0	738.5	633.0
Domestic consumption	Orange	728.0	728.0	728.0	728.0	728.0
	Tangerine/mandarin	675.0	675.0	675.0	675.0	675.0
Export	Orange	135.0	98.2	6.4	(85.4)	(177.2)
	Tangerine/mandarin	380.0	274.5	169.0	63.5	(42.0)
Reduction in fruit available for export	Orange		36.8	128.6	220.4	312.2
	Tangerine/mandarin		105.5	211.0	316.5	422.0
	Total		142.3	339.6	536.9	734.2
	Percent change		28%	66%	104%	143%

Sources: Global Development Solutions, LLC, estimates based on data in 2015 Morocco Citrus Annual Report, USDA Foreign Agricultural Service, 10 Dec 2015.
Note: MY = market year.

For example, a 50-hectare farm that switched from a 50 meter well to a 150 meter well (since the 50 meter well ran dry) found that pumping cost increased from MAD 0.80 to MAD 2.40/m^3 of water used. While smaller farms can irrigate during times of lower electricity tariff, larger farms must pump continuously to fill their irrigation reservoirs in order to have sufficient water for an irrigation cycle. The resulting increase in irrigation cost reduces funds available for orchard care, further impacting yields.

FIGURE A3.2.2 Source of Water for Citrus Irrigation

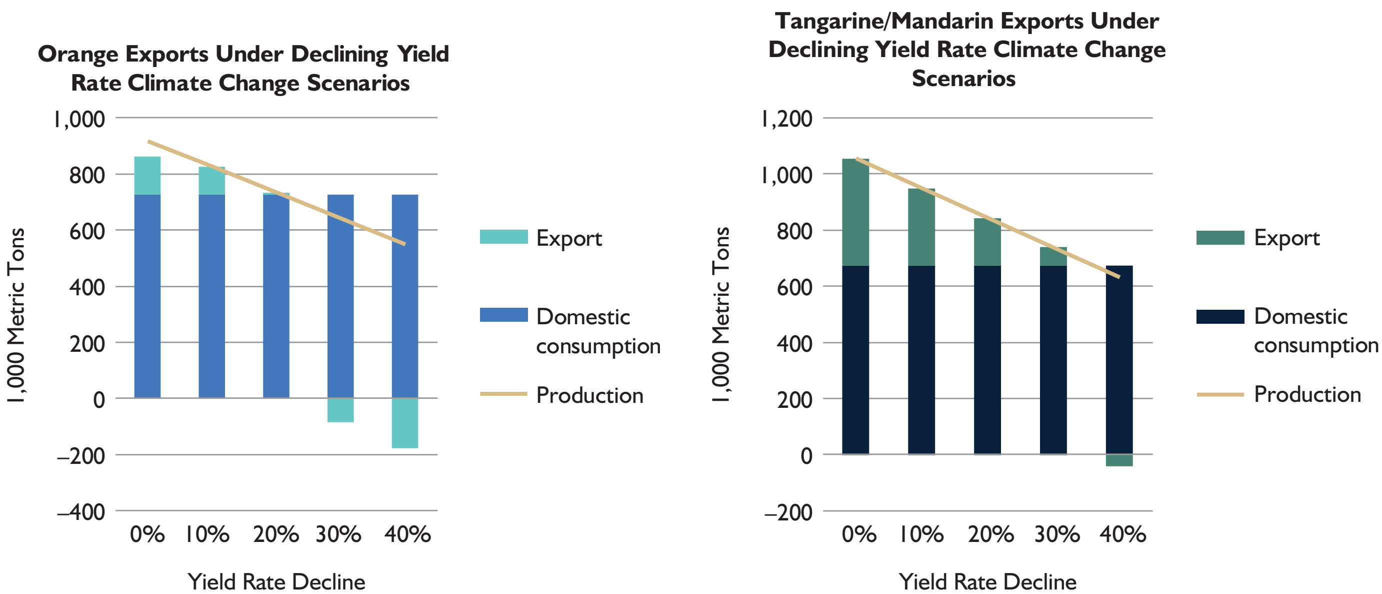


Source: World Bank data.
Note: BMK = Béni Malal-Khénifra; SM = Souss-Massa.

Impact on Exports. In MY2015–16, Morocco produced 918,000 MT of oranges and 1,055,000 MT of tangerines/mandarins, of which 79 percent and 64 percent, respectively, were consumed locally, with the balance exported (see Figure A3.2.3).

As noted previously (see Figure 3.4 in the main text), individual citrus growers reported declining yield rates of 10 percent to 55 percent due the effects of climate change-induced drought. Should the effects become more widespread at a national level, Morocco's ability to export citrus fruit would be adversely affected. Applying various yield rate decline scenarios to the MY2015–16 production levels, and assuming that local demand remains constant, under a 10 percent yield rate decline, Morocco would export 142,300 MT (28 percent) less fresh citrus fruit (both oranges and tangerines/mandarins). If yield rates declined 30 percent for oranges and 40 percent for tangerines/mandarins, there would be insufficient production to satisfy domestic demand, and Morocco would need to import citrus fruit (see Table A3.2.2 and Figure A3.2.3 below).

FIGURE A3.2.3 Citrus Exports Under Declining Yield Rate Climate Change Scenarios



Source: World Bank data.

ANNEX
3.3

ECONOMIC IMPACTS OF CLIMATE CHANGE ON OLIVE SUBSECTOR PRODUCTION AND EXPORTS

Reductions in crop volume due to drought reduce olive sector employment, especially for on-farm laborers. Every 10 percent decline in yield rate per hectare implies 17,178 fewer direct jobs nationally.

There are opportunities for job creation in the face of climate change, however. Similar to the citrus findings, jobs in research, technology and technical assistance will be crucial to adaptation, food security, and export competitiveness of the olive sector. Required jobs and skills include those in the related to:

- Climate-resistant cultivars
- Production, sale, and application of agrochemicals to reduce drought impact on trees
- Grower technicians
- Extension services
- Waste management, biofuel and other uses for oil processing by-products
- Local testing labs for soil/leaf and oil properties
- Affordable water management

Impacts on Irrigation. The majority (91 percent: overall; 100 percent in Marrakech-Safi [MS]; 82 percent in Béni Malal-Khénifra [BMK]) of surveyed olive growers irrigate to some extent, though irrigation by smallholders is generally inconsistent compared to systematic water management. Irrigation systems vary widely due to cost and availability of water. Drip systems were used by 67 percent of growers surveyed in MS, and none in BMK. Gravity systems were used by 8 percent of growers in MS and 67 percent in BMK (see Figure A3.3.1 below). It should be noted, however, that in official Government of Morocco (GoM) statistics, only drip and gravity systems are considered "irrigated" farms, since other irrigation methods are less permanent and/or less consistently applied. Under that categorization, the number of irrigated olive farms drops to 67 percent for BMK and 75 percent for MS. Such irrigation levels still are likely higher than the regional or national averages for olives, since the survey focused on growers with a commercial orientation versus growers with a household consumption orientation, which traditionally follow a rainfed approach and minimal inputs.

An International Olive Council (IOC) study of 15 member countries estimated that, globally, rainfed production accounted for 67.7 percent of total olive area, while irrigated production was 32.2 percent. Within olive production systems, 85.0 percent of intensive and super-intensive systems were irrigated, while only 13.7 percent of traditional systems were irrigated (International Olive Council, 2015). By these metrics, irrigation rates in the target regions (91 percent overall) surveyed compare favorably to global irrigation rates for olive cultivation. However, Moroccan growers that reported using irrigation did not do so consistently or systematically and so were not necessarily "irrigated" per se, as they also relied heavily on rainfall, except in the case of well-managed drip-irrigation systems (on both traditional and intensive farms). Growers with drip systems installed were more likely to irrigate regularly, while those with gravity and other systems were less so, especially when water was not readily available (e.g., canal water quotas combined with gravity systems) or affordable (e.g., purchased cisterns of water and manual irrigation).

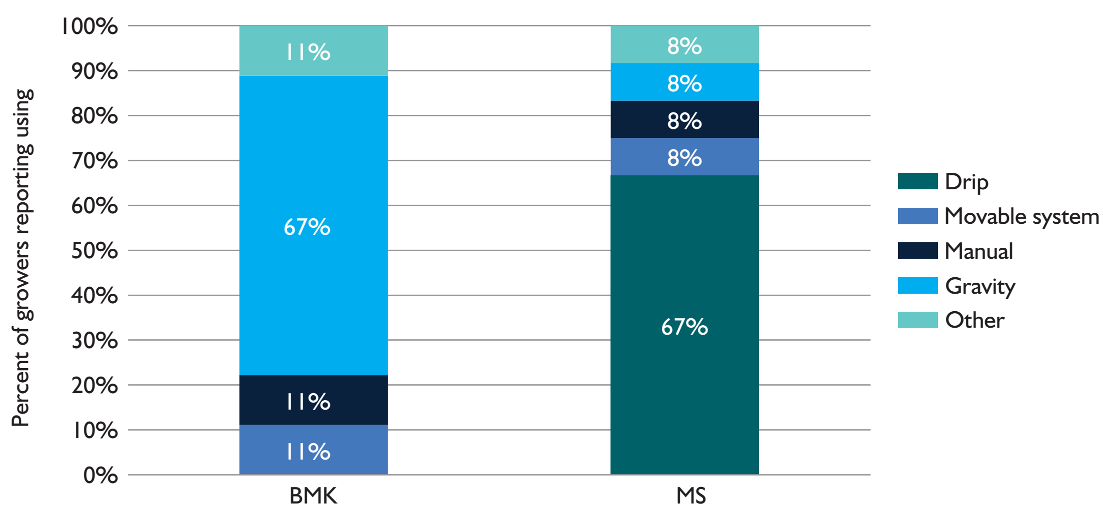
Further, growers with older orchards that had installed drip irrigation systems reported that yields decreased subsequent to drip irrigation installation, which they attributed to deep root systems of older olive trees being unable to benefit from drip irrigation water that only penetrated soil surface. Several such growers were considering removing the drip and returning to gravity or other systems. Growers with new trees, who had drip installed from orchard inception, reported greater satisfaction with the drip irrigation systems and posited that tree roots were trained to seek the surface water, so there was more success. Given that olive production results are affected by not only the irrigation system but many other factors, including climate change, and that growers using drip irrigation did not necessarily

TABLE A3.3.1 Estimated Employment Impact along Olive Value Chain from Climate Change

National Job Loss for Every 10% Decline in Olive Yield Rate		
Average yield rate (2020 target)	1.9	MT/ha
Decline in yield rate	10%	
Reduction in production yield rate	0.2	MT/ha
National planted area (2020 target)	1,300,000	ha
Reduction in national production quantity	250,000	MT
Job loss (permanent and FTE)	**15,309**	**On farm**
	1,869	**At mill/maasra**
	17,178	**Total**

Source: World Bank data.
Note: MAPM data indicate 2020 target olive yield rate of 1.92 MT/ha. However, growers surveyed reported higher average yields (6.2 MT/ha), implying greater potential job loss impact (e.g., 49,000 on-farm FTE job loss per 10 percent yield rate decline). FTE = full-time equivalent; ha = hectares; MAPM = Ministry of Agriculture and Marine Fisheries; MT = metric tons; MT/ha = metric tons per hectare.

FIGURE A3.3.1 Irrigation Method for Olive Growers



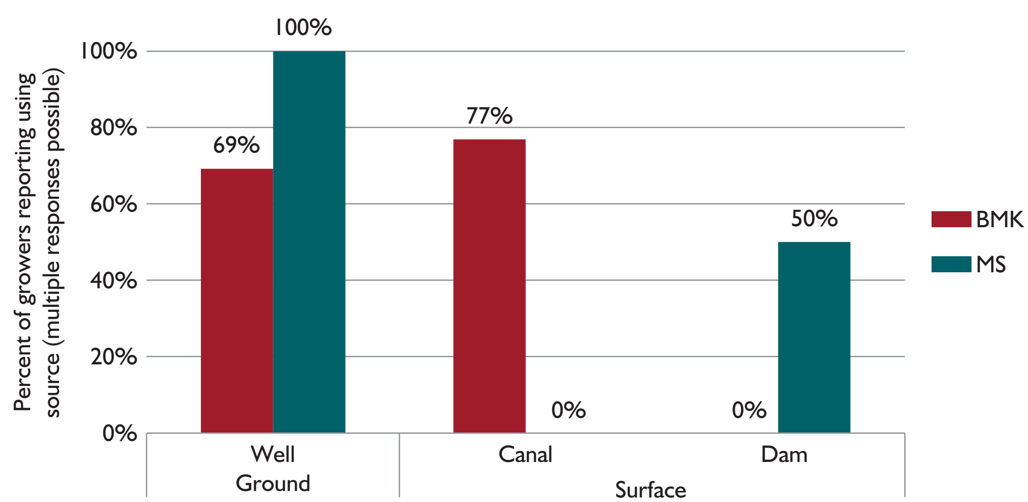
Source: World Bank data.
Note: BMK = Béni Malal-Khénifra; MS = Marrakech-Safi.

install or utilize it effectively (for example, they had no or limited technical assistance or training regarding its installation or use), further research and technical support is required to identify how to maximize the benefits of drip irrigation for olive production and determine and guide regarding the appropriate irrigation system by farm type, tree age and type, agro-zone, and other factors.

The MS and BMK regions transect the Tadla-Haouz water basin, which anchors several large-scale irrigation projects. However, both regions also have large areas where olive production relies on rainfall or irrigation via individual wells, whose source aquifers are increasingly water-stressed. Growers typically rely on multiple sources of surface and/or groundwater to ensure adequate irrigation volume (see Figure A3.3.2 below). Moroccan wells are drying up; some growers reported being on their 3rd or 4th well. MS growers rely primarily on wells (73 percent) followed by dams (45 percent) for irrigation water. BMK growers use canals (i.e., public irrigation schemes) if available, but canal water is not accessible to all growers (only available to 55 percent of BMK and 9 percent of MS olive growers surveyed). The patchwork of non-contiguous inherited plots in BMK poses irrigation challenges as well, since the water source may not reach all the plots, and pumping and other equipment would need to be centrally sited while traversing others' land to reach the various plots, for which rights access would need to be negotiated. No BMK interviewees had wells, and smallholders report that permitting and land tenure challenges prevent them from digging a well and obtaining permission to run irrigation equipment across land owned by others. Farmers often do not formally own land or are unable to provide notarized land title, thereby complicating obtaining credit or permits and thus limiting investment in irrigation and other farming inputs. Some growers, lacking access to irrigation schemes or wells, reported using water purchased in large cisterns and transported to the orchard for irrigation use.

Olive Sector Exports and Climate Change. Under the Green Growth Plan (Plan Maroc Vert or PMV), Morocco plans to double its olive production from 900,000 metric tons (MT) of olives harvested on 720,000 hectares in 2008, to 2,500,000 MT of olives harvested on 1,300,000 hectares by 2020

FIGURE A3.3.2 Source of Water for Olive Irrigation



Source: World Bank data.

Note: "Other" includes purchased water cisterns and non-specified sources. BMK = Béni Malal-Khénifra; MS = Marrakech-Safi.

TABLE A3.3.2 Olive Oil Goals under Plan Maroc Vert

Metric	2005–2010 Average	2020	Percent Change
Area of olive trees planted (ha)	720,000	1,300,000	81%
Total olives harvested (MT)	900,000	2,500,000	178%
Olives for olive oil (MT)	550,000	1,650,000	200%
Potential quantity of olive oil produced (MT)	90,000	330,000	267%

Source: Millennium Challenge Corporation, n.d.
Note: ha = hectares; MT = metric tons.

(see Table A3.3.2 and Figure A3.3.3) (Millennium Challenge Corporation, n.d.). Morocco's olive strategy appears to be on track, as an estimated 1.6 million MT of olives were harvested on 947,000 hectares in 2014, and new plantings are expected to produce olives before 2020 (FAOSTAT 2017).[55]

Under PMV, by 2020, Morocco expects to double its olive production and increase oil production by 2.7 times. Olive oil plans under PMV include production of 330,000 MT of olive oil by 2020, for which 1,650,000 MT of olives will be needed. Currently Morocco consumes 3.5 kilograms of olive oil per capita, leaving little output available for export. Increased production of olives, as well as planned improvements in processing, will theoretically enable Morocco to increase olive oil exports to 203,629 MT in 2020, while still producing enough oil to satisfy local demand (see Table A3.3.3 below). However, should climate change effects continue unmitigated, with growers unable to cope and experiencing yield rate declines, the impact on olive oil exports will be significant. Since local demand still must be satisfied, any decline in oil production will be most pronounced on the export side. Under a 10 percent decline in yield rate due to climate change, Morocco's prospective 2020 olive oil exports would decline by 33,000 MT or 16.2 percent. Under a 30 percent yield rate decline, Moroccan exports would decline by 99,000 MT or 48.6 percent. As noted in Figure 3.4 in the main text, some olive growers report even higher yield rate declines, up to 70 percent; at that level of decline at a national level, Morocco would need to import olive oil to meet domestic consumption needs.

The above scenario is simplified for illustration purposes and can be considered optimistic as it assumes that local demand for olive oil will grow in lockstep with population growth. In reality, in recent years, growth in domestic consumption of olive oil has outpaced growth of the general population.[56] Smallholder growers, who comprise the majority of olive production, are unlikely to sell their olives or oil until household and family needs for olive oil are met. The limit of household oil needs is not yet clear. Retained oil would increase the ratio of olive oil consumed locally and reduce oil available for export, unless measures are taken to increase total olive production, such that a greater supply of olives is available for oil processing. Thus, to meet national goals for olive oil exports, it will be imperative not only to increase planted area but also to support cultivation know-how, including climate change adaptation techniques, so that growers can maximize orchard productivity.

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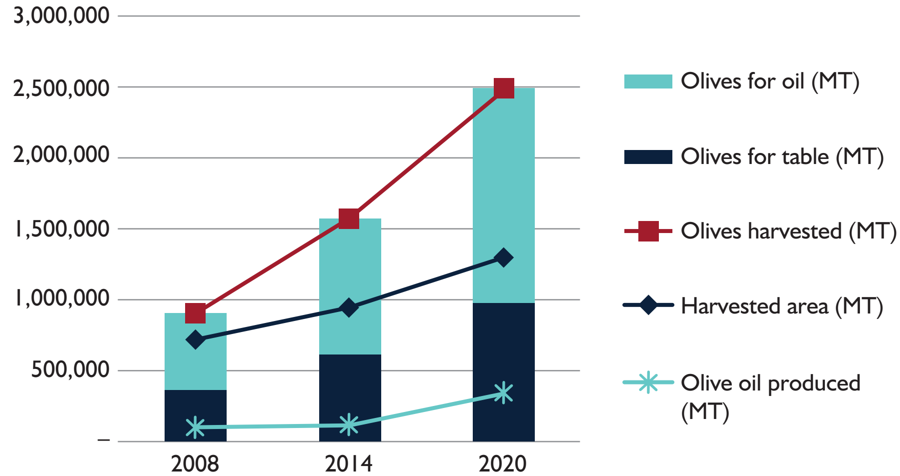
[55] For more information on Morocco olive production trends, see Global Development Solutions (2017b).

[56] Moroccan olive oil consumption increased 33 percent from 2009–10 to 2014–15, outpacing population growth of 6 percent during the same period. See Global Development Solutions (2017b).

FIGURE A3.3.3 Olive Sector Targets to 2020 under Plan Maroc Vert



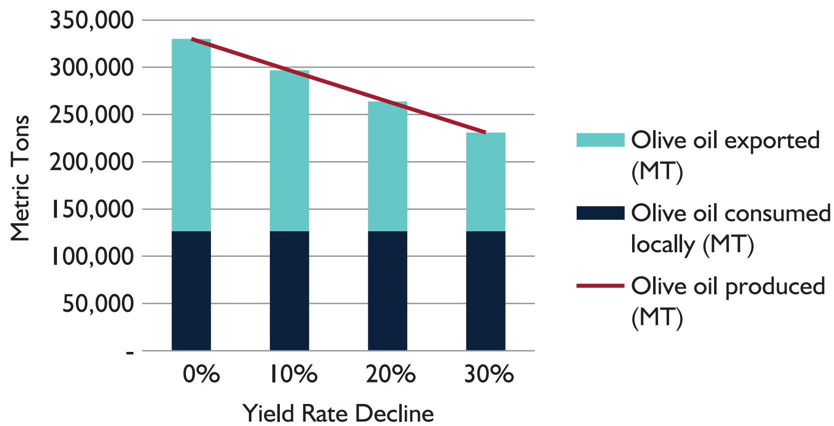
Sources: FAOSTAT 2017; Millennium Challenge Corporation, n.d.
Note: ha = hectares; MT = metric tons.

TABLE A3.3.3 Prospective Olive Oil Exports under Climate Change Scenarios

Indicator	2008	2014	2020 (PMV Goal)	2020			
				Goal per PMV	Yield rate decline		
					10%	20%	30%
Harvested area (ha)	720,000	946,818	1,300,000	1,300,000	1,300,000	1,300,000	1,300,000
Olives harvested (MT)	900,000	1,573,206	2,500,000	2,500,000	2,250,000	2,000,000	1,750,000
Olives for table (MT)	350,000	611,802	972.222	972.222	875,000	777,778	680,556
Olives for oil (MT)	550,000	961,404	1,527,778	1,527,778	1,375,000	1,222,222	1,069,444
Olive oil produced (MT)	90,000	100,000	330,000	330,000	297,000	264,000	231,000
Olive oil exported (MT)	21,000	20,000	203,629	203,629	170,629	137,629	104,629
Olive oil consumed locally (MT)	69,000	80,000	126,371	126,371	126,371	126,371	126,371
Reduction in olive oil available for export versus PMV goal (MT)					33,000	66,000	99,000
Reduction in olive oil available for export versus PMV goal (%)					16.2%	32.4%	48.6%

Sources: World Bank, based on International Olive Council, World Bank, and FAOSTAT data.
Note: Assumes annual population growth rate of 1.04 percent and per capita olive oil consumption of 3.49 kilograms.

FIGURE A3.3.4 Olive Oil Exports under Declining Yield Rate Climate Change Scenarios, 2020 Estimates



Source: World Bank data.
Note: MT = metric tons.

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